MINERALOGY OF ARIZONA

THIRD EDITION

John W. Anthony

Sidney A. Williams

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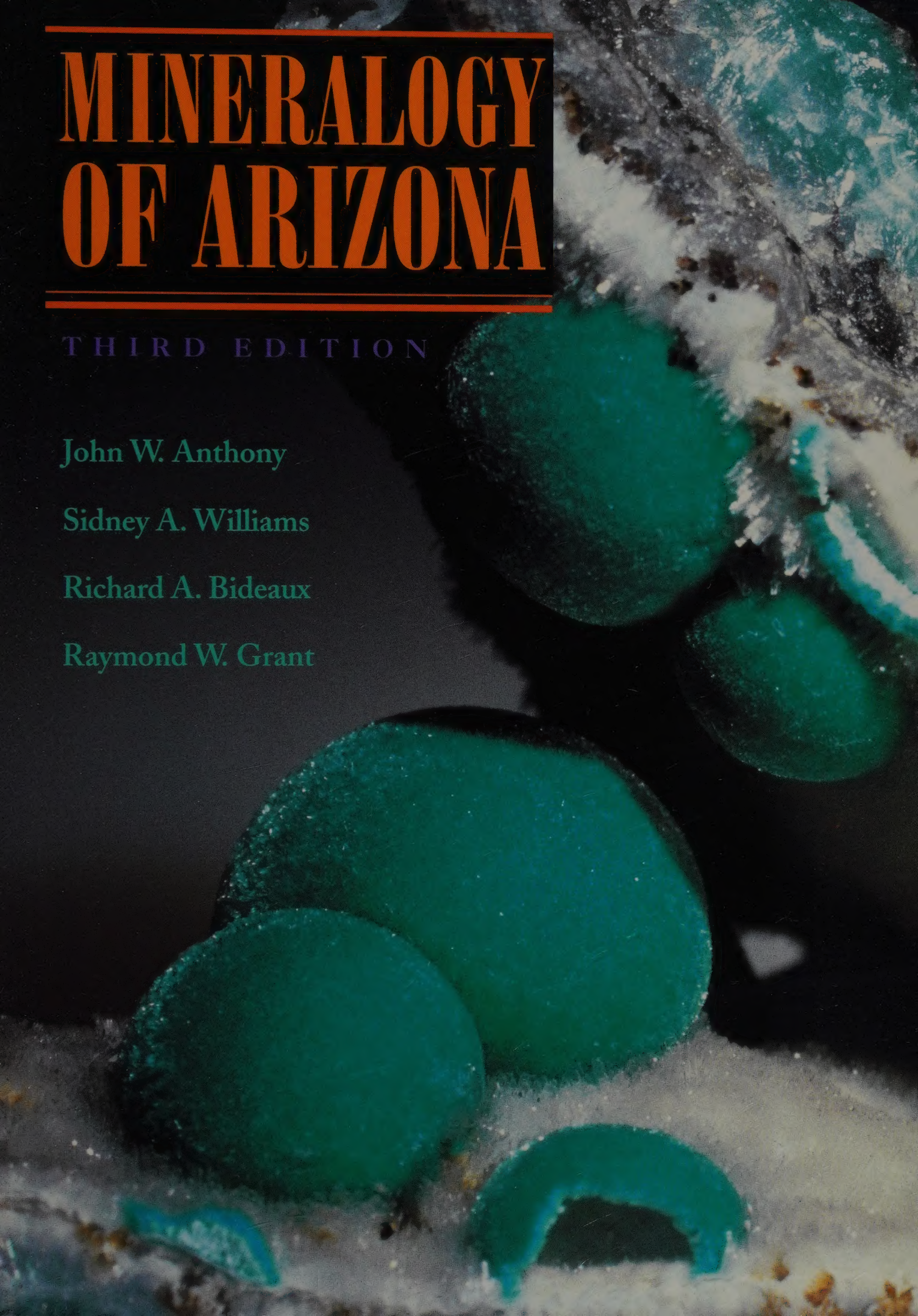

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Wulfenite. Red Cloud mine, Silver district, Trigo Mountains, La Paz County, Arizona. Smithsonian Institution. Formerly in the Arthur Montgomery collection; collected by Ed Over. Chip Clark photo.

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PHOTOGRAPHY EDITOR

Wendell E. Wilson

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Barbara Nichols carefully placed the first edition, progeny of pencil and typewriter, into our word processors. One of us (JWA) thanks Richard Bevins and Peter Williams (University of Cardiff, Wales) and Tom Segalstad (University of Oslo) for access to their geological libraries and for their many professional courtesies. The Department of Geological Sciences of the University of Texas at El Paso made facilities available during preparation of the manuscript. The Arizona Geological Survey provided information on mining camps and, with the permission of Larry Fellows, director, supplied the county maps that show the mineral districts of Arizona, which were originally published in Welty et al. (1985).

Through its former president, Leonard Judd, the Phelps Dodge Corp. has again provided funding for the color photographs in *Mineralogy of Arizona.* We express our appreciation for both their generosity and their continued interest.

We thank the Tucson Gem and Mineral Society and its members for their generous and indispensable financial help in the publication of this work. We also acknowledge the staff of the University of Arizona Press for their skill in designing and producing this third edition.

John W. Anthony
Sidney A. Williams
Richard A. Bideaux
Raymond W. Grant

MINERALOGY OF ARIZONA

1

INTRODUCTION

Introduction to the Third Edition

The goals of the first edition of this work and its revised reprinting (published in 1977 and 1982, respectively) were to document the mineral occurrences in Arizona and describe the geology of the more interesting (in our eyes!) provenances. To achieve the latter, we discussed the following topics: porphyry copper deposits; porphyry-copper-related deposits, including those at Bisbee and Tiger; uranium and vanadium deposits; "mine fire" minerals at the United Verde mine in Jerome; and Arizona meteorites. In this third, the chapters on uranium and vanadium minerals and Arizona meteorites have been augmented; a discussion of the classical Tombstone district has been inserted between those of Bisbee and Tiger in the section on porphyry-copper-related and other hydrothermal deposits; and two topics have been added, the history of Arizona mining and mineralogy, and Arizona pegmatites.

Since the first edition was published, new occurrences of most minerals have been found, and publications on these species have burgeoned commensurately. Many Arizona specimens are housed in a handful of museums (Table 1.1). Since 1977 the number of minerals first identified in Arizona has increased from 48 to 76 (Table 1.2) and 232 minerals new to the state have been discovered (Table 1.3), bringing the total of Arizona minerals to 809. We have added mineral occurrences known to us from the literature and other sources through December 1993.

Two factors are mainly responsible for this escalation of activity: (1) More competent mineralogical observers are abroad, and many of them, although not necessarily trained in the quantitative nuances of mineral description, take advantage of the interest of skilled professionals in governmental, industrial, and consulting laboratories, which (2) are equipped with more powerful analytical tools than were known to our predecessors. Although the typically minute sample of a suspected

Table 1.1. Abbreviations for Some Museums Containing Arizona Mineral Specimens

Code	Museum
AEC	Atomic Energy Commission, now the Energy Research and Development Commission, Grand Junction, Colorado
AM	American Museum of Natural History, New York
ASDM	Arizona-Sonora Desert Museum, Tucson; x = micromount collection
ASU	Arizona State University, Center for Meteorite Studies, Tempe
H	Harvard University, Cambridge, Massachusetts
MM	Mineral Museum, Arizona Department of Mines and Mineral Resources, Phoenix
NHM	Natural History Museum, formerly the British Museum (Natural History), London
S	Smithsonian Institution, National Museum of Natural History, Washington, D.C.
UA	University of Arizona, Mineral Museum, Tucson; x = micromount collection

new mineral makes its description difficult, modern instrumental techniques are frequently equal to the task and are actually responsible for characterizing most of the species newly reported here. Two such instruments have been especially helpful. The widely used electron microprobe can often generate complete quantitative chemical analyses from minuscule amounts of mineral material; few such measurements were possible a generation ago. The Gandolphi X-ray diffraction camera has proven comparably effective in identifying tiny crystalline samples.

The detailed knowledge that mineralogists can now acquire about chemical makeup has resulted in a mild proliferation of new mineral names. For example, new measurements that show extensive substitution in a given atomic position within a known mineral structure may well result in a new mineral name. A splendid illustration is afforded by Clifford Frondel and his coworkers' (1976) treatment of zippeite. Thanks to their careful studies, Arizona is now home to a plethora of zippeite "clones" (three, possibly four), whereas only one had been known before their work. Despite these technological advances, one should remember that the discerning eye still makes the decision whether to look more closely at a rock or mineral that is casually picked up in the field.

Recently, one researcher has said that the effort expended in identifying new minerals known only in minute quantities and bearing "ludicrous or undignified names" is time wasted. We disagree. We believe that view to be an unproductive assessment of the human relationship with Mother Nature. For it is only through comprehensive knowledge of her many mineralogical manifestations that the scientist can resolve the enigmas of their origins.

Table 1.2. Minerals First Discovered in Arizona

Mineral	Citation Source
Ajoite	Schaller and Vlisidis, 1958
Andersonite	Axelrod et al., 1951
Antlerite	Hillebrand, W.F., 1889a
Apachite	Cesbron and Williams, 1980
Aravaipaite	Kampf et al., 1989b
[Arizonite]	Palmer, 1909
Artroeite	Kampf and Foord, 1995
Bayleyite	Axelrod et al., 1951
Bermanite	Hurlbut, 1936
Bideauxite	Williams, S.A., 1970a
[Bisbeeite]	Schaller, 1915
Brezinaite*	Bunch, J.E., and Fuchs, 1969
Butlerite	Lausen, 1928
Bütschliite	Milton and Axelrod, 1947
Chalcoalumite	Larsen, E.S., and Vassar, 1925
[Cliftonite]	El Goresy, 1965 (discredited)
Coconinoite	Young, E.J., et al., 1966
Coesite	Chao, E.C.T., et al., 1960
Coronadite	Lindgren and Hillebrand, 1904
Cowlesite	Wise and Tschernich, 1975
Creaseyite	Williams, S.A., and Bideaux, 1975
Cryptomelane	Richmond and Fleischer, 1942
Cuprotungstite	Schaller, 1932
Dugganite	Williams, S.A., 1978
Duhamelite	Williams, S.A., 1981b
Emmonsite	Hillebrand, W.F., 1885
Fairbankite	Williams, S.A., 1979
Fairchildite	Milton and Axelrod, 1947
Flagstaffite	Guild, 1920
Gerhardtite	Wells, H.L., and Penfield, 1885
Gilalite	Cesbron and Williams, 1980
Girdite	Williams, S.A., 1979
Graemite	Williams, S.A., and Matter, 1975
Grandreefite	Kampf et al., 1989b
Guildite	Lausen, 1928
Haxonite*	Scott, 1971
Hemihedrite	Williams, S.A., and Anthony, 1970
Henryite	Criddle et al., 1983
Jeromite	Lausen, 1928
Junitoite	Williams, S.A., 1976a
Jurbanite	Anthony and McLean, 1976
Khinite	Williams, S.A., 1978
Kiddcreekite	Harris et al., 1984

Table 1.2. (continued)

Mineral	Citation Source
Kinoite	Anthony and Laughon, 1970
Krinovite*	Olsen and Fuchs, 1968
Laurelite	Kampf et al., 1989b
Lausenite	Lausen, 1928; Butler, G.M., 1928
Lonsdaleite*	Frondel, C., and Marvin, 1967a,b
Luddenite	Williams, S.A., 1982
Luetheite	Williams, S.A., 1976b
Macquartite	Williams, S.A., and Duggan, 1980
Mammothite	Peacor et al., 1985
Maricopaite	Peacor et al., 1988
Moissanite*	Kunz, 1905
Murdochite	Fahey, 1955
Navajoite	Weeks et al., 1954, 1955
Nickel-zippeite	Frondel, C., et al., 1976
Oboyerite	Williams, S.A., 1979
Papagoite	Hutton and Vlisidis, 1960
Parakhinite	Williams, S.A., 1978
Paramelaconite	Koenig, G.A., 1891
Paulkerrite	Peacor et al., 1984
Pinalite	Dunn et al., 1989
Pseudograndreefite	Kampf et al., 1989b
Ransomite	Lausen, 1928
Ruizite	Williams, S.A., and Duggan, 1977
Schieffelinite	Williams, S.A., 1980a
Selenium	Palache, 1934
Shattuckite	Schaller, 1915
Sodium-zippeite	Frondel, C., et al., 1976
Spangolite	Penfield, 1890
Stishovite	Chao, E.C.T., et al., 1962
Swartzite	Axelrod et al., 1951
Wherryite	Fahey et al., 1950
Wickenburgite	Williams, S.A., 1968
Winstanleyite	Williams, S.A., 1979
Yavapaiite	Hutton, 1959a
Yedlinite	McLean et al., 1974
Zinc-zippeite	Frondel, C., et al., 1976

[ ] Not included in total; not an accepted species

* Found in meteorites

Table 1.3. Species Added to the Arizona Mineral List, 1977–94

Aenigmatite	Daubreelite*	Huntite
Alloclasite	Dickinsonite	Hydrohetaerolite
Altaite	Dugganite	Hydromagnesite
Anorthoclase	Duhamelite	Hydroxyapophyllite
Apachite	[Dunhamite]	Hydroxylapatite
Aravaipaite	Eclarite	Ingodite
Argentojarosite	Edenite	Iranite
[Arizonite]	[Eichbergite]	Iriginite
Arseniosiderite	Emplectite	Jahnsite
Arsenosulvanite	Empressite	Jalpaite
Artroeite	Eosphorite	Kanonaite
Augelite	Eugenite	Kesterite
Aurorite	Fairbankite	Kettnerite
Barringerite*	Fairfieldite	Khinite
Bianchite	Ferricopiapite	Kiddcreekite
Bilinite	Ferrierite	Koechlinite
Blödite	Ferro-actinolite	Kostovite
Bogdanovite	Ferrocolumbite	Krennerite
Böhmite	Ferrokaersutite	Kulanite
Bokite	Ferrotapiolite	Kuramite
Botallackite	Fervanite	Kutnohorite
Boulangerite	Fibroferrite	Lanarkite
Brackebuschite	Fillowite	Laurelite
Braunite II	Fraipontite	Lautite
Brazilianite	Freibergite	Lawsonite
Brockite	Friedrichite	Leucosphenite
Bursaite	Frohbergite	Levyne
Calaverite	Garronite	Lewisite
Canfieldite	Geikielite	Lime
Carbonate-fluorapatite	Gersdorffite	Linnaeite
Carlsbergite*	Gilalite	Lizardite
Cesbronite	Girdite	Luddenite
Chalcomenite	Gladite	Luzonite
Chamosite	Goldfieldite	Mackinawite*
Chlorapatite	Gonnardite	Macphersonite
Choloalite	Gormanite	Macquartite
Claringbullite	Grandreefite	Magnesiocopiapite
Clinobisvanite	Gyrolite	Mammothite
Clinohedrite	Hawleyite	Manganbabingtonite
Corrensite	Haxonite*	
Crandallite	Hectorite	Manjiroite
Crednerite	Henryite	Maricopaite
Cupropavonite	Hocartite	Matildite
Danburite	Hodrushite	Mawsonite
Darapskite	Hörnesite	Mckinstryite

Table 1.3. (continued)

Melilite	Petzite	Stilpnomelane
Melonite	Pinalite	Stützite
Meta-alunogen	Plumbotsumite	Switzerite
Molybdofornacite	Polylithionite	Sylvanite
Montebrasite	Pseudograndreefite	Talmessite
Moorhouseite	Queitite	Tellurite
Mroseite	Quetzalcoatlite	Tellurobismuthite
Nantokite	Ralstonite	Tetrataenite*
Naumannite	Rameauite	Tlapallite
Nekrasovite	Rammelsbergite	Tobermorite
Neltnerite	Rancieite	Tocornalite
Neyite	Reevesite	Tolbachite
Nickel-zippeite	Rhodostannite	Triploidite
Nolanite	Roaldite*	Tschermakite
Nordströmite	Rodalquilarite	Ulvöspinel
Nsutite	Rozenite	Uytenbogaardtite
Nukundamite	Rucklidgeite	Vanmeersscheite
Oboyerite	Ruizite	Vaterite
Okenite	Santafeite	Velikite
Omphacite	Scawtite	Volkonskoite
Opal	Schieffelinite	Volynskite
Osarizawaite	Schubnelite	Wakefieldite-(Y)
Parakhinite	Scorzalite	[Whelanite]
Pararammelsbergite	Serpierite	Winstanleyite
Paratellurite	Siderotil	Wittite
Pargasite	Siegenite	Woodwardite
Parisite	Sodium-zippeite	Wüstite
Parnauite	Sonoraite	Wyllieite
Partzite	Spertiniite	Xocomecatlite
Paulkerrite	Sphaerocobaltite	Xonotlite
Pecoraite	Spionkopite	Yafsoanite
Pectolite	Spiroffite	Yarrowite
Pekoite	Stannite	Zincobotryogen
Periclase	Stannoidite	Zinc-zippeite

[ ] Not included in total; not an accepted species

* Found in meteorites

In the brief time since the first edition of this book was published, Arizona's miners have extracted about 30 billion lb of copper. Including the 40 billion lb produced before 1977, Arizona's copper output has totaled 70 billion lb. A very thin copper wire (about 1 micron in diameter) drawn from this mass would reach the nearest star, Proxima Centauri. It would, in fact, extend far beyond that 4.3-light-year distance—on and on, up to 500 light years from Earth!

Introduction to the First and Second Editions

Since the inception of modern mining activity in the Arizona Territory in the latter half of the nineteenth century, Arizona has been known as a copper-mining state. The statistics recounting the commercial end-product of a century of continuously accelerating effort expended in digging out the mineral wealth of this enormous area are impressive: over 40 billion pounds of copper were mined during this period. If there were any doubt that this is a lot of copper, the blasé should be impressed by the image of a solid copper pyramid, square-based, two football fields on an edge and two football fields high. By comparison, the largest of the pyramids of ancient Egypt, the Great Pyramid of Khufu, originally measured about 756 feet along the square base and was about 481 feet high. Although copper has constituted the great part of Arizona's metallic mineral wealth through the years, exploitation of the ores of gold, silver, lead, zinc, molybdenum, uranium, mercury, and tungsten has not been neglected; nor has development of a host of nonmetallic mineral resources which are becoming increasingly important as the population grows.

It is inevitable that this century of mining leave its imprint on any extensive collection of mineral data. The most cursory glance through the mineral occurrences listed in this volume will make it obvious that the "average" mineral reported is in or near a mine or mineral prospect.

The pace of geological and mineralogical activity in Arizona has accelerated during the 1960s and 1970s. The efforts of the many skilled geologists working in the state, augmented by the contributions of an ever-increasing number of skilled amateur collectors, have unearthed a host of new occurrences and brought to light a surprising number of mineral species not previously known to occur in the state.

We had several goals in undertaking this venture. We wished to collect into one source much of the Arizona mineralogical information that has become available since the 1959 edition of Galbraith's and Brennan's *Minerals of Arizona.* We also attempted to document as many as we could of the sources of the older, unreferenced, locality citations in that volume. Although our list of references is by no means exhaustive, the majority of significant papers is included.

We believe that this information will be of assistance to the geologist whose primary concern is with scientific aspects of mineralogy, and to the applied geologist searching for those natural mineral commodities so rapidly being depleted. We believe, too, that this book will appeal to those sharing with us aesthetic appreciation of the beauties inherent in the magnificent minerals so long a source of pride to Arizona. On the bases of geological and economic inference, it appears that Arizona, and for that matter the world, will seldom if ever again provide mineral specimens to equal the quality of those from the distinguished Arizona mining camps.

The first comprehensive collections of information on the minerals of the state appeared in 1909 and 1910 when two pioneers of Arizona geology, William Phipps Blake (1826–1910), Territorial Geologist and Director of the School of Mines, University of Arizona, and Frank Nelson Guild (1870–1939), Professor of Chemistry and Mineralogy, University of Arizona, independently published summaries of the minerals of the Territory. Blake's effort appeared in 1909 as a report directed to the Honorable J.H. Kibbey, Governor of the Territory; it discussed approximately 100 minerals. Guild's book, *The Mineralogy of Arizona,* privately printed in 1910, described about 120 species. Blake, incidentally, also compiled the first California mineral list, and the centennial of that occasion was commemorated in the appearance of *Minerals of California,* by Murdoch and Webb (1966).

No further compilation was undertaken until 1941, when Frederic William Galbraith, Professor of Geology, University of Arizona, compiled *Minerals of Arizona.* By that time the number of species reported had grown to about 193. First issued as Bulletin 149 by the Arizona Bureau of Mines, the work progressed through two revisions, the second being co-authored with Daniel J. Brennan. This work enjoyed considerable popularity with amateur and professional geologists and mineralogists alike. With the exception of a few popular works aimed at the amateur mineral collector, *Minerals of Arizona* remained for years the only convenient single source of information on mineral occurrences in the state. The number of species reported in the 1959 revision had grown to about 403, of which twenty subsequently were dropped from the mineral list.

The body of data assembled in the works of our predecessors constitutes the nucleus of this book, and the reader will observe that many entries are unchanged from their earlier form. Quite a number of mineral occurrences were gathered by Galbraith from word-of-mouth sources either unknown or no longer available to us. Although in some instances the information is rather vague and not in the detail which could be desired, it is retained. In other instances, entries have been modified to accord with more recent data on specific occurrences. We have, of course, rejected a number of mineral citations in the earlier works where subsequent study has shown material to have been incorrectly identified.

Some mineral names have been changed to conform to the most widely accepted nomenclature. As examples we cite the preference for the name vesuvianite over idocrase; the substitution of acanthite for argentite to designate the silver sulfide phase stable under ordinary conditions of temperature; and the revision of the nomenclature of the silver halogen minerals to follow systematic current usage. Some minerals have been reduced from species to varietal status. For example, the mineral formerly called smaltite is now regarded as an arsenic-deficient variety of skutterudite.

New detail has been found in the mineralogies of some of the older well-known occurrences, primarily as the result of the widespread use of X-ray diffraction methods of mineral identification. A good example is seen in the studies of manganese oxide deposits. Several workers, among them Hewett and Fleischer, unraveled the complexities of some of these deposits whose mineralogies had been lumped under the catch-all terms "wad" and "psilomelane," and presented us with a number of mineral species previously not known to occur in Arizona.

Another unexpected complexity has arisen from studies of copper sulfides. New species such as djurleite have been discovered in copper sulfide ores formerly thought to consist only of chalcocite. One can anticipate that this and other related species will prove to be even more widespread than is known at this writing.

The largest single group of species newly reported here, however, was encountered in the oxidized portions of base metal deposits. The blessing (and oft-times we must add, bane) of the professional mineralogist who undertakes to identify exotic minerals brought to him, is the keen eye of the well-informed amateur collector who may approach the encyclopedic in his knowledge of the rare, colorful, and well-crystallized secondary oxidized minerals found in the near-surface portions of the mines of the Southwest. Arizona has its share of such avid devotees, and we are most happy to acknowledge their contributions to whatever claim this book can lay to completeness. Their excursions (occasionally nocturnal and surreptitious) into mine workings inaccessible to most of us have provided a wealth of study material.

The means of pinpointing the geographical locations of mineral occurrences is an inheritance of Arizona's mining bias. In addition to being geopolitically divided into 14 counties, Arizona is partitioned into some 240 mining districts. These rather vaguely delineated regions were early established as quasi-political regulatory entities to promulgate rules to be followed in local mining practice; individual districts, like as not, followed different mining mores. With the advent of the county governmental structure, however, the need for this regulatory function diminished until the mining district remains largely as an anachronism. But the habit is hard to break, and it is still common practice in some western states to discuss mines, prospects, and even geology in terms of the old mining district names. Because so many of the locality references in the literature are to mining districts, we have found it expedient to perpetuate this well-ingrained custom. Maps are included showing the locations of the mining districts in the various counties.

An alternative would be to situate each mineral occurrence in a coordinate system such as latitude and longitude, or by means of the Standard Land Survey, which fixes a location by a statement of section, township, and range, referred to either the Gila and Salt River or the Navajo Base and Meridian. The latter system is used for a few localities listed in this book, but the requisite information often is lacking. Commonly, the only means of obtaining the required data is to scale them from maps. Many of the localities reported are so indefinite that a series of formal symbols designating them would impart to the reader an erroneous sense of precision. No one will be more aware of the vagueness of many of the localities here given than the authors.

In selecting the format of this book we have taken the position that inclusion of basic descriptive data for each mineral species would be needless duplication of information to which the reader has ready access in many excellent reference works. We have, however, continued the practice of stating chemical formulas; written versions of the chemical compositions have been added to assist those who may not have facility with chemical symbology. Brief statements of the geological modes of occurrence of each mineral species are also included.

The verbal sketches of the two kinds of mineral occurrences for which Arizona is particularly noted—the porphyry copper deposits and the Colorado Plateau–type uranium and vanadium deposits—are designed to help the reader appreciate the geological nature of these remarkable mineral assemblages to which reference is repeatedly made throughout the systematic compilation.

The detailed descriptions of the mineralogies at the Mammoth–St. Anthony mine at Tiger and of the mines at Bisbee, which surely rank among the mineralogical wonders of the world, are intended to partially fill a long-standing void in the mineralogical literature; for although many excellent geological studies of these mines have been reported, there have appeared no inclusive summaries of their mineralogies incorporating recent work. We intend that these descriptions also serve as types to which the many other similar mineral occurrences throughout the state can be compared.

As a convenience to the reader, mineral entries are arranged in alphabetical order rather than according to a conventional chemical-structural classification.

The names of individuals who provided information on mineral occurrences follow each citation.

We have noted catalog numbers of some of the Arizona specimens held in the collections of some of the museums with whose holdings we are familiar. These entries follow the mineral locality citations and are coded as shown in Table 1 [1.1].

The soil-forming clay minerals and the common rock-forming silicate minerals have been accorded what may appear to be somewhat cavalier treatment. Each of these groups is discussed in an extensive literature: the former in the journals of soil and agricultural science, and civil engineering; the latter in the geological journals. It is not practicable to include a systematic listing of the many occurrences of the soil clay minerals or of the common rock formers, and we recognize that persons interested in these will consult the extensive specialized literature sources. Some minerals (quartz, for example), in addition to their occurrences as essential constituents of rocks, form under a wide variety of other geological conditions, and, in general, the rock associations of such minerals are not systematically treated in this compilation.

2

HISTORY OF ARIZONA MINING AND MINERALOGY

The early history of the State of Arizona is largely the history of the search for and mining of minerals, metals, and ores. Initially, exploration targeted the precious metals, gold and silver, then focused on copper and eventually lead, zinc, and other base metals and industrial minerals. Because of the relatively late development of Arizona in comparison to the rest of the United States, fortunately most of its early Spanish, Mexican, and American history was recorded, including much of its mining history.

The story of the exploration of Arizona is also the story of the development of transportation within the state. The Spanish Jesuits and military traveled by foot and horseback along the Santa Cruz River to settle Tubac and Tucson and to work silver mines in the Santa Rita Mountains. The first easy pathways were along the Gila River, east to west, and the Colorado River, south to north. Following the Jesuits, Mexican and American miners, trappers, scouts, and military men made the early discovery of rich gold placers and silver-lead deposits. Around these discoveries the first settlements arose. Some of these were inhabited for only a few years, however, as the rich surface deposits were worked out or prices waxed and waned in response to events far removed from Arizona. This history is recounted in sources such as Tenney (1927), Heineman (1938), and Tuck (1963).

Wagon haulage and stage lines were established to transport men and equipment to the mines and to return with the ores. These transportation methods were eventually replaced by the long-line railroads, the Southern Pacific and Santa Fe, which crossed the state, and the short-line railroads, most of which were constructed to serve the larger mining camps.

In those early years, placer gold and silver halides lay at the surface. The richest ores and many interesting mineral specimens were contained in the upper portions of these deposits. Very few specimens have been preserved from these early operations, but many fine examples must have been processed as ore or discarded into the waste heaps. There is little mention of mineral specimens in the earlier literature of economic geology and mining that discusses metals or ores.

The Prehistoric Period

The earliest residents, the American Indians, sought, sometimes by trade and sometimes by large-scale mining, various minerals for utilitarian and ornamental purposes. Northrop (1959) listed minerals specifically found at the extensive abandoned Indian settlements at Chaco Canyon, New Mexico (Table 2.1). Some of these minerals were probably imported: azurite, copper, galena, garnet, malachite, muscovite, serpentine, talc, and turquoise.

Northrop (1959) included minerals from Sidney Ball's lists, which were combined from excavations at other New Mexico and Arizona Pueblo Indian dwellings (Table 2.2). He also listed minerals that George Switzer identified as "among ceremonial articles found in pouches of Navajo singers . . . [in] eastern Arizona as well as western New Mexico" (Table 2.3).

Table 2.1. Minerals Found at Chaco Canyon, New Mexico

Aragonite	Hematite	Flint
Azurite	Reddle	Jasper
Calcite (crystals)	Red ocher	Milky quartz
Calcareous tufa	Jet	Onyx
Chalk	Kaolinite	Petrified wood
Limestone	Limonite	Rock crystal
Copper	Yellow ocher	Serpentine
Galena (crystals)	Malachite	Picrolite
Garnet (pyrope?)	Muscovite	Sulfur
Gilsonite	Pyrite	Talc
Goethite	Quartz	Soapstone or Steatite
Gypsum (rock)	Agate	Turquoise
Alabaster	Chalcedony	
Selenite	Chert	

Table 2.2. Minerals Found at Other Indian Dwellings in Arizona and New Mexico

Actinolite	Magnesite	Quartz	Scapolite
Apatite	Magnetite	Amethyst	Sillimanite
Diopside	Olivine	Carnelian	Smithsonite
Feldspar	Opal	Prase	
Fluorite		Smoky quartz	

Table 2.3. Minerals Used as Navajo Ceremonial Articles

Aragonite ("mirage stone")	Jet	Quartz
Azurite	Lignite	Flint
Clay (white)	Limonite	Rock crystal
Galena	Yellow ocher	Serpentine (chrysotile)
Halite	Malachite	Sulfur
Hematite	Mendozite	Turquoise
Red ocher		
Specularite		

In Arizona, turquoise was mined by aborigines at Mineral Park, Mohave County and near Courtland, Cochise County. Fewkes (1912) mentioned the following:

> Crystals of quartz are prized by many of the Southwestern tribes for medicinal purposes. These crystals are found in several ruins in northern Arizona. . . . Numerous quartz crystals were found at Casa Grande [near Coolidge, Pinal County]. It is known from legends of the Pima as well as from Pueblo traditions that such crystals were employed in the practice of medicine; specimens have been found in the fetish bags of the dead.
>
> Fragments of artificially worked mica, asbestos, galena, and chalcedony are also in the collection from Casa Grande. Like the ancient people who inhabited the northern pueblos, those of the south prized petrified wood, obsidian, any stone of grotesque shape, fossils, and water-worn pebbles. Many of these specimens must have been brought a considerable distance, as they are different from stones found in the immediate vicinity. . . .
>
> The inhabitants of Casa Grande appear to have been ignorant of all metals except float copper, a specimen of which was found in the excavations. Two copper bells were picked up on the surface of the ground. These bells do not differ in shape or size from those found in ruins along the Little Colorado or elsewhere in the Southwest and may have been obtained in trade in Mexico, although there is no evidence that they were not made by the Casa Grande people.

Arizona Under Spanish Rule

1539 Capt.-Gen. Francisco Vasquez de Coronado sends Friar Marcos de Niza and the Moor Estevan to find the Seven Cities of Cibola (Zuni, New Mexico).

1540 Coronado's expedition enters and crosses Arizona on the way to the Seven Cities of Cibola and determines that the cities are seven Indian villages without metallic riches. They are the first Europeans to enter Arizona. Winship (1896) translated the letter from Coronado to Viceroy Don Antonio de Mendoza (August 3, 1540):

> Of the situation and condition of the Seven Cities called the Kingdom of Cevola, and the sort of people and their customs, and of the animals which are found there . . . I think that they have a quantity of turquoises, which they had removed with the rest of their goods, except the corn, when I arrived, because I did not find any women here, nor any men under 15 years or over 60, except two or three old men who remained in command of all the other men and the warriors. Two points of emerald [peridot from Arizona?] and some little broken stones which approach the color of rather poor garnets [pyrope from New Mexico or Arizona?] were found in a paper, besides other stone crystals [quartz?], which I gave to one of my servants to keep until they could be sent to Your Lordship. He has lost them, as they tell me.

1557 Bartolome de Medina of Pachuca, Mexico, invents the patio process of silver amalgamation, economical "where wood and water are scarce, the ore suitable, the climate favorable, and labor cheap" (Küstel, 1863).

1583 Antonio de Espejo discovers a deposit said to be silver ore, perhaps the United Verde deposit at Jerome, Yavapai County, near the headwaters of the Verde River: "with my own hands I extracted ore from them, said by those who know to be very rich and to contain much silver."

1604 Juan de Oñate explores northern and western Arizona and also finds silver ore, either in the Aquarius or Hualpai Mountains, Mohave County.

1691 Padre Eusebio Francisco Kino enters Arizona, traveling as far north as Bac, near present-day Tucson, Pima County. For 20 years he explores and assists in developing the Papago country, Pimeria Alta.

1705 Kino mentions the mining of rich silver ores, probably the deposits in the Santa Rita Mountains, Santa Cruz County.

1736 The famous Bolas y Planchas de Platas (Balls and Plates of Silver) discovery is made at Real (a mining town) de Arissona in northern Sonora, Mexico, about 15 miles southeast of Nogales, Santa Cruz County, on the present Arizona border. Slabs of silver reportedly weighed from 8 to 2,700 lb. This discovery stimulated further exploration to the north, the entire area of which took the name *Arissona,* replacing *Pimeria Alta.* Later the State of Arizona took its name from the name of this ranch and surrounding hills. The name is originally from the Papago *Arizonac,* softened by the Spanish to *Arissona.*

1750 Some copper is mined at Ajo, Pima County.

1767 The Jesuits are expelled from Mexico.

1774 Placering for gold is conducted in the Quijotoa district, Pima County.

1776 The Spanish garrison is transferred from Tubac, Santa Cruz County, to Tucson.

1777 Arivaca, Pima County, is mentioned as a mining community.

1792 The legal ratio between the dollar values of gold and silver is 16 to 1.

1821 Arizona and New Mexico become a part of the Spanish Republic of Mexico.

1823 Mexico obtains its independence. The missions are abandoned and raided by Indians.

1825 The first American scouts begin to explore Arizona. James and Sylvester Pattie explore the copper deposit at Santa Rita, New Mexico, and continue on into Arizona.

1832 The scout Pauline Weaver first comes to Arizona.

1836 The Apaches become unfriendly because of the murder of their Chief, Juan Jose.

1837 The first edition of James Dwight Dana's *The System of Mineralogy* is published.

1846 War is declared between the United States and Mexico. Arizona becomes a provisional territory under Gen. S.W. Kearny, whose Army of the West follows along the Gila River. Their caissons are the first wheeled vehicles to traverse Arizona. Following after them, the Mormon Battalion, under Capt. Phillip St. George Cooke, briefly raises the U.S. flag in Tucson. Capt. William H. Emory (1848), topographical engineer with Kearny, reports the following:

> Our camp was on a flat sandy plain, of small extent, at the mouth of a dry creek, with deep washed banks, giving the appearance of containing at times a rapid and powerful stream, although no water was visible in the bed. At the junction, a clear, pure stream flowed from under the sand. From the many indications of gold and copper ore at this place, I have named it Mineral Creek [Ray, Gila County]; and I doubt not a few years will see flat-boats descending the river from this point to its mouth, freighted with its precious ores.

Metz and Rose (1966) emphasized this contribution by the Army of the West: "Although the copper showings attracted the attention of Indians who mined chrysocolla with large diabase hammers, the first written record of them was made in 1846 by members of the Army of the West, who named Mineral Creek for the numerous mineral deposits found along its banks."

1847 Marshall discovers gold in California. Tens of thousands of argonauts follow the Gila Trail across Arizona in succeeding years.

1848 The Treaty of Guadalupe-Hidalgo is signed, ending the war with Mexico.

1850 The U.S. Boundary Commission under the direction of John R. Bartlett enters Arizona. Jose Francisco Velasco (Willey, 1986) writes, "Between the presidio of Tucson and Tubac, there is a sierra (mountain range) called 'de la Madera' (Timber) and 'puerto de los Muchachos' (mountain pass of the Children). In it are seen enormous masses of virgin iron, many of which have rolled to the foot of the said range. From these masses, a middle-sized one was taken to Tucson, where for many years it has remained in the plaza of said presidio." This is the first known mention of the noted Tucson Ring meteorite.

1852 The first steamboat travels the Colorado River. Lt. Amiel Whipple's route across northern Arizona is established. LeConte (1852) states the following:

> In February, 1851, while at Tucsan [*sic*] in Sonora, I saw two large masses of iron, evidently meteoric, which were used as anvils by the two blacksmiths of that town. They were irregular in form, and although imbedded in the ground to make them steady enough for use, they were about three feet high. I endeavoured to have some pieces cut off, and although a high price was offered, the characteristic Mexican indolence could not be overcome. The only answer I could obtain, was the metal was "muy duro." These pieces were brought from a valley in a small mountain chain about forty miles southeast of Tucsan, east of the road leading to Tuvaca [Tubac]. In the valley, fragments similar to those seen, and of various sizes, were said to be abundant. From the occurrence of this metal, the valley was called "Cañada de Hierro," or iron valley. Silver mines of great richness are very numerous in that vicinity; the metal occurs as sulphuret [acanthite], with galena and blende [sphalerite], and also in native form.

1854 The Gadsden Purchase makes the area in Arizona south of the Gila River part of the United States. Charles D. Poston begins the search for silver near Tubac. The Arizona Copper Co. incorporates in San Francisco and begins the first mining of copper by Americans in Arizona, at Ajo.

1855 Mexican troops leave Tucson and Tubac and are replaced by Americans. Rich copper ore is hauled from Ajo to San Diego. Dr. Thomas Antisell (Parke and Campbell, 1857), a geologist with the Pacific Railroad Survey expedition along the 32nd parallel, reports the following:

About five miles north of camp, (June 22,) at the base of Big Horn mountains, are two small hills, one flat topped and more easterly conical; on the western edge of the latter, or in the trough between the two hills, which are not more than 600 feet high, is a vein of native copper, which is found distributed a mile distance from the hill along the bed of a rivulet. The party who brought in the specimens (on foot) described the ore as found very abundantly. Accompanied by a single private soldier as escort, I crossed the river to examine the locality of this native copper, samples of which had been brought into camp the day previous by that individual. After a delay of some hours in finding a fordable spot in the river, (as it abounds in quicksands here, and forms a series of islands,) and endeavoring to force a passage through the brushwood lining the bank, we at length arrived near the place where the copper had been picked up. It was in an arroyo which descended from the most westerly of the two hills, and small specimens of the ore were found in the creek bed, accompanied with metamorphic sandstone and basalt. The ore was no doubt in the hill higher up; but as the camp had moved on, and we were some hours behind, it was not deemed safe to remain any longer in the locality, and we retraced our steps to meet the trail.

Chemical Analyses . . . Native Copper of Rio Gila. Crystallized in small cubes and octagonal prisms, from apparent passage of the octahedra into the prism; surface rough, and coated with a layer, 1/8 inch thick, of malachite, in botryoidal excrescences; masses 1 1/2 inch thick, the breadth of the seam; small cavities in the interior, with incrustations of malachite.

Analysis of two specimens.

	Found.		Calculated.	
	1.	2.	1.	2.
Copper	11.00	8.97	81.84	80.66
Silica	1.30	1.29	9.67	11.61
Water	1.10	.77	8.18	6.96
Carbonic Acid				
Loss	.04	.05	.31	.77
	13.44	11.08	100.00	100.00

Before the blowpipe faint traces of arsenic were detected. . . .
The ore might then be represented as made up in 100 parts of—

Hydrated carbonate of copper—"green malachite"	28.63	24.36
Native copper	61.39	63.36
	90.02	87.72

The difference representing the silica and impurities.

List of Minerals Collected: . . . 15, native copper, with malachite, Big Horn Mountains, . . . 17,18, Jasper and metamorphic quartz, 19, Chalcedony (agatic), 20,21,22, Oxide of titanium, rutile and sagente, Maricopas, . . . 25,26, Azure copper ore, chrysocolla and malachite, near Tucson, 27, 28, impure red oxide copper, do.

J.L. Smith (1855) publishes an analysis of "fragments of the meteorite from Lt. Jno. G. Parke, of the U.S. Topographical Engineers, who cut them from the mass at Tucson. . . . Found about 20 miles distant towards Tubac, and about 8 miles from the road where we are told there are many larger masses."

1856 The Sonora Exploring & Mining Co. is organized by Charles D. Poston, with Maj. Samuel P. Heintzelman as president, and opens the Santa Rita silver mine near Tubac. The Cerro Colorado Mountains, Pima County, are explored for minerals. The U.S. military occupies the Gadsden Purchase, including Tucson.

1857 Gold ore is found near Sacramento Valley, Mohave County. The San Antonio and San Diego stage-coach mail line is established. Known as the "Jackass Mail," passengers frequently have to ride a mule between Fort Yuma and the coast.

From the Heintzelman mine in the Cerro Colorado Mountains, "a case of ore specimens was exhibited at the Cincinnati Merchants' Exchange in July, 1857, and again at the annual fair of the Ohio Mechanics Institute in September and October" (North, 1980).

1858 The Pima (later Mowry) mine, Santa Cruz County, is discovered, as are the Gila City placers, Yuma County; within 3 months 1,000 men are at work. The Butterfield Stage begins operations and ships some high-grade ores during its 18 months of service: "for sheer discomfort and danger, it has had few peers in the history of transportation" (Tenney, 1927). Gen. Heintzelman notes the following in his diary (North, 1980):

Tubac. Sun. Sept. 26. 1858: . . . Mr. Küstel has discovered a new mineral substance like chloride of silver. Its chemical composition is 75 p.c. silver and 25 chlorine. Under the blowpipe it gives a green color in vapor and stains the coal same color. Mr. Schuchard thinks the green color is occasioned by the metal Osmium. The mineral he thinks is Osmium Chloren [chloride]. . . .

Cerro Colorado. Tuesday Dec. 7. 1858: . . . Mr. Brunckow brought me the finest specimen of ore from the H. mine I have yet seen. It contains nearly or quite all the ores we find in the mine. . . .

Cerro Colorado. Thurs. Dec. 16. 1858: . . . We have just been getting out some of that very rich ore—silver copper glanz or Sulphurets of Silver copper [stromeyerite]. I got a few specimens and a fragment assayed yielded 50 percent. . . .

Cerro Colorado. Fri. Dec. 17. 1858: . . . We also found a very rare mineral—only found in Zacetecas, Mexico—the Iodide of silver [iodargyrite]. I have just obtained from Mr. Brunckow some fine specimens of Iodide of silver and chlorate. . . .

Cerro Colorado. Wed. Dec. 22. 1858: . . . Mr. Brunckow has just assayed some black Fahl ore, with sulphuret of copper and it yielded 3,840 oz. of silver to the ton. Our ores have decidedly improved within the last week or so. Fahl ores contain silver, copper, Antimony, Zinc and arsenic and iron . . . [tetrahedrite-tennantite].

1859 Lt. Sylvester Mowry purchases the Pima (then called Mowry) mine. The first newspaper in Arizona begins publication, the *Weekly Arizonian,* in Tubac.

1860 Richard C. McCormick's report (Browne, J.R., 1869) on the Maricopa Lode or Gray's mine, about 70 miles north of Tucson and 4 miles south of the Gila River, includes the (January 1860) report of Fredrick Brunckow, assayer and mining engineer, on

some selected specimens from this mine, from which this extract is taken:

The specimens consisted of the outcrop ore of a powerful vein, and bear the unmistakable signs of a true vein. . . . As commonly by all outcrop ore, so here carbonates and silicates make their appearance, while the main body of the vein, to some extent below the surface probably, will consist in general of gray sulphuret of copper and other ores which already in large quantity appear on the surface. . . . I divided the ores into different classes and assayed them accordingly.

1. Fahl ore [tetrahedrite] mixed with carbonate, contained to the ton 50 per cent. copper and 104 ounces silver.

2. Gray sulphuret [chalcocite] containing to the ton 60 per cent. copper and 93 ounces silver.

3. Silicate of copper [chrysocolla] containing 20 to 25 per cent. copper, and 20 to 25 ounces of silver to the ton.

4. Carbonate of copper [azurite, malachite] containing 25 to 50 per cent. copper and only a trace of silver; as carbonates and silicates are secondary formation, a large yield of silver could not be expected.

1861 The Civil War begins. U.S. troops withdraw from Arizona; Apache depredations follow. The staff at the Santa Rita silver mines are massacred, with the exception of Raphael Pumpelly. The population of Tubac is about 800; Tucson, 400–500; Gila City, 1,200.

1862 Confederate troops occupy Tucson and are driven out by the California Column under Gen. J.H. Carleton. The La Paz (near Ehrenberg, La Paz County) gold placers are discovered by Pauline Weaver; 5,000 men are soon at work. The Lynx and Hassayampa Creek (Yavapai County) gold placers are discovered by the Walker party.

Arizona as a Territory

1863 Arizona becomes a territory, with its first capital at Prescott, Yavapai County. Mineral discoveries include Castle Dome, Yuma County; the Moss gold mine, Oatman district, Mohave County; the Vulture mine near Wickenburg, Maricopa County; the Planet copper mine, near Bill Williams River, Yuma County; the Antelope Peak placers, Yavapai County, by Pauline Weaver; and the Silver district, La Paz County. The first formal mining districts are organized: Castle Dome, Pioneer, Quartz Mountain, Walker, Weaver, and Yavapai. Pumpelly (1863), in an address to the California Academy of Sciences, says this:

The ore (at the Heintzelman mine) is separated by hand into two classes, rendered necessary by the difference in their chemical character and their richness in silver. The first class consists of the more massive and richer ore, composed of Stromeyerite, tetrahedrite, blende, and galena, with native silver; the gangue is quartz, with some barytes, and the carbonates of magnesia and lime [dolomite and calcite]. . . . The second class contains the same minerals as the first, but they are more intimately associated with the gangue, which in this class forms the bulk of the ore. The blende and galena have a moderate percentage of silver (thirty to fifty ounces), while the tetrahedrite (Fahlerz, or gray copper ore) varies from one to one and a half per cent., and the Stromeyerite is said to rise as high as twenty-six per cent. Chlorobromide of silver [bromian chlorargyrite] and native copper have occurred, and native silver in small flakes is frequent. Two varieties of quartz are found, one in the ordinary glassy form, often comby; and an opaque white variety, very brittle, and associated with the richer minerals. Crystallized specimens are very rare, and of the copper silver glance none have been observed.

Galena, blende, and tetrahedrite are usually closely associated with each other in this ore, while the argentiferous sulphuret of copper is entirely independent of them, but is, at times, mixed with erubescite [bornite]. Native silver occurs in the common filigree form in cavities in the argentiferous copper glance, and is often observable in the minute specks on the tarnished surface of blende and tetrahedrite.

Küstel (1863) describes several tests he conducted on an unknown mineral:

Iodid of Silver and Mercury.—Silver 40–42, iodine, quicksilver, and sulphur (chlorine?) Color dull, dark red. Streak shining. Powder dark red, but changes soon into lead-gray if exposed to the light. In a closed tube it gives three sublimates, separated in rings. The nearest to the assay, is black (sulphide of mercury), the second yellow (subchloride of mercury?), the third is gray (metallic mercury). An addition of bisulphate of potassa causes it to yield violet vapors, which come from the iodine. In an open tube it gives the same sublimate, but the black is very slight; it gives also yellow fumes. A gold particle in the tube becomes amalgamated. Litmus paper at the upper end is colored red by the sulphur. Heated on charcoal, it turns black, fuses easily, and yields silver globules. Melted with soda, it draws partly into the coal. If this crust is broken out, and laid on a blank piece of silver, with a drop of water, the sulphur in it will cause a black spot on the silver. Heated with a small piece of pure lead, it gives a beautiful green coating with a yellow border nearest the assay. This coating (iodine and lead) is far off from the test. With copper oxyd, like the iodyrite. This mineral occurs to my knowledge only in the Heintzelman mine (Arizona). [This species, perhaps tocornalite or perroudite, was the first well-described, unknown Arizona mineral.]

Küstel (1863), reporting on the Mowry mine, says, "The lode, which is over 14 feet wide, runs east and west, between limestone and granite-like porphyry. It consists of sulphurets and carbonate of lead [galena and cerussite] in manganese, often pure, containing iron, frequently in large chambers."

1864 Henry Clifton rediscovers rich copper carbonate ore at Morenci in eastern Arizona, Greenlee County. The *Arizona Miner* begins publication in Prescott. The population of Arizona reaches 4,573, whereas the population of Gila City plummets to 0 after the rich placers are exhausted.

1865 The Civil War ends. Copper ore is produced from the Silver Bell district, Pima County. Richard C. McCormick (1865), Secretary of the Territory, reports the following on Pima County:

Its silver veins are among the richest upon the continent. Some of them have been worked for centuries, and if they have not constantly yielded a large return it has been more from a lack of prudent management or the incursions of hostile Indians than from any defect in the quality or quantity of the ore, or in the facilities for extracting or working the same. The ores are chiefly argentiferous galena, and are best adapted to smelting. Some of the mines at a depth, have a silver-copper glance, iodid of silver, and a mineral containing quicksilver. The copper ores of Pima County are surprisingly rich, yielding in some instances as high as 90 per cent. of pure copper. They are chiefly red oxides and gray sulphurets.

1866 The Apaches go on the war path. William P. Blake (1866) compiles the first systematic mineralogical list for California and Arizona, including the following:

Cerusite [*sic*] . . . , in heavy encrusting masses upon the galena of the Castle Dome district. . . .

Chalcopyrite . . . , at the Apache Chief mine, after getting below the "surface" ores. At the San Pedro mines, near Fort Buchanan [Santa Cruz County]. . . .

Chloride of silver . . . occurs in the Willow Springs district [Coconino County], and in the veins of El Dorado Cañon [Mohave County]. . . .

Chrysocolla . . . , along the Colorado River, very common at and near the surface where the veins containing copper glance are decomposed. Fine specimens were taken from the Great Central claim, about twenty miles from La Paz and at the Blue Lode. . . .

Cinnabar . . . , about eighteen miles from the Colorado River; at Olive City [La Paz County], at the Alma Claim, and the Eugenie, located by Mr. Ehrenberg, associated with silver. . . .

Copper . . . , on the Gila River, about ninety miles from Fort Yuma, at the Arizona Copper Company's mine; associated with red oxide of copper [cuprite] and green carbonate, and spread in crystalline masses through a gangue of calcspar (Cabinet of the author.) . . .

Copper glance . . . , the most common ore of copper, especially in Weaver district, near La Paz, or Olive City. It is usually argentiferous, and is there associated with gold in quartz veins. Found also in the Chahuabi valley, the Tajo, and the San Pedro mines. . . .

Fluor spar [fluorite] . . . , in crystals and large cleavable masses of various tints—white, pink, and purple and green, like the specimens from Derbyshire, England, in the veins of galena and blende, Castle Dome district, Colorado River. . . .

Galena . . . , abundant in the veins of the Castle Dome district, twenty-five miles from Fort Yuma, and in the Eureka District on the same river, about twenty-five miles further north; also in the Picacho district, and in the Weaver district, near La Paz; at the Santa Rita mine, with gray copper ore; in the Tajo vein, with copper glance [chalcocite], blende, tetrahedrite and gold; in the Santa Cruz mountains, south of Fort Buchanan; at the Mowry and Patagonia mines; at San Xavier, on the Santa Cruz, (Pumpelly.) . . .

Hematite . . . , (specular iron ore.)—This is a very abundant ore in California, and Arizona, on the Colorado river, near William's Fork [Mohave County]. Some of the dry arroyos or cañons in that region are crowded with blocks of the pure ore, from one to two feet in diameter. It is broken from beds and seams in an impure metamorphic limestone. The structure is granular, passing into micaceous, and freshly broken surfaces are extremely brilliant. Specimens of similar ore were brought in by Jules Marcou, in eighteen hundred and fifty-three, from the valley of William's Fork, further north. . . .

Molybdate of lead [wulfenite] . . . , in good crystals in the ——— (?) mine, Weaver district. . . .

Red oxide of copper . . . , at the Arizona Copper-Mining Company's claim, near the Gila river, in large masses, with native copper and thin crusts of green carbonate. At the claim known as No. 15, Yavapais [*sic*] district, with native copper. . . .

Stromeyerite . . . , Heintzelman mine. . . .

Tetrahedrite . . . , (gray copper.)—at the Heintzelman mine, containing from one to one and one-half percent of silver. (Pumpelly.)

The noted Yale University scientist Benjamin Silliman (1866) visits the San Francisco (later Oatman) district in Mohave County and finds at the Moss mine "rich gold specimens easily obtained. . . . The rich specimens of free gold in quartz, of which over a ton weight were taken at one time in 1864. . . . fluorspar, free gold, horn silver [chlorargyrite] sometimes in distinct dodecahedral crystals, and iron gossan. . . . The precious metal is sometimes embedded in a compact red jaspery quartz, presenting, when cut and polished, beautiful graphic goldstone."

1867 The capital is moved from Prescott to Tucson.

1868 J.R. Browne (1868) recounts this story:

> A legend is told of the derivation of the name, SALERO or Salt-cellar, which may be worthy of record. On the occasion of a visit from the Bishop of Sonora to Tumacacori [the mission near Tubac], the good father in charge of that establishment furnished, as in duty bound, the best entertainment for his superior that his limited resources would allow. The Bishop was delighted with the sumptuous feast laid before him; the chickens, the fruits, the wines were all excellent; there was only one thing lacking to complete his temporal happiness—a salt cellar! The poor Padre was deeply mortified; he had forgotten all about the salt cellar; in fact, had long since forgotten the use of such luxuries. Salt-cellars were as scarce in Arizona then as they are now. "Never mind!" said he, as a happy thought struck him, "your Excellency shall have a salt-cellar tomorrow." A few trusty men were dispatched to the Santa Rita mountains, with orders to dig and smelt some silver ore and make a salt-cellar, and sure enough, by dinner-time the next day a massive salt-cellar was presented to the Bishop, and from that day forth the mine out of which the ore was dug was called the Salero.

1869 Richard C. McCormick, governor of Arizona, is quoted by J.R. Browne (1869):

> AJO MINES.—These copper mines, sometimes called the Arizona mines, are situated northwest of the Cababi mines about 60 miles, and 40 miles south of the Gila River. The ores are principally of red oxide, malachite of copper, and gray sulphurets. A number of veins have been opened, and the mines were steadily worked for three years. The ore was carried to Fort Yuma and thence shipped to San Francisco, to Swansea, Wales, and to Boston. A shipment of 30 tons of the red oxide ore sent to Swansea sold for $360 per ton, and is said to have been the richest copper ore of the class ever received there.

1870 The population of Arizona totals 9,658, of which 1,039 work in the mining, manufacturing, and machinery industries.

1872 The town of Clifton in Greenlee County is founded by Metcalf and Stevens. A truce is made with the Apache Indian chief, Cochise. The "Great Diamond Hoax" takes place, supposedly in northern Arizona but later determined to be in Colorado.

1873 The U.S. Mint discontinues the coinage of silver dollars. Silver prospectors organize the Mineral Creek (Gila County) mining district. The Silver King (Pinal County) outcrop is discovered by the soldier, Sullivan, who showed a piece of rich ore to Charles G. Mason, a farmer of Florence.

Brush (1873) writes, "Associated with some specimens of galena from Castle Dome District, Arizona, there is found a compact banded mineral, very much resembling some of the varieties of wood-tin from Cornwall . . . compact anglesite."

1874 Globe, Gila County, becomes a booming silver-mining camp. A railroad is built from Clifton to Metcalf, the first in Arizona. The McCracken silver mine, Yavapai County, and the Richmond Basin district, Gila County, are discovered.

1875 A one-ton copper furnace is built at Clifton; the first copper is mined at the site. The Silver King mine in the Superior district is rediscovered by Mason, Regan, Long, and Copeland, farmers from Florence, while they are prospecting for copper near Globe. They also discover the Silver Queen (later called Magma) mine earlier on the same trip (all in Pinal County).

Emerson Stratton, a contemporary mining man, said this about the farmers (Kitt, 1964): "None of them knew much about mining however, and when they sorted out and shipped a carload of ore they left great 'planchas' of silver behind on the dump. That shipment cost them twelve hundred dollars. . . . Four Nevada miners then came along and found the owners of the Silver King throwing sulfide of silver [acanthite] on the dump while carefully picking out and saving the galena. . . ."

Elliott (1884) said, "Mr. Munson found a solid bowlder of chloride of silver in Globe District, weighing 300 pounds, and valued at $3,400."

1876 The Southern Pacific Railroad reaches Gila Bend, Pima County, from Yuma. The United Verde orebody is discovered at Jerome, Yavapai County, by M.A. Ruffner. Mining activity in the Mineral Park district, Mohave County, flourishes. Hinton (1878) states that 13,000 mining claims are made during the year.

According to Harry Brook, quoted in the *Pinal Drill*, "Great chunks of absolutely pure virgin silver were dug out of the Silver King. The superintendent, Aaron Mason, would sometimes drive down from the mine to the mill with a string of wire silver several feet long twisted around his sombrero. They sent native silver to the mint, and had it made into silver dollars, which were given away as souvenirs."

1877 John Dunn, an army scout, locates the first claim in the Warren district (Bisbee, Cochise County). Ed Schieffelin goes to "hunt his tombstone" and records the Tombstone claim, Cochise County. Hodge (1877) exhibits mineralogical knowledge well above that of the average mining man of his day, in discussing, for example, the mines around Mineral Park, Mohave County:

> The Keystone mine, incorporated in California, is a few hundred yards north of the town, and has a vein of mineral from one to three feet in width, consisting of gray antimonial silver, carrying ruby [pyrargyrite or proustite] and native silver, zinc pyrites [sphalerite] and sulphurets of iron [pyrite], and a trace of copper. . . . The Lone Star Mine is one mile northeast of the town, and is incorporated under the laws of Arizona.

It carries beautiful ore, rich in horn, ruby, and native silver. . . . In the Poland Mine, are many beautiful specimens of white crystallized sulfate of lead [anglesite], a rare mineral in all mining countries.

One of the pecularities of the Globe district is the wonderful planets of silver,—planchas de plata,—which are masses of almost pure silver nuggets, from a few pounds in weight to five hundred or more pounds. These nuggets are found in various localities, but more especially in and around Richmond Flat, where mining claims are staked off and dug up with pick and shovel like gold placers.

1878 The first shipment of copper matte is made from the Copper Queen claim, Cochise County. Silver again becomes legal tender. Cinnabar is discovered in the Dome Rock Mountains near Quartzsite, La Paz County. The Twin Buttes mine, Pima County, is discovered. The Stonewall Jackson mine in Richmond Basin begins production. The Gunsight mine, Pima County, is discovered: "From the croppings one of the discoverers whittled himself a pure silver gunsight, to replace one that had been lost."

Hinton (1878), in discussing Yavapai County, the principal seat of Arizona mining at the time, gives notable mineral and geological descriptions:

Gold has been found in nearly every locality in Yavapai County wherever diligent search has been made, both in veins and in bars and gulches. It is noticed that the lodes when first opened carry a good percentage of gold, but at a greater depth run into or carry a large percent. of silver. It is found also in the granitic, feldspathic, quartzose, hornblendic, slate, and talcose rocks, free and intimately mixed with various sulfides, often in beautiful crystals of the octohedral [*sic*] form; wire gold has been found; also scales and nuggets of respectable size.

Silver occurs, native, in various lodes, in tangled wires, arborescent filaments and in nuggets; also, as horn silver, chloride, chloro-bromide, as sulphide associated with lead, iron, antimony, zinc, etc. The Black Warrior lode has produced beautiful specimens of wire silver; also the Peck, Silver Prince, Tip-Top, Silver Flake, Kit Carson, Lone Star, Little Tiger, and others. The Sumner lode produces a new combination of ore. The principal vein matter is micaceous iron, iodide of silver, gold, sulphurets of iron, and antimony. The name Arizonite has been given to it by Mr. H.G. Hanks, of San Francisco. Horn silver from the Peck lode has been found in crystals, assuming the forms of the cube, and with corners truncated, tetrahedral, dodecahedral and hexagonal, and in masses weighing several pounds. Ruby silver of beautiful color has been discovered in several districts.

Many valuable lodes of copper are found, some of the red oxyds assaying as high as 80 per cent.; some producing metallic copper in nuggets and in the dendritic form; also malachite, blue and green carbonates and alacamite [atacamite] as a muriate, as silicate, also as sulphides and oxyds. Gray copper is found in Black Warrior and many other lodes.

Lead is found in abundance as sulphide [galena] and carbonate [cerussite]—rarely as a sulphate [anglesite]; it is found in crystals in the Peck lode; chromate [crocoite] and phosphate [pyromorphite] in beautiful crystals from the Lone Tree lode, as molybdate and wulfenite, from the Accident lode, Lynx Creek district; oxyd and chloride of lead abundant in many lodes and usually carrying silver, and sometimes gold. Zinc, as a sulphide [sphalerite], reddish, brownish red, white and black. It is not very abundant as an ore.

Hinton (1878) also describes the Stonewall Jackson mine: "The 'Champion' vein is about three feet in width, between walls of graywacke; the gangue is mostly sulfate of baryta [barite], silica mixed with carbonate of lime and argillaceous earths, and is in a high state of crystallization, producing large and beautiful specimens of crystallized chloride of silver, brittle sulphuret of silver, silver glance, (argentite) and, as a result of the decomposition of the two latter varieties produced by surface influences, black sulphide of silver."

Ed Schieffelin (1926) described how he found the first valuable claims at Tombstone in 1878:

> Sometime before I had found a piece of very pretty ore; it was something of a telluride, assaying about $5,000 to the ton, and carrying a good deal of gold. . . . [Richard Gird, an assayer, was his partner and had set up at the "Bronco" (Brunckow) mine nearby to provide assays.] In the afternoon I found where the ore had come from, and was building a monument when my brother [Albert] returned, having killed a deer. I called to him to come and see what I had found, if he did not think there was rich ore in that country. I had printed the head of my pick down into the rock, and he said "Yes, that is rich ore." It was the claim we called the "Lucky Cuss," and the croppings were six or seven inches wide, and probably 40 or 50 feet long; it cropped boldly out of the ground, and in many places you could print a half-dollar into it. . . . it assayed $15,000 to the ton.

1879 The boom starts at Tombstone. The town of Bisbee, Cochise County, is named. The Seventy-Nine mine is claimed in the Banner district, Pinal County. The Mammoth mine is also claimed in Pinal County.

George W. Maynard is sent to examine the outcrop that would become the United Verde mine at Jerome. He reported (*Engineering Mining Journal,* March 13, 1909), "The outcrop projected well above the surrounding surface, and was made up of malachite, azurite, chrysocolla and cuprite, a veritable flower garden, for a width of 15 feet. . . . 100 feet vertically below, an adit had been driven into the vein. . . . in this crosscut there was considerable chalcopyrite and some chalcocite."

1880 The population of Arizona reaches 40,440; 7,374 work in the mining, manufacturing, and machinery industries. Silver-copper ore is mined from the Silver Queen (Magma) mine. Southern Pacific Railroad tracks and the first train reach Tucson.

1881 The Southern Pacific Railroad crosses Arizona and reaches Lordsburg, New Mexico. The Old Dominion Copper and Smelting Company starts operation at Globe. On the recommendation of Dr. James Douglas, Phelps, Dodge & Co. purchases interests in both Morenci and Bisbee.

W.P. Blake (1881a,b) writes, "vanadinite in the lead-bearing veins of Castle Dome District, Arizona, associated with wulfenite, cerussite, galena and fluor-spar." He also states, "beautiful crimson-red crystals of vanadinite from the Hamburg mine and fine wulfenites, sometimes in octahedral crystals, from the Red Cloud mine, the 'Oakland Boys' claim, and other points in the Silver District, Arizona."

Silliman (1881) publishes the following:

> *Vanadinite.*—This hitherto rare species promises now to be comparatively abundant. In the so-called "Silver District," in Yuma County, Arizona, about 50 miles north of Fort Yuma, is a large area traversed by veins of quartz carrying argentiferous galena, with salts of lead, but no gold, and rather extensively explored. The lead salts which I have seen from this region are wulfenite, of remarkable beauty, vanadinite, and massive anglesite with galenite. Vanadinite occurs in three mines, near together, the "Hamburg," the "Princess," and the "Red Cloud." The crystals of vanadinite are extremely beautiful, alike for brilliancy of color, luster and perfection of form.
>
> *Wulfenite* crystals of rare beauty are found in the "Red Cloud" Mine, already mentioned as furnishing the vanadinite. The specimens sent me are from a depth of about 300 feet. They show very solid tabular crystals of large size, brilliant luster, and rich orange-yellow to orange-red color.
>
> *Crocoite-group.*—Three if not four of the species of this group occur among the ores of the Vulture region, and especially in the "Collateral" and "Chromate" veins. These two veins together with the "Blue Jay" and the "Phoenix mine," form a group of singular mineralogical interest, furnishing, among more common minerals, the species, crocoite, phoenicochroite, vauquelinite, jossaite(?), vanadinite, volborthite(?), Descloizite(?), Chileite(?), wulfenite.
>
> Thenardite from Rio Verde, Arizona Territory. Some months since I received a lump of a saline mineral marked "Salt," reported by my informant, Mr. Treadwell, of Phoenix, to occur in abundance on the River Verde, in Maricopa County. It proved, on examination, to be anhydrous sodium sulfate or *thenardite,* a species which has hitherto been found in very limited quantity.

1882 The United Verde Copper Co. is organized. The Atlantic and Pacific (Santa Fe) Railroad crosses northern Arizona.

Hills (1882) reports, "The rare mineral dioptase has been recently found at the Bon Ton group of mines, near the head of Chase Creek, about 9 miles from Clifton, Arizona. It occurs in brilliant crystals lining cavities in what is called locally the 'mahogany ore,' a dark-brown compact mixture consisting principally of limonite and oxide of copper in varying proportions."

W.P. Blake (1882) writes that in the Contention mine (Tombstone) vein, "The only metallic contents so far found, with the exception of the pyrites and some galenite and lead carbonate, are gold and silver in a comparatively free state; part of the gold, if not all, being free, and the silver occurring chiefly as chloride, or horn-silver (most probably with iodide), in crusts and films, also occurring in minute crystals upon cleavage surfaces." Water first appears in the Tombstone mines.

1883 The Ray Copper Company is organized. Some copper is mined at Ray. A small smelter is built at Jerome. W.P. Blake (1883) writes this about the Silver King mine:

> in the mine, native silver, stromeyerite, argentite [acanthite], sphalerite, galenite, tetrahedrite, bornite, chalcopyrite, pyrite, quartz, calcite, siderite, barite. Near the surface, in the decomposed parts of the vein, where the ores are partially oxidized and desulphurized, we find in addition horn-silver (cerargyrite), malachite, azurite, native copper, cuprite, besides oxides and carbonates of lead and possibly embolite, the chlorobromide of silver, also the Argentite, in pure black lumps. . . . Native silver in the filamentous form, coarse and fine, very white, and striated as if made up of bundles of fine wire, and ranging in size from the size of a pin or knitting needle to masses half an inch through, but solid and much twisted or gnarled. It is also finely filiform in long wires, in one instance twenty-four inches long, and in threads fine as hair or silk, filling cavities or branching from the coarser wires.

1884 A general economic depression begins. The United Verde Copper Co. sends a fine exhibit of Arizona minerals to the New Orleans Exhibition.

1885 The Copper Queen Consolidated Mining Co. is formed and builds a concentrator and smelter. The Territorial Legislature creates the University of Arizona and its School of Mines in Tucson. The Tempe Normal School is established.

W.F. Hillebrand (1885) first describes emmonsite from Tombstone. H.L. Wells and Penfield (1885) first describe gerhardtite from Jerome: "This mineral was first identified as a new species by Prof. Geo. J. Brush, who found it among a lot of copper minerals from the United Verde Copper Mines, Jerome, Arizona, which were left at the Sheffield Scientific School [Yale University] by Mr. G. W. Stewart, assayer, from that place."

1886 Geronimo surrenders and the Indian wars cease. The bonanza ores are exhausted at Morenci, where a concentrator is built to treat oxidized ores that average (only) 6.5% copper. The Bagdad claims in the Eureka mining district, Yavapai County, are discovered.

1887 The Congress gold mine, Yavapai County, is discovered. W.B. Smith (1887b) describes dioptase from Riverside, Pinal County.

1888 The first building to house the School of Mines is completed at the University of Arizona. The Harquahala gold deposit, La Paz County, is discovered. The Silver King mine is depleted.

1889 Senator W.A. Clark gains control of the United Verde mine. W.F. Hillebrand (1889a) first describes antlerite from the Antler mine, Mohave County, and provides an analysis. W.F. Hillebrand (1889b) also describes cuprodescloizite from the Lucky Cuss mine, Tombstone, Cochise County. Diller and Whitfield (1889) describe dumortierite from Clip, La Paz County.

1890 The population of Arizona totals 88,243. Penfield (1890) first describes spangolite from near Tombstone:

> During the summer of 1889, while visiting Mr. Norman Spang of Etna, Allegheny County, Pa., my attention was called by him to a very beautifully crystallized specimen of an unknown mineral which he had obtained from a man living near Tombstone, Arizona. The original owner had a small collection of minerals which he had gathered together within a radius of about two hundred miles but he had no idea of just where he had found the specimen, though he thought it was from the Globe District. Mr. Spang had forgotten the name of the man from whom he had secured it, so that until other specimens are found uncertainty must exist about the exact locality and mode of occurrence. On expressing a desire to investigate the mineral, Mr. Spang very generously lent me the specimen and has since presented me with it, and it is now deposited in the collection of Professor Geo. J. Brush, at New Haven. A preliminary blowpipe examination showed that the mineral was undoubtedly a new species and essentially a hydrated sulfate and chloride of copper, and I take pleasure in not only expressing at this time my thanks to Mr. Spang for his kindness but also in naming the mineral, which as will be shown, is of unusual interest, *Spangolite,* after him.

Genth (1890) describes tetradymite, which was found 2 miles south of Bradshaw City, Yavapai County. W.P. Blake (1890) mentions "thenardite, mirabilite, glauberite, halite and associates, of the Verde Valley, Arizona Territory" and bournonite from the Boggs mine, Big Bug district, Yavapai County: "this is believed to be the first announcement of the occurrence of this species in the United States."

1891 The cyanide process becomes a success in South Africa and revolutionizes gold mining worldwide. G.A. Koenig (1891) first describes paramelaconite and "footeite" (connellite) from Bisbee. Pirsson (1891) describes cerussite twins from the Red Cloud mine.

1892 The Pima County recorder announces that 33,000 mining claims have been filed. *The System of Mineralogy,* (sixth ed.), by J.D. and E.S. Dana, presents a summary of minerals from the Arizona Territory that are of national interest:

ARIZONA

APACHE CO. Copper Mountain—Chalcocite, azurite, melaconite, sphalerite, pyrite. And at Greenlee Gold Mountain, chalcocite, malachite, cuprite, auriferous gravel.

Near Holbrook.—Forest of *petrified wood!* ("Jasperized wood"), *amethyst.*

Navajo Reservation (also in part in N. Mexico).—*Pyrope garnets! chrysolite* (Job's tears)! chrome-diopside.

COCHISE CO.—Bisbee.—Copper Queen mine (and Holbrook mine), *azurite! malachite! cuprite! chrysocolla,* melaconite, paramelaconite, footeite, wad, *calcite* enclosing malachite, *stalactites* of either aragonite or calcite (or perhaps both) aurichalcite.

Tombstone.—Emmonsite. At West Side mine, hessite, yellow wulfenite. At Empire mine, yellow wulfenite. At Contention mine, yellow wulfenite and hyalite. Lucky Cuss mine, descloisite, cuprodescloisite.

GILA CO.—Globe.—Old Globe mine, *malachite! azurite!, chrysocolla!* quartz on chrysocolla, *melaconite, calcite.* Vermont mine (near Globe), chalcocite. Stonewall Jackson mine (near Globe), native silver in crystals, argentite.

MARICOPA CO.—Vulture.—Vulture mine (60 m. N.W. of Phoenix), *jarosite,* crystallized gold, yellow wulfenite. Farley's Collateral mine (about 20 m. N.E. of Vulture P.O.) *vanadinite,* red and yellow; yellow *vanadinite* in clear calcite! red *wulfenite,* chrysocolla, (and according to Silliman) crocoite, vauquelinite, etc. Phœnix mine (about 20 m. N.E. of Vulture), *vanadinite,* yellow and red, the former very like mimetite; descloisite.

Hassayampa Distr.—Montgomery mine, tetradymite.

Santa Catarina Mts. (also Pinal and Pima Cos., exact locality not known).—*Aurichalcite!*

Turquois Mts.—Turquois.

GRAHAM CO.—Clifton.—At the Longfellow Mine (5 m. from Clifton), *malachite, azurite! cuprite,* native copper. Metcalf mine (6 m. from Clifton), brochantite. At the Bon Ton mines (exact locality doubtful), dioptase. Garfield mine (about 9 m. from Clifton, on Chase Creek), argentiferous *tetrahedrite,* azurite.

Morenci.—Humming Bird mine (about 6 m. from Clifton), *malachite* and azurite in short *stalactites* with concentric structure, *chrysocolla,* wad. Yavapai mine (about 5 1/2 m. from Clifton, via the Longfellow mine, and 1 m. from Morenci, *chalcanthite* fibrous, brochantite, drusy azurite. Copper Mt. mine, in Morenci, *lettsomite!* [cyanotrichite], *chalcotrichite!,* cuprite! arborescent and bright *native copper, azurite.*

Mineral Park.—Turquois.

PIMA CO.—Flux Mine.—Cerussite!

PINAL CO.—Oracle.—At The Mammoth Gold mine, *descloisite! vanadinite!* wulfenite.

Near *Riverside.—Brochantite! dioptase!* in small but well-defined crystals.

Pinal.—Hollow quartz crystals, *chalcedony.*

Silver King Mine (near Pinal).—Fine aurichalcite, crystallized *silver! sphalerite!,* argentite, pyrite, chalcopyrite. At Silver Queen mine (near Pinal) red *cerussite!*

Picket Post.—Red *wulfenite.* Black Prince mine, red *vanadinite.*

YAVAPAI CO.—Boggs Mine, in the Big Bug distr.—Bournonite.

Grove Mine, in the Humbug distr.—Embolite! Also in same distr., brown vanadinite, barrel-shaped crystals. 2 miles from Bradshaw, tetradymite crystals!

Jerome (30 m. N.E. of Prescott).—in the United Verde copper mines, *gerhardtite, atacamite, brochantite, azurite, chalcanthite.*

Rio Verde.—near Camp Verde.—*Glauberite, thenardite,* mirabilite, halite, etc.

YUMA CO.—*Red Cloud Mine* (about 30 m. N. of Yuma).—*Red wulfenite!* mimetite, *cerussite,* hyalite, calcite. Also fine *vanadinite!* at the following mines: Hamburg, Princess, Clara, Black Rock, Rover, Melissa, etc. All of these mines (also the Red Cloud) are in the "Silver District," and are one to five miles distant from the Red Cloud.

Melissa and Rover Mines.—*Wulfenite* (red), occasionally in simple octahedral crystals of small size.

Clip (about 5 m. N. of Red Cloud),—*dumortierite!* cyanite.

Castle Dome District (about 30 m. N.E. of Yuma).—*Wulfenite* in gray, waxy, almost cubical crystals, green and purple *fluorite* and crystallized *anglesite!* galena and cerussite, also anglesite of woody appearance!

1893 Silver is demonetized; its price drops from $1.29/oz to 25¢/oz. In panic, prospectors turn from silver to gold. The Copper Queen mine works its first copper sulfides. Moses (1893) describes ettringite from the Lucky Cuss mine in Tombstone.

1894 A rail connection is completed to Jerome. A mine fire starts in the sulfide orebody at Jerome. Geo. L. English & Co. advertises the following in the *Mineral Collector* (v. 1, p. 4): "ARIZONA VANADINITE is now quite scarce, so that we are delighted to announce the receipt of a little shipment of extra good specimens. The crystals are large and curiously hollowed out, of intense dark red color, and nicely sprinkled over the matrix; 25c. to $4.00. A few good RED WULFENITES at 50c. to $10.00 accompanied this shipment."

1895 The cyanide process is installed at the Congress mine. Dr. A.E. Foote advertises in the *Mineral Collector* (v. 2, p. 1):

COPPER QUEEN MINERALS! We have obtained the whole of a recent find which includes some of the most remarkable specimens ever found. Gem-like crystals of AZURITE, of marvelous luster and perfection, are sparingly scattered over a durable velvet surface of wad stalactites, making, with minute tufts of Malachite, a combination that will tempt every collector. They are unique in the wonderful brilliancy and sharpness of crystallization, and will be an indispensable addition to even the largest suite of this species.

CUPRITES in bright octahedral and cubical crystals.

STALACTITES of a delicate pale green tint; some, of the curious "curtain" form.

Washington A. Roebling, who built the Brooklyn Bridge and whose mineral collection became the foundation of the Smithsonian Institution collection, advertises for specimens he lacks, including these from Arizona: "Antlerite, Yucca, Mohave County. Emmonsite, Tombstone. Footeite, Bisby [*sic*]. Gerhardtite, Jerome. Spangolite, Tombstone."

Another advertisement by Dr. A.E. Foote (the *Mineral Collector,* v. 2, p. 7) lists, "RED WULFENITE from Arizona. We were the first to collect this magnificent mineral in quantity and introduce it to mineralogists. None has been obtained for many years. In '88 Dr. Foote made a trip to the mine, making us a large shipment. A small box which was mislaid at that time has just been opened, disclosing some wonderfully beautiful single crystals and groups. Old prices still hold, 10c. to $1.50 for crystals; groups $1.00 to $7.50."

1896 The Commonwealth mine at Pearce, Cochise County, is discovered. A 100-ft shaft is sunk entirely in chrysocolla ore in Webster Gulch at Miami, Pinal County. Disseminated copper ore is successfully worked for the first time at Morenci, 3 years before it was worked at Bingham Canyon in Utah. W.P. Blake (1896) reports the following:

Iodobromite [iodian bromargyrite] This rare mineral occurs in thin seams and crusts in a silver-bearing vein of quartz and calcite near Globe, Pinal County. (Hechman's mine.) Its crystallization is obscure, but the species is known to crystallize in the monometric [cubic] system. It is soft, like talc, luster vitreous; color light lemon-yellow to sulphur-yellow and canary-yellow. The reactions before the blowpipe are remarkably beautiful and interesting. Heated in a closed tube with bisulphate of potash the mineral quickly changes color to a dark salmon or orange-red; heavy brownish-red fumes of bromine are given off and bromine condenses in the higher portion of the tube; violet vapor of iodine then appears and crystals of iodine form below, or nearer the assay, than the condensed bromine. The fused assay floating in the flux is brilliant cherry-red, at first a very dark red, but as cooling progresses it gradually loses this color passing through various shades of red until the normal yellow color is restored. The fused mass then being removed from the tube and reheated until all the bromine is expelled and then heated with carbonate of soda on charcoal a button of metallic silver is obtained. The fused carbonate of soda dissolved from the coal reacts for chlorine with silver nitrate. In the final reduction of the assay to metal a slight yellow areola, like that from lead, was observed and referred to a probable slight impurity.

Geo. L. English & Co. advertises in the *Mineral Collector* (v. 2, p. 11):

AZURITES! AZURITES!! AZURITES!!! The largest and most gorgeous display ever seen in this country! 400 *exquisite specimens.*

Any price you want up to $50.00. Our 25-cent specimens average 1 × 1½ inches with ½-inch crystals of the very finest quality. Larger cabinet sizes 50c. to $5.00; splendid Museum specimens, $5.00, $7.50, $10.00, $12.50, $20.00, $35.00 and $50.00. Even old collectors who have several drawers full of Azurite have been most liberal buyers of these marvellously fine specimens. *Their special merit* lies in the exceeding sharpness and brilliancy of the crystals, but their rich color and unusual transparency are also well worthy of notice as well as the great perfection of the crystals, the shapeliness and general attractiveness of the specimens. We believe the present is an opportunity to secure the finest Azurites ever found which is never again likely to be presented to collectors. In the deeper levels of the mine which is now being worked, the ore is largely Chalcopyrite with scarcely any carbonates, and it would not be surprising if no new finds of Azurites and Malachites were ever made. Every collector who notes the rapidly advancing prices of minerals from Phoenixville, French Creek, the Red Cloud Mine, etc., and remembers how abundant they once were, will appreciate the importance of securing at once a fine series of the Arizona Azurites which are unquestionably the finest in the world.

The Niven & Hopping Co. also advertises in the *Mineral Collector* (v. 3, p. 5):

ARIZONA. EKDEMITE, on wulfenite, a large new lot just received, bright yellow and red, a very few prettily associated with light blue chrysocolla. It makes a very showy specimen. The ekdemite [not ecdemite, but mimetite] is powdery on the conglomerated wulfenite crystals, some of which are good, bright and clear.

CUPRITE, green, octahedral crystals on the dark gangue, with azurite, etc., very good. 25c. to $1.00.

AZURITE, in fine large crystal groups, the larger crystals are not as bright as the smaller and are not so closely set on the matrix. Large groups with "green cuprite" 50c. to $4.50. Small groups postpaid, 25c. Museum specimens, $5.00, $10.00, $12.50, $20.00. Bright specimens of malachite and azurite, massive, postpaid, 25c.

MALACHITE, a few specimens of the rare conic variety, $1.50 to $3.00.

VANADINITE, from Pinal County, dark red with black descloizite, 10c. to $3.00. Also from Yavapai County, the peculiar light brown variety, 10c. to 50c.

STALACTITES of Calcite, sometimes with aragonite, conical and grotesque forms, tinted greenish blue. 10c. to $2.00. A nice specimen postpaid 25c.

CUPRITE, small groups of bright crystals postpaid 25c. to 50c.

CHALCOTRICHITE, good color, nice specimens, 25c. to $2.00.

A small microscopic box mount postpaid, 25c.

CERUSSITE, large cabinet specimens, 35c.

1897 Geo. L. English & Co. advertises the following in the *Mineral Collector* (v. 4, p. 2):

A GREAT STRIKE AT MAMMOTH, ARIZONA. Two pockets were struck by our collector containing beautiful brown and black, sparkling *Descloisite* associated with brownish-red crystals of *Vanadinite* 10c. to $2.00 for fine specimens are prices which ought to suit every collector. A few quite good *wulfenites from Mammoth* associated with *scarlet Descloisite* 25c. to $2.50. A few specimens of *Leadhillite* from this locality, 50c. to $2.00. Massive *Anglesite with Linarite and Chrysocolla,* 10c. to $1.00.

QUARTZ ON CHRYSOCOLLA FROM GLOBE. A few exquisite specimens of this most beautiful of combinations, 50c. to $4.00. Order by return mail or you will be too late.

RED WULFENITE FROM RED CLOUD, in fairly good groups, 25c. to $2.00.

Manard Bixby also advertises in the *Mineral Collector* (v. 4, p. 2):

California and Arizona Minerals.

AZURITE. The choice of a new cave at Morenci. These are exceedingly beautiful specimens associated with a manganese mineral. They are of a novel form and very desirable.

CRYSTALLIZED SILVER in Calcite, very delicate and pretty crystals.

CUPRITE. Elegant octahedrons on native copper.

QUARTZ ON CHRYSOCOLLA, very showy specimens.

PLACER NUGGETS OF CRYSTALLIZED SILVER.

VANADINITE, groups of choice crystals, also semi-crystallized masses with descloizite and ecdemite.

LINARITE from a new locality.

After a visit to the Globe district, Maynard Bixby reports the following (the *Mineral Collector,* v. 4, p. 5):

> Of all the magnificent velvet malachite found in former years, not a single fine piece remains in the camp. Fine octahedral cuprite crystals were formerly obtained, but now only from some of the collections. The beautiful quartz on chrysocolla is now found only in the collections in town. A late find was a very few octahedrons of copper in groups, and occasionally very perfect single crystals. Chalcotrichite occurs rarely at the Old Dominion Mine, generally coating or enclosed in calcite, and probably less than a dozen specimens have been found. A few specimens of calcite have been collected very rich in native silver, usually crystallized in beautiful and delicate feathery forms. . . . At Richmond Basin, about 20 miles distant, rare specimens of crystallized silver in rolled nuggets have been found loose in the soil. I obtained one weighing several pounds, and a larger piece weighing about 30 lbs. was taken out several years ago. Placer silver is more abundant at this camp than at any place I have known, and in fact these nuggets are the largest and rarest of this metal in the United States. Fluorite occurs here in large purple crystals, on the dump of one of the prospects.

A Lazard Cahn advertisement (the *Mineral Collector,* v. 4, p. 11) lists "ETTRINGITE, Lucky Cuss Mine, Tombstone, Arizona, exceedingly rare. $5.00 to $10.00."

1898 The war with Spain begins. Lazard Cahn advertises the following in the *Mineral Collector* (v. 5, p. 10): "Scheelite from Dragoon, [Cochise County], Arizona. Fine, large rich, reddish-brown crystals, loose and on quartz gangue, have been acquired and will be placed on sale in a few days. I am sure they will greatly please all who see them. They are irresistible and will not remain in stock long. I again urge, therefore, promptness in ordering."

1899 Ward's Natural Science Establishment advertises in the *Mineral Collector* (v. 5, p. 12):

> WULFENITE. We have just purchased a fine assortment of orange-yellow, well crystallized specimens, the last that can be obtained from the famous Mammoth Gold Mine, Pinal County, Arizona; and offer them at prices ranging from 25 cents to $12. The latter a magnificent specimen, $5 \times 3^1/2$ inches, thickly strewn with beautiful crystals.
>
> VANADINITE from the same mine. This interesting Lead Vanadate appears glossy-black in surfaces covered with minute crystals, reddish-brown in specimens with medium sized ones, and brownish yellow in those with large hexagonal prisms. Prices from 50 cents to $10.

Dr. James Douglas (1899) reports on the Copper Queen mine:

The Copper Queen mine has become famous for its beautiful specimens of carbonates, both malachite and azurite. The malachite is never found in such large and compact masses as to make it commercially valuable for decorative purposes; besides, occurring generally in thin botryoidal masses, it is usually streaked with manganese, which detracts from its purity. Its most striking mode of occurrence is in geodes, which are lined with velvety crystals of the same mineral. These hollow spheres, the walls of which are composed of concentric layers, are rare, but, when found, are usually in nests imbedded in soft, wet, ferruginous or manganiferous clays, such as constitute the gangue, or "ledge-matter," of nearly all the ore; and they occur at no great distance from a limestone wall or partition.

The slabs of azurite, also, usually occur near limestone, but preferably in the manganiferous, clayey gangue. The oxidized copper-ores, however, which are mined in economic quantities, consist usually of cuprite and carbonate, disseminated through limonite; or of carbonates, chiefly of the green variety, in streaks or crystals scattered through ferruginous or manganiferous clay; or of minute particles of metallic copper, with more or less cuprite crystals, disseminated through yellow clay. These yellow clays are generally more distinctly bedded than the masses of red and black clays which carry the highly oxidized-copper compounds. Masses of any considerable size of native copper are found almost exclusively, not at the surface, where the oxidizing agencies have been most active, but in the deepest layers of the large ore-bodies, where apparently some reducing-agent has been more actively at work than elsewhere, and where the ore is fartherest [*sic*] removed from atmospheric interference. On the sill-floor of the 300-foot level (at the bottom of the great southwest orebody already referred to) native copper was abundant in masses, some of them of several hundred pounds in weight. The surface of the native copper lumps and masses is always more or less perfectly crystallized, as of course is the case in those mines where all these secondary copper-ores were deposited slowly from the dissolved constituents of the original sulfides.

A feature of the Bisbee mines is the large caves, which have had some influence on the occurrence of the oxidized ore-bodies. The walls, roofs and floors of these caves are always covered with stalactitic accretions, which are often tinted green, blue and red by the copper- and iron-solutions which are mixed with a solution of carbonate of lime. What however gives these caverns practical interest is that they have invariably covered oxidized ore-bodies. . . . When a cave is now met with, drifts are run beneath it to strike the ore body. It is a fair assumption that the cave, if not originally formed by the contraction of an ore-body, was increased by the shrinkage of the latter during its oxidation, and that, therefore, a genetic relation really exists between the cave and the underlying ore.

1900 Phelps, Dodge & Co. builds a smelter in Douglas, Cochise County. Rich gold ore is mined in the Oatman district. The population of Arizona reaches 122,931. Geo. L. English & Co. advertises the following in the *Mineral Collector* (v. 6, p. 11): "A single fine specimen of DIOPTASE FROM ARIZONA is worthy of note because of its excessive rarity and modified crystals; $15.00."

An advertisement by Dr. A.E. Foote (the *Mineral Collector,* v. 6, p. 12) lists, "PINK FLUORITE. Rare color in a common mineral,—seldom observed from localities other than Switzerland. A correspondent made a special trip and secured for us a limited supply, which yielded some excellent octahedral cleavages. A specimen, one to three inches from tip to tip, is particularly striking on account of the unusual color and its resemblance to the crystallized Pink Fluorite from St. Gothard,—a mineral with appreciated value. From Yuma County, Arizona, at 50c. to $3.00."

1902 The Calumet and Arizona Company is organized. A smelter is built at Sasco, Pima County, for Silver Bell ores. Roy Hopping advertises the following (the *Mineral Collector,* v. 9, p. 2): "Prince Henry Azurites: In honor of the recent visit of royalty I have secured from Bisbee, Ariz., a small lot of the most gorgeous Prussian-blue Azurites. They are now ready but will not be put on sale until Saturday afternoon, April 5th, at 2 P.M. Prices, 15c, 75c, $1.25, $1.75, and $2.50.

"Malachites, solid green, some velveted, others prettily banded with black-green, one botryoidal and one stalactitic, 15c, 20c, 25c, 35c, 75c, $1.25."

Louis P. Gratacap (in the *Mineral Collector,* v. 9, p. 4) discusses the collection of minerals in the American Museum of Natural History and the Bement Collection: "Previous to the purchase of the Spang collection [in 1891], a very remarkable group of specimens of Azurite and Malachite (the green and blue carbonate of copper) had been presented to the museum by the Copper Queen Consolidated Mining Company of Arizona. This unique and very striking assemblage of specimens, together with later additions from the same source, is now installed in the single large case at the north end of the smaller hall."

1903 The 8-hour day for underground miners is signed into law. The Gold Road mine is discovered at Oatman. Headden (1903) describes cuprodescloizite from a locality near Nogales, Santa Cruz County. C.H. Warren (1903) describes arsenic from the Double Standard mine, Washington Camp, Santa Cruz County.

1904 Ransome (1904) publishes a report on the Bisbee district. Lindgren and Hillebrand (1904) first describe coronadite from the Coronado vein at the Clifton-Morenci mine, Greenlee County. Charles O. Brown, Tucson mining engineer and keeper of the Congress Street Saloon, sells his mineral cabinet. Once prominently displayed in the saloon, the cabinet contains rare and unusual examples collected from Arizona mines for more than 40 years (*Arizona Daily Star,* August 4).

1905 Lindgren (1905) publishes a report on the Clifton-Morenci district. Lindgren and Hillebrand describe several minerals from the Clifton-Morenci district (Clark, F.W., et al., 1905): coronadite, chalcocite, willemite, calamine [hemimorphite], dioptase, chrysocolla, copper-pitch ore [melaconite or manganoan chrysocolla], morencite [nontronite], libethenite, brochantite, spangolite, and gerhardtite. Kunz (1905) first describes moissanite from the Canyon Diablo meteorite, Coconino County.

1906 The first low-grade porphyry ores are produced from the Morenci mine. The first claims are filed on San Manuel, Pinal County. The Petrified Forest is made a National Monument.

1907 Daniel C. Jackling starts churn-drill exploration at Ray. Arizona becomes the U.S leader in copper production, surpassing Montana. Garrison (1907) describes a "unique" association of molybdenite and copper ores. Petereit (1907) publishes a photograph of crystallized copper from Bisbee. This may be the earliest published photograph of an Arizona mineral.

1908 The Miami Copper Co. and Inspiration Copper Co. are organized. The operations at the Tom Reed gold mine at Oatman become extensive.

1909 Sacramento Hill in Bisbee is drilled. Ajo is also drilled, but the deposit is rejected. Arizona leads the world in the production of copper ore. Palache and Merwin (1909) describe connellite and chalcophyllite from the Calumet & Arizona mine, Bisbee, and suggest that Bisbee may be the type locality for spangolite. Palmer (1909) describes arizonite from a pegmatite about 25 miles southeast of Hackberry, Mohave County.

W.P. Blake (1909) reports to the governor in *Minerals of Arizona* 91 species and 15 varieties, including the following:

Calcite—at the Silver King it occurred in small obtuse rhombohedral crystals, "nail-head spar," strung, like beads, on silver filaments, or wire silver.

Chalcedony—a variety of chalcedony, colored bluish green and blue by copper oxide, has attracted attention as a gem mineral, and has been brought to notice by H.P. Wightman of Globe, Arizona, who sent samples to the United States Geological Survey. The mineral is said to occur in small stringers in the Keystone copper mine in that district. It varies in color from bright to pale blue, bluish-green and nearly apple green, resembling some chrysoprase. It bears some resemblance to the bluish chalchuite [turquoise], but is more brilliant and translucent. It takes a high polish, is hard, and when well cut, *en cabachon,* and mounted forms a pleasing jewel.

Chalcocite—In the old mine, Cornelia shaft, at the Ajo it is an important mineral. Col. Bean presented to the museum at the university, through W.P. Blake, an 80-pound mass.

Copper—Of all the occurrences of native copper so far observed in the territory, that at the historic Ajo is the most important, for all the readily accessible masses of the metal have long since been shipped away. It was in close association with the red oxide, cuprite, penetrating its substance, ramifying through it and binding it in solid, heavy masses many pounds in weight. . . . On the 1,050-foot level of the Calumet and Arizona mine native copper occurs in branching crystalline masses beautifully incrusted, with crystals of cuprite.

Cuprite—The collection of choice specimens from the Copper Queen made by Mrs. L. Williams contained a remarkably fine single crystal of cuprite about half an inch square, a perfect cube having a rich, ruby-red or cherry-red color, and transparent.

Dioptase—A sample of copper ore containing dioptase was received for the St. Louis exhibition from Mr. Messeger of Glendale, in 1863. It came from the claim of the Illinois Copper Co. about 15 miles southwest of Wickenburg, and one and one-half miles northwest of the Angel mine.

Garnet—Mr. J.L. Hubbell of Ganado, Arizona, mentions a locality about seventy-five miles west of north of Ganado where garnet is found abundantly over a stretch of country about ten miles long. The garnets are picked up from the surface by the Indians. They occur in sandy soil, and are uncovered by the action of the wind. The largest of these garnets are transparent and suitable for cutting.

Gold—Vulture mine, coarse gold in brilliant sheets was often found, associated with galena and wulfenite, jarosite and pyrite.

Linarite—Found in the ores of the Mammoth mine at Schulz, Pinal county, with cerussite, galena and wulfenite in specimens with a beautiful, clear indigo blue color.

Silver—A fine, large nugget of nearly pure silver was found in the placer deposits about twelve miles north of Globe in 1895. It weighed thirty-one pounds and was 900 fine. It was fully rounded by much attrition, all angles and asperities of surface had been worn away. This mass was figured and described in the governor's report of 1899, p. 37.

Sphalerite—At the famous Silver King mine, for example, it is in close association with native silver, so close that fractured masses of blende are held together by wire-like threads of very white, pure silver. The blende of this mine is generally light emerald or sea-green in color and transparent, forming very beautiful cabinet specimens, especially when traversed by native silver or closely associated with stromeyerite and silver sulfide.

Wulfenite—The Mammoth gold mine at Schulz, Pinal County, has yielded probably the finest crystallized groups of this mineral and in a massive form in the greatest profusion, for though great care was taken to separate the masses of galenite and of wulfenite from the auriferous quartz before crushing and milling, it appeared in quantity in the tailings, which afterward became an available source of the mineral. Two or three carloads were washed out of these tailings by sluicing.

1910 The Magma Copper Co. is formed to work the Silver Queen (Magma) mine. The population of Arizona totals 204,354. Guild (1910) publishes *The Mineralogy of Arizona,* listing 115 species plus additional varieties and properly identifies mixtures. A sampling from this work follows:

Copper, Cu . . . It is especially abundant at Bisbee, in the Copper Queen mines, the Shattuck, and others, where it occurs in sheets, nodules and arborescent growths associated with cuprite, kaolin, calcite, limonite, and other minerals. . . . A large sample of native copper presented to the University, by Dr. H.W. Fenner, of Tucson, shows delicate sponge-like forms consisting of arborescent masses altered superficially to malachite. Another interesting mode of occurrence observed in situ by the mining class of the University while on one of its annual trips, was that of delicate mosslike masses containing embedded rhombs of calcite of almost perfect development. . . .

Two important masses of meteoric iron have been discovered in the vicinity of Tucson, but thoroughly reliable data as to the exact point where they fell seems to be lacking. . . .

Petrified Wood.—This form of silica or quartz is very abundant in Arizona, whose specimens are justly prized by museums and private collectors in all parts of the world. . . . A section of a large log showing these variegated tints, weighing over 15 tons, has been polished and deposited in the Museum of Natural History in Paris. The most highly prized specimens are found in the vicinity of Holbrook [Navajo County] and Adamana, where many square miles are literally covered with petrified logs, branches and small broken fragments of bright colors. These have been highly prized by the Indians on account of their hardness and color, and may be found with other indian relics in various parts of the southwest. . . .

Precious Garnet.—In the extreme northern part of the State the Moki Indians and others bring into the towns large quantities of loose garnets many of which are cut and show a beautiful dark ruby tint. They are known among gem dealers as the Arizona rubies and are without doubt the finest garnets in the United States. They are picked up in gravel deposits and around ant-hills where these industrious workers have brought them from the surrounding country. The associated minerals are peridot, pyroxene, magnetite and similar minerals. The gem has never been found in place but owing to its associations, one is authorized in assuming that it was developed in some of the ultrabasic rocks such as the peridotites. They are always found in well rounded and polished pebbles varying from a few millimeters to two centimeters in diameter. The latter however are never of gem quality.

Peridot [olivine].—It is found in beautiful tints near Talkai, and is frequently collected, together with the red garnets with which they are sometimes found, by the Indians and prospectors. A crystal from this locality, exhibited at the World's Fair, at Portland, in 1905, after being cut, was a beautiful gem of 25³/4 carats. . . . Like garnets, they are found around ant-hills. One hill investigated by members of the United States Geological Survey was found to be made up of 75 per cent. of peridot grains, the remainder being garnet, quartz, diopside, etc.

Turquoise—Mineralogically this gem mineral is a phosphate of alumina and copper. Because of its delicate blue color it has been highly prized by the prehistoric people of western United States and Mexico. It is, therefore, found in many of the Aztec ruins in Mexico and in ruins, of perhaps similar origin, in Arizona. It is found *in situ* in the Dragoon mountains, on the road between Pearce and Gleeson, where it occurs in a greatly decomposed rock, perhaps a kaolinized rhyolite, in the form of irregular patches and veinlets.

When these deposits were first discovered, there were abundant evidences of mining in a crude way, doubtless the work of some Indian tribe or of a prehistoric people. Some implements were found and evidences of the use of fire employed, perhaps, for the purpose of breaking up the rock. Another important locality is in Mineral Park, Mohave County. During the last two or three years this district has produced considerable material for the market. Several mining companies are operating in the district, among which may be mentioned the Arizona Turquoise Co., Los Angeles Gem Co., Southwest Turquoise Co., and the Aztec Turquoise Co.

Linarite, $(Pb,Cu)(SO_4)$, $(Pb,Cu)(OH)_2$—This beautiful and rare mineral is found in the Mammoth-Collins mine at Schulz, Pinal Co., associated with cerussite, wulfenite and other lead minerals. It is deep blue in color and when mingled with pure white cerussite which is also of adamantine luster, presents an appearance of unusual beauty.

W.P. Blake (1910b) lists 31 mineral species in Pima County:

The mineral cabinets and great museum collections of the world have been enriched by the brilliant crystallizations of azurite, malachite and cuprite from the stopes of the Copper Queen mine at Bisbee, in the adjoining Cochise County. Fortunately for such collections, and for science, the management of the mine under Dr. James Douglas has ever been an appreciate [*sic*] conserver and distributor of gems of the mine. A fine series may be seen in the Museum of the University.

Other remarkably beautiful crystallizations of the rare mineral known as Wulfenite, the molybdate of lead, have been taken from the Mammoth mine north of Oracle, and from the Old Yuma, specimens of which are also in the Museum.

Among other comparatively rare species occurring at several places in Pima County, we may mention molybdenite, vanadinite, Des Cloizite and tungstic ochre.

1911 The American Smelting and Refining Co. smelter is built at Hayden, Pinal County. Large-scale production begins at Ray. The Tombstone mines close because of flooding and the low price of silver.

Statehood

1912 Arizona is admitted to the Union as the 48th state. The proclamation is signed by President Taft using a pen made of Arizona gold.

1913 A.F. Rogers (1913) describes delafossite crystals from Bisbee, confirming the species that Geo. Friedel described from Russia in 1873.

1914 World War I begins. Tom Jeffords, former Indian agent at Fort Bowie and "blood brother" to Cochise, dies at Owlhead, "his only luxury his mineral specimens, two cabinets of them" (Sonnichsen, 1982). Ford (1914) describes the type specimen of spangolite as being certainly from Bisbee, not Tombstone.

1915 The flotation process is introduced at the Inspiration mine, the first of such operations in the United States. The International Smelting Co. smelter opens at Miami. The Arizona Bureau of Mines is created by the Arizona

Legislature. Schaller (1915) first describes bisbeeite and shattuckite from Bisbee, Cochise County. Ford and Beadley (1915) identify "footeite" from Bisbee as connellite. Schrader and Hill (1915) write the following:

> [On the Flux mine] From the roof in the inner part of the south or 260-foot tunnel and adjacent parts of the crosscuts hang great masses of closely spaced acicular or filiform silky white cerusite [*sic*] about a foot in length. . . .
>
> [On the Mowry mine] The ore consists mainly of the argentiferous ore minerals, cerusite [*sic*], coarse galena, anglesite and bindheimite, all contained in a manganiferous and ferruginous gangue consisting principally of psilomelane and massive pyrolusite and hematite. . . .
>
> [On the Salero mine, later named the Santa Rita silver mines] The ore minerals are principally argentite and chalcopyrite, with also a little copper carbonate and a very little galena; pyromorphite is reported. In the surface ores occurred also considerable horn silver, or cerargyrite.

1916 The United Verde Extension mine cuts 300 ft of 15% copper ore. The *Directory of Arizona Minerals* (Arizona Bureau of Mines, 1915–16) and *Mineralogy of Useful Minerals in Arizona* (Arizona Bureau of Mines, 1916) are published.

1917 Production begins at the New Cornelia mine in Ajo from leaching low-grade ores, the first of such operations in the United States. The name of the Copper Queen Consolidated Mining Co. is changed to the Phelps Dodge Corp.

1918 Steam-shovel operations begin at Bisbee.

1919 An experimental flotation plant is built at Ajo. Open-pit operations begin at Jerome.

1921 The postwar depression causes the shutdown of copper properties.

1922 The depression ends. Morenci operations are controlled by the Phelps Dodge Corp.

1923 The Copper Queen mill begins production.

1924 A concentrator is built at Ajo, and a smelter is built at the Magma mine.

1925 Larsen and Vassar (1925) first describe chalcoalumite from Bisbee, Cochise County.

1926 The main line of the Southern Pacific Railroad reaches Phoenix.

1928 Lausen (1928) first describes butlerite, guildite, jeromite, lausenite, ransomite, and rogersite from Jerome, Yavapai County. G.M. Butler (1928) redefines rogersite as lausenite.

1929 The economic boom reaches a climax; the Great Depression begins.

1930 The price of copper collapses from 18¢ to 10¢/lb.

1931 Great Britain abandons the gold standard.

1932 Copper operations are curtailed; gold placering becomes extensive. The Sacramento Hill orebody at Bisbee is exhausted.

1933 The price of gold is raised to $25.56/oz; the U.S. Mint pays 64¢/oz for silver.

1934 The price of gold is raised to $34.95/oz; gold exploration booms. Palache (1934) first describes selenium from Jerome, Yavapai County.

1935 The price of silver is raised to 77.57¢/oz. The Phelps Dodge Corp. purchases the United Verde mine.

1936 Hurlbut (1936) first describes bermanite from a pegmatite on the 7U7 Ranch, Yavapai County.

1938 The orebody at the United Verde Extension mine is depleted; the smelter is dismantled and sold.

1939 World War II begins. The Arizona Department of Mineral Resources is created by the Arizona Legislature.

1941 Pearl Harbor is bombed; the United States enters the war. Galbraith (1941) writes *Minerals of Arizona.*

1942 Large-scale open-pit production begins at Morenci. Most gold mines are closed by government order. Richmond and Fleischer (1942) first describe cryptomelane from Tombstone, Cochise County.

1943 The U.S. Bureau of Mines starts drilling operations at San Manuel.

1945 World War II ends. The San Manuel Copper Corp. is formed by the Magma Copper Co.

1947 The Atomic Energy Commission Division of Raw Materials is organized. Milton and Axelrod (1947) first describe bütschliite and fairchildite from Grand Canyon National Park, Coconino County.

1948 Underground development begins at San Manuel.

1949 Uranium is discovered in Arizona in the Vermillion Cliffs district near Lee's Ferry.

1950 Open-pit production begins at Ray, Gila County. The Phelps Dodge Corp. commences development of the Lavender Pit at Bisbee. The Banner Mining Co. lease-options the Mineral Hill mine in the Twin Buttes district. The Cyprus-Pima deposit is found by geophysical methods. A uranium boom is underway in the Four Corners area, including northeastern Arizona. Fahey et al. (1950) first describe wherryite from the Mammoth mine, Pinal County.

1951 The American Smelting and Refining Co. begins large-scale open-pit development at Silver Bell, Pima County. A government purchase plan for tungsten ores commences. Axelrod et al. (1951) first describe andersonite, bayleyite, and swartzite from the Hillside mine, Yavapai County.

1952 The Banner Mining Co. and Pima Copper Co. become prominent Arizona mineral producers. The Government Service Administration opens the Wenden manganese ore-purchasing depot.

1953 Operations cease at the United Verde mine.

1954 The Inspiration Consolidated Copper Co. options the Christmas mine. The American Smelting and Refining Co. begins production from the Silver Bell mine. Weeks et al. (1954) first describe navajoite from Monument Valley, Apache County.

1955 Underground production ceases at Ray. The Atomic Energy Commission opens a uranium ore-buying station at Cutter. The manganese ore-buying station at Wenden closes. Fahey (1955) first describes murdochite from the Mammoth–St. Anthony mine, Pinal County.

1956 The San Manuel smelter begins operations. The government purchase plan for tungsten ends. The Pima mine (Pima mining district, Pima County) begins production.

1957 The ore mill at the Pima mine begins operations. The Esperanza mine of the Duval Sulfur Co. begins concentrator construction. A zinc price drop closes the Old Dick, Trench, Johnson Camp, and San Xavier mines. The Cutter uranium-purchasing depot is closed.

1958 The Kennecott Copper Co. smelter at Hayden begins operations. The American Smelting and Refining Co. Mission mine (Pima district, Pima County) begins underground operations. Schaller and Vlisidis (1958) first describe ajoite from Ajo, Pima County.

1959 Underground mining at Miami ceases after 48 years. The U.S. government ceases car-lot purchases of manganese ore. Hutton (1959a) first describes yavapaiite from Jerome, Yavapai County.

1960 E.C.T. Chao et al. (1960) first describe coesite from Meteor Crater, Coconino County. Hutton and Vlisidis (1960) first describe papagoite from Ajo, Pima County.

1961 The American Smelting and Refining Co. Mission mine starts open-pit production.

1962 Operations begin at the Christmas mine of the Inspiration Consolidated Copper Co. E.C.T. Chao et al. (1962) first describe stishovite from Meteor Crater, Coconino County.

1965 El Goresy (1965) first describes cliftonite from the Canyon Diablo meteorite, Coconino County.

1966 E.J. Young et al. (1966) first describe coconinoite from a locality near Cameron, Coconino County.

1967 C. Frondel and Marvin (1967a,b) first describe lonsdaleite from the Canyon Diablo meteorite, Coconino County.

1968 Olsen and Fuchs (1968) first describe krinovite from the Canyon Diablo meteorite, Coconino County. S.A. Williams (1968) first describes wickenburgite from a locality near Wickenburg, Maricopa County.

1969 J.E. Bunch and Fuchs (1969) first describe brezinaite from the Tucson Ring meteorite, Pima County.

1970 Anthony and Laughon (1970) first describe kinoite from Helvetia, Pima County. S.A. Williams (1970a) first describes bideauxite from the Mammoth–St. Anthony mine, Pinal County. S.A. Williams and Anthony (1970) and McLean and Anthony (1970) first describe hemihedrite from the Tortilla Mountains, Pinal County.

1971 Scott (1971) first describes the iron-nickel carbide, haxonite, from the Canyon Diablo meteorite, Coconino County.

1972 The Tucson Ring meteorite, in the collections of the Smithsonian Institution in Washington, D.C., briefly returns to Tucson for display at the Tucson Gem and Mineral Show.

1974 McLean et al. (1974) first describe yedlinite from the Mammoth–St. Anthony mine, Pinal County.

1975 S.A. Williams and Bideaux (1975) first describe creaseyite from the Mammoth–St. Anthony mine, Pinal County. S.A. Williams and Matter (1975) first describe graemite from Bisbee, Cochise County.

1976 S.A. Williams (1976) first describes junitoite from the Christmas mine, Pinal County. Anthony and McLean (1976) first describe jurbanite from San Manuel, Pinal County. The mineral from the Sue mine, Cherry Creek district, Gila County, described by Granger and Raup (1969) as the sodium analog of zippeite, is formally renamed sodium-zippeite by C. Frondel et al. (1976). The Tucson Ring meteorite once again briefly returns to Tucson for the opening of the Flandrau Planetarium.

1977 S.A. Williams (1977) first describes luetheite from a locality near Patagonia, Santa Cruz County.

1982 S.A. Williams (1982) first describes luddenite from the Artillery Peaks area, Mohave County.

1983 Criddle et al. (1983) first describe henryite from Bisbee, Cochise County.

1984 Peacor et al. (1984) first describe paulkerrite from a locality near Hillside, Yavapai County. Harris et al. (1984) first describe kiddcreekite on material from Ontario, Canada, and the Campbell mine, Bisbee, Cochise County, which are co–type localities.

1985 Peacor et al. (1985) first describe mammothite from the Mammoth–St. Anthony mine, Pinal County.

1988 Peacor et al. (1988) first describe maricopaite from the Moon Anchor mine, Maricopa County.

1989 Kampf et al. (1989) first describe grandreefite, pseudograndreefite, laurelite, and aravaipaite from the Grand Reef mine, Graham County. Dunn et al. (1989) first describe pinalite from the Mammoth–St. Anthony mine, Pinal County.

3

NOTABLE ARIZONA MINERAL DEPOSITS

Porphyry Copper Deposits

Arizona produced over 20 million tons of copper in the first 100 years or so of its mining history. In 1972 alone, the value of the total mineral production of the state exceeded $1 billion, 92% of which came from nonferrous metals. Copper accounted for over 94% of the Arizona nonferrous-metal production and made up 54% of the total U.S. copper production. About 100,000 oz and 6.5 million oz of gold and silver, respectively, were produced during the same year, mostly as by-products of copper mining.

Lest the mineral collector mourn the loss of incalculable quantities of fine mineral specimens that may have been demolished while this copper was being extracted, he should be aware of the nature of these copper concentrations in the Earth's crust. For reasons that will emerge, the minerals in the ore in these large deposits are quite unprepossessing. In fact, the skilled eye of a trained observer is often required to recognize whether the ore contains any copper minerals. This generalization, happily, has many exceptions.

The minerals from which most of this copper was produced are actually few: chalcopyrite, chalcocitelike minerals, and locally, bornite are the only abundant sulfides; chrysocolla, malachite, and cuprite are the principal oxide minerals.

Most of this metal has been produced from unusual copper concentrations, termed *porphyry* or *disseminated copper deposits.* Because so many of the minerals listed in this book are associated with this type of deposit, and because the deposits have yielded impressive amounts of copper, a brief review of their geology and mineralogy is presented.

For reasons that are geologically complex (and not fully understood, although clearly related to large-scale movements of the Earth's crust), many of these deposits are in the southern half of Arizona, localized in the Basin and Range physiographic province and overflowing into adjacent parts of Sonora and New Mexico. The following features are typical of these copper deposits.

1. The deposits are characteristically large, measuring from a few tens of millions to billions of tons of ore reserves. Their sizes largely depend on the ore grade that prevailing metallurgical practices can profitably process. Mineralized areas of noncommercial grade may extend well beyond the economically dictated boundaries of the mines.

2. The deposits are low grade, the ore invariably averaging less than 1% (20 lb of copper per ton of rock). Modern mines of this type produce ores that average between about 0.4 and 0.6% copper.

3. Ore mineralization is always associated with an intrusive calc-alkalic porphyritic rock of intermediate composition, typically quartz monzonite, tonalite, or granodiorite. An intrusive coarse-grained rock of granitoid texture and similar composition may have preceded the porphyry intrusion. The ages of these rocks range from late Mesozoic through middle Tertiary, for the most part, although an earlier (Jurassic) age is ascribed to the intrusive rocks at Bisbee. The term *porphyry copper* reflects the common presence of this rock type.

4. The host, or country, rock into which the igneous rocks intruded may be of almost any type or age. Limestones, shales, sandstones, volcanic rocks, schists, and gneisses are representative host rocks.

5. Structural movements, probably assisted by shrinkage of the intrusive rock masses during cooling, fractured their fabrics and those of the intruded rocks and prepared them for the subsequent entrance of aqueous fluids. The rocks of these deposits are typically intensely shattered and may contain stockworks and brecciated areas as manifestations of postconsolidation structural events.

6. Waves of hot, aqueous (hydrothermal) fluids moved upward from a source thought to be genetically related to the intrusive rocks themselves and permeated the fractured rocks, chemically attacking and mineralogically altering them. Because the hydrothermal fluids were not in chemical equilibrium with the invaded rocks, the fluids reacted with them in a corrosive manner. The mineralogical products of this chemical activity are varied, complex, and commonly so pervasive that in many places the original rocks are altered almost beyond recognition.

The hydrothermal alteration process may have partly overlapped in time the late stages of cooling and consolidation of the porphyritic intrusion. Important and abundant minerals that formed during this phase in the developmental history of the porphyry deposits include sericite (a variety of muscovite), biotite, hydromica, chlorite, epidote, clinozoisite, calcite, clay minerals (especially the kaolin and montmorillonite groups), potassic feldspar (typically orthoclase), albite, and quartz. All of these minerals will not necessarily be present in one deposit. Large masses of rock in some deposits were so completely altered they became aggregates of essentially nothing but sericite, quartz, and pyrite. The large amounts of sericite in some deposits probably formed only where potassium had been introduced with the hydrothermal fluids. The common development of abundant quartz suggests the introduction of silica. Iron must have also been introduced because tremendous quantities of pyrite formed in the deposits. Copper, of course, is another element introduced in abundance.

7. Associated with the intrusion and probably partly related to the hydrothermal alteration, contact metamorphic mineral assemblages, termed *skarn* or *tactite,* were developed in the country rocks of some deposits. The minerals that developed largely depend on the country rock: carbonate sediments, shales, impure sandstones, or volcanic rocks gave rise to calc-silicates such as diopside-hedenbergite, tremolite, and garnet; shales may be silicified; carbonate rocks are commonly marbleized by recrystallization of calcite; and bodies of magnetite may have formed locally, especially in limestones.

8. During and after hydrothermal alteration, pyrite and other sulfur-bearing minerals were introduced along with copper sulfides, especially chalcopyrite. The copper-bearing sulfides probably continued to form after the initial hydrothermal alteration.

The major primary (hypogene) ore mineral, chalcopyrite, and much less importantly, bornite, seem to have been deposited more or less simultaneously. Pyrite is typically the most abundant sulfide and commonly encloses blebs of chalcopyrite or bornite. Pyrite was also typically the first sulfide to form and commonly continued to crystallize throughout these primary developmental phases of the deposit. Small amounts of molybdenite, sphalerite, galena, or other sulfides may be present. The primary sulfide minerals formed as disseminated grains (whence came the name *disseminated deposit*), as veinlets filling fractures in the host rocks, and as replacements of other minerals. In places, the disseminated sulfide grains cluster markedly near the dark ferromagnesian minerals of the porphyry: biotite, pyroxenes, or amphiboles. Molybdenum, gold, and silver, although they are in small concentrations in the copper ores, may be important by-products of the extractive processes.

9. After alteration and primary sulfide mineralization ceased, the deposits remained quiescent through periods during which their upper exposed portions were subjected to weathering. Erosion stripped away overlying rock, exposing the primary sulfides (protore) to further weathering. Oxygen contained in the atmosphere and in meteoric and underground waters chemically attacked and dissociated pyrite and other sulfides in the upper reaches of the deposits. Sulfuric acid and iron and copper sulfates formed. In the presence of acidic waters, copper and iron were in solution, but whether the solutions could percolate downward depended on the chemical nature and permeability of the rocks themselves. If they were strongly reactive to the acidic solutions (e.g., limestone), the copper and iron in solution would tend to precipitate as carbonate minerals. If, however, the rocks were chemically nonreactive or neutral in behavior (e.g., sandstone or quartzite), the metal-

bearing solutions would migrate downward into the deposit. It is perhaps fortuitous that the porphyritic rocks that are always present in these deposits behaved neutrally to these acidic solutions and did not inhibit their downward passage into the upper parts of the mineralized rocks.

As the downward percolating solutions encountered neutralizing or chemically reducing environments, copper and iron ions precipitated as new sulfides or replaced preexisting minerals (especially the primary chalcopyrite) to form secondary sulfides. Chalcocite is by far the most abundant of these secondary (supergene) copper sulfides, although subsidiary covellite, bornite, djurleite, and even chalcopyrite are known to form in this manner.

This complex process, which removes copper from the upper portion of the deposit and transports it in solution into the unoxidized rock below, depends on several circumstances, paramount among which is a supply of pyrite sufficient in quantity to provide the necessary acid.

It is generally held that the reducing conditions below the groundwater table near the deposit were an important factor in localizing precipitation of secondary sulfide minerals. The relatively simple undulating surface of the groundwater table in many places controlled the distribution of chalcocite so that a more or less blanketlike configuration resulted. The chalcocite blanket is typically situated between an upper oxidized zone and a lower primary ore zone and commonly overlaps both. In many deposits the supergene chalcocite mass became sufficiently enriched and large enough to constitute the major orebody of the mine. The presence of the chalcocite-enriched zone transformed many deposits, which otherwise would have been too low in grade, into commercially feasible ventures. The deposit at Morenci, for example, would not be of workable grade were it not for immense tonnages of supergene chalcocite. In some deposits local complexities in the behavior of the water table resulted in zonations that are not as simple as suggested above, and some ores are complex mixtures of primary and secondary sulfides and oxides of copper; the Castle Dome, Copper Cities, and Bisbee deposits are examples. With improved extractive techniques and deeper levels of mining, the industry has relied less and less on the presence of secondarily enriched ores.

10. The residua left near the surface after the oxidation of sulfides and the ensuing leaching processes are termed *leached* or *oxidized capping* or *gossan.* The presence of these distinctive and interesting mineralogical assemblages has led to the discovery of large orebodies at depth. Gossans are typically siliceous microcavernous rocks consisting of the altered and weathered original rock impregnated with mixtures of secondary iron oxides and sulfates, the aggregate of which is loosely termed *limonite.* The most common minerals in the limonite cappings are hematite, lepidocrocite, goethite, and jarosite. Alunite is present in some places, as is turquoise. Copper solutions that could not migrate out of the oxidized zone because of the presence of reactive gangue formed new mineral phases at varying distances from the point of origin of the solutions. Malachite, azurite, chrysocolla,

cuprite, copper, and a variety of less common secondary minerals may be formed in the oxidized zone of the deposits. Indeed, the copper-bearing portions of the oxidized zones of some porphyry copper mines have provided large amounts of ore. This is true, for example, of the Ray, Inspiration, and Twin Buttes deposits.

Manmade leaching systems, reminiscent of this secondary leaching process, are commonly used to dissolve copper from some of these oxidized zones, which contain ore that cannot be metallurgically processed in the same manner as sulfide ores. In situ leaching is practiced in some mines; water and sulfuric acid are spread on the surface, and the copper-charged liquids that percolate downward through the oxide ores are trapped underground. Other mines heap-leach broken ores that have been spread on the surface.

A distinctive feature of the surface outcrops overlying many of the large, low-grade, porphyry copper orebodies is their coloration. A variety of tones and hues in reds, browns, yellows, and grays results from the abundance of secondary iron minerals. Sufficient amounts of malachite and chrysocolla may impart greenish tinges to the surface exposures.

Spectacular mineral specimens are not, as a rule, found in the low-grade sulfide deposits. The open-pit mines from which most of these ores are produced are usually thought to be mineralogically unexciting and rather drab in appearance, as those who have stood high on the lip of one of these enormous excavations will likely attest. There are exceptions, however. The beautifully symmetrical New Cornelia open-pit mine at Ajo, for example, is unusual because the ore largely consists of primary chalcopyrite and bornite with little supergene mineralization. The mine contained a large mass of coarse orthoclase-rich pegmatite associated with quartz monzonite porphyry.

On the other hand, colorful and exotic minerals have been gratifyingly abundant in the oxidized portions of many of the same deposits. A few noteworthy examples include the rare phosphate-sulfate, tsumebite, found in the capping at Morenci; the copper silicates, ajoite and papagoite, first described from the New Cornelia mine, and crystallized copper and magnificent azurite crystals from the same mine; the copper molybdate, lindgrenite, in the oxidized ores of the Live Oak pit of the Inspiration mine near Globe and from the Esperanza mine in the foothills of the Sierrita Mountains; and the delicate, gypsum-enclosed chalcotrichites and copper found in the Sierrita pit near Tucson.

From the mineral collector's perspective, the most important sources of mineral specimens in Arizona may have been the regions that are peripheral to a few porphyry copper deposits. Not all fine specimens have come from such areas, but the importance of several of these localities, which are probably genetically related to porphyry copper mineralization, makes this group of deposits worthy of special mention.

Little attention has been given in the preceding discussion to these marginal regions enveloping the mineralized central porphyry. Many of the contacts between the intrusive rocks and the invaded country rocks are complex. The structural deformations that shattered the marginal host rocks into which the hydrothermal fluids seeped also gave rise to systems of faults and shattered zones that commonly extend for considerable distances outward from the central intrusions. Solutions related to those responsible for the disseminated mineralization also moved outward from the porphyry mass into the permeable surrounding rocks and altered and mineralized them in and adjacent to the peripheral faults and sheared zones. Sulfide minerals were deposited in open fissures and created veins, and locally, the hydrothermal solutions chemically attacked and replaced susceptible host rocks, creating replacement deposits. Limestones and dolomites were particularly receptive to this replacement process. Although they are smaller than the main porphyry deposits, the concentration of ore minerals in the vein and replacement deposits is much more pronounced, and the minerals formed in them tend to be more coarsely crystallized.

Where open spaces were prevalent in the host rocks, the conditions may have been locally ripe for the growth of large, in some places spectacular, crystalline masses and single crystals of many kinds of primary minerals. Oxidation and secondary enrichment processes functioned in these peripheral orebodies in much the same way as in the mineralized porphyry masses, even though the sulfide mineralization was of higher grade and confined to smaller areas. Porosity and open-space conditions developing in the oxidized upper portions of these deposits permitted the growth of large crystals of many kinds of secondary minerals. It is from this provenance that some of the world's great specimens of copper-bearing minerals have been won.

Prospectors who scoured the mountains of southern Arizona during the latter half of the 19th century, typically attracted by colorful secondary copper minerals, stumbled upon outcrops of the peripheral ore deposits but were hardly aware of the

Table 3.1. Porphyry Copper Deposits of Arizona

Name of Deposit	County	Name of Deposit	County
Bagdad	Yavapai	New Cornelia	Pima
Castle Dome	Gila	Pima	Pima
Christmas	Gila	Ray	Pinal
Copper Cities (Miami)	Gila	Sacaton	Maricopa
Dos Pobres	Graham	Sanchez	Gila
Esperanza	Pima	San Juan	Graham
Inspiration	Gila	San Manuel	Pinal
Lakeshore	Pima	San Xavier North	Pima
Lavender Pit (Bisbee)	Cochise	Sierrita	Pima
Mineral Park (Ithaca Peak)	Mohave	Silver Bell	Pima
Mission	Pima	Twin Buttes	Pima
Morenci	Greenlee		

potentially greater wealth that lay beneath the unspectacular oxidized cappings. Some of their discoveries, of course, gained renown in the annals of mining.

The reader interested in pursuing the subject of porphyry copper deposits will find good summaries in Titley and Hicks (1966), C.A. Anderson (1969), J.D. Lowell and Guilbert (1970), and Titley (1982), which also provide extensive references.

Table 3.1 lists most of the important porphyry copper deposits of Arizona. A few relatively small deposits and some undeveloped large prospects are not included.

Porphyry-Copper-Related and Other Hydrothermal Deposits

Nearly all of the large, low-grade, porphyry copper orebodies have associated with them peripheral underground mines that exploited ores of higher grade than those of the porphyry bodies themselves. Typically, these mines had been known and worked for years before technological advances and changing economic conditions made exploitation of the lean porphyry copper ores profitable. The presence of the older mines commonly helped delineate target areas in the search for the large, low-grade, orebodies. The metal production of the porphyry copper segment of an area is almost always substantially greater than the contribution from the associated underground mines, which work smaller orebodies of higher grade. This is the case, for example, at Morenci, San Manuel, and Ajo. Bisbee, however, is a notable exception. The total metal production of the vast complex of underground workings, mined since the late 1870's, substantially exceeded the copper production of the relatively short-lived, open-pit copper mines of the district. The scope of its underground workings, a long and fascinating mining history, and the great variety and beauty of its minerals make Bisbee special in mining annals. The cessation of most mining in the Bisbee area in 1975 ended a century of continuous activity in a region that has few peers for the amount of nonferrous metal mined and for the quality and quantity of mineral specimens recovered and preserved.

Like Bisbee, the Mammoth–St. Anthony mine at Tiger was discovered in the late 1870's. The huge, nearby porphyry copper orebody at San Manuel, however, was not brought into production until 1956. The geological relationships between the San Manuel deposit and the peripheral Mammoth–St. Anthony mine are not as obvious as those between the underground mines and the Sacramento Hill and

Lavender porphyry orebodies at Bisbee. The unusual variety and exceptional quality of the colorful and beautifully crystallized secondary minerals from the mine at Tiger, however, earned it an international reputation as one of the world's exceptional mineral localities.

The Bisbee District, Cochise County

The Bisbee district has long been a premier mineral-producing camp. Actually, *Warren* is the formal name of the mining district in which the celebrated mining area of Bisbee is situated, and the name *Warren* has had priority for years. The name *Bisbee* is used in this discussion because few persons who are not in the mining profession would be aware that the famous Bisbee mineral locality lies in the Warren mining district. In Part Four, the catalog section, however, the name *Warren* is typically retained.

Ores were first found here in 1876, and for 3 years thereafter mining was carried out on the Hendricks claim. Although Bisbee has become particularly famous for its copper minerals, the first mining was for lead from cerussite ores in limestone. In 1880 the Copper Queen mine began operations on a large body of copper ore in limestone outcrops on Queen Hill. Ever since that time, up to the 1970's, the district had been a steady copper producer. Early production came from underground mines in oxidized and sulfide ores in limestone; more recently, this production has been overshadowed by mining operations in the Lavender Pit.

The copper ores at Bisbee were introduced by an intrusive porphyritic igneous rock approximately 180 million years ago. Much of the copper and iron released by this intrusion replaced the enclosing limestones, forming irregular masses of ore that were typically isolated within barren, seemingly unaffected, limestone. Scattered sulfide grains were also retained in the intrusion, and these lower grade ores were later mined by open-pit methods.

Large masses of some of these sulfides have been found in the mines. Pyrite is common everywhere, typically as large, granular masses, but good crystals, especially large ones, are rare. Sizable masses of other sulfides have been discovered in the underground workings. Veins of alabandite are found in some areas. Bornite-chalcocite intergrowths are common, as is chalcopyrite. Very nice pseudohexagonal chalcocite crystals have been found in the Cole shaft. The rarer sulfides are generally visible only under the microscope in polished samples.

The original primary ores were sulfides, and the variety of minerals is relatively limited. In most cases these minerals are not of specimen quality, and even the richest ores may be quite drab in appearance. The primary minerals, mostly sulfides, that have been found at Bisbee are listed in Table 3.2.

The rock mass that introduced ores at Bisbee is a quartz monzonite porphyry. In most places the original silicate minerals in this rock (quartz, orthoclase, plagio-

Table 3.2. Primary Minerals at Bisbee, Cochise County

Acanthite	Emplectite	Powellite
Aikinite	Enargite	Pyrite*
Alabandite	Famatinite	Rhodostannite
Altaite	Galena*	Rickardite
Arsenic	Gold	Rucklidgeite
Arsenosulvanite	Goldfieldite	Silver
Bismuth	Greenockite	Sphalerite*
Bismuthinite	Henryite	Spionkopite
Bogdanovite	Hessite	Stannite
Bornite*	Hocartite	Stannoidite
Calaverite	Hodrushite	Stromeyerite
Canfieldite	Jalpaite	Stützite
Cassiterite	Kesterite	Sylvanite
Chalcocite*	Kiddcreekite	Tellurobismuthite
Chalcopyrite*	Kostovite	Tennantite*
Cinnabar	Krennerite	Tetradymite
Colusite	Kuramite	Tetrahedrite*
Covellite*	Matildite	Uraninite
Cupropavonite	Mawsonite	Velikite
Digenite*	Melonite	Volynskite
Djurleite*	Molybdenite	Wittichenite
Dyscrasite	Nekrasovite	Wolframite
Electrum	Petzite	Yarrowite

* Major ore minerals

clase, and biotite) have been destroyed, and the rock is recrystallized beyond recognition. The altered rock typically consists of granular quartz enclosing pyrophyllite (locally sericite) scales loosely bunched together so they show the outlines of earlier plagioclase and biotite phenocrysts. Rutile commonly accompanies the altered biotite. Of the sulfide grains scattered throughout the altered porphyry, pyrite is by far the most common.

Quartzites invaded by the porphyry are altered strongly and typically closely resemble the intrusion because they also largely consist of quartz, sericite, and scattered pyrite grains. Shaly rocks in the walls have been similarly altered but contain considerably more sericite than the quartzites. Perhaps the most pronounced effects are in calcareous rocks near the intrusion. These rocks have been converted to calc-silicate tactites, which may be rich in minerals such as epidote, garnet (commonly grossular-andradite), diopside, and tremolite. The tactites also contain calcite. If the rock is leached in weak acids, one may see good microcrystals of the calc-silicate minerals, but typically they are tightly intergrown grains with poorly developed crystal faces.

Sulfide ores in these metamorphosed wall rocks are commonly formed in irregular bodies, as widely scattered grains, or as heavily disseminated grains that may replace one particular bed or lamina in the original sediment. Sulfides have also formed in well-defined veins, however, and the gangue minerals in these veins commonly include quartz and calcite or minerals such as barite, chlorite, and magnetite. Sulfides, together with minerals such as tremolite, epidote, or even diopside, may also be found in veins that formed during the peak of metamorphism.

Sulfides have formed in calcareous rocks that are so far from the porphyry that the effects of metamorphism may not be visible. Some of these sulfide "plums" are mystifying because they may be encased in massive limestone that shows neither the effects of recrystallization nor trace quantities of the metals that are so abundant just a few inches away. Orebodies of this nature can be found only by luck and persistence or by geophysical methods.

The rock-forming, gangue, and alteration minerals that have been found at Bisbee are listed in Table 3.3.

The fame of Bisbee as a mineral locality is largely due to the effects of weathering in relatively recent geological times. As the abundant pyrite dissolved, immense quantities of acid were released, which furthered dissolution, not only of other sulfides but also of encasing rocks, particularly the limestones.

Where the limestone contained ore pods or veins, the acids (carrying iron and copper) were eventually neutralized, but in the process some leaching of limestone occurred and caverns developed. The copper and iron remaining in these "spent" acids were deposited along the walls of these cavities, typically as thick layers of

Table 3.3. Rock-forming, Gangue, and Alteration Minerals at Bisbee, Cochise County

Allanite	Delessite	Hematite	Pyrophyllite
Allophane	Diaspore	Hornblende	Rhodochrosite
Alunite	Dickite	Hydrobiotite	Rutile
Aragonite	Diopside	Illite	Sanidine
Augite	Dolomite	Kaolinite	Sericite
Barite	Dravite	Laumontite	Siderite
Biotite	Enstatite	Magnetite	Sphene
Böhmite	Epidote	Metahalloysite	Stevensite
Brookite	Fluorapatite	Microcline	Thomsonite
Calcite	Fluorite	Muscovite	Tremolite
Celadonite	Gibbsite	Olivine	Variscite
Chromite	Graphite	Orthoclase	Zircon
Clinochlore	Grossular	Penninite	Zoisite
Clinochrysotile	Gypsum	Plagioclase	
Clinozoisite	Halloysite	Pumpellyite	

iron oxides (goethite and hematite) and less commonly as crusts of copper carbonates or oxides. Perhaps the most spectacular specimens formed in this way are the magnificent crystalline specimens of azurite and malachite such as those found in the Copper Queen mine. The Phelps Dodge Corp. (which controls the Bisbee mines) displays in its geological offices specimens of these minerals that are several feet across; azurite crystals up to 0.5 in. or more have formed crusts up to 1 in. or more thick and show varying stages of alteration to crystalline or fibrous malachite.

Pods of supergene clays in shaly limestones commonly contain large masses or nuggets of crystalline cuprite and copper. Cavities in the cuprite provide good hunting grounds for small but spectacular crystals of rarer minerals such as connellite, brochantite, spangolite, atacamite, and chlorargyrite. These masses are typically thickly rimmed with tenorite, chrysocolla, and malachite. Paramelaconite was undoubtedly found in similar material. G.A. Koenig (1891) described this rare mineral, but no specimens have been found at Bisbee since then. The original crystals were splendent black prisms 1 in. long. Spangolite, described by Penfield (1890), undoubtedly came from Bisbee originally (Palache and Merwin, 1909), although Tombstone has been cited as the type locality. (In the early days the Tombstone mining district included Bisbee; it became a separate district later.) The largest spangolite crystal on Penfield's specimen was 8 mm in diameter and 5.5 mm long.

Azurite has also formed in clayey seams, commonly as embedded balls or nodules of exceptionally large (up to 4.5 in.) curved crystals. When cleaned, these are handsome specimens indeed!

In many places the acid copper-bearing waters were not completely neutralized, and sulfates such as brochantite formed. Spectacular sprays of long, slender, brochantite prisms have been found, especially in the early days; some were accompanied by small but brilliant cerussite crystals.

The sulfate-rich waters were commonly not thoroughly neutralized because they reached clay-rich seams in the limestones; a variety of copper-aluminum sulfates formed as a result. Typically these minerals are not coarsely crystalline, but they provide superb micromount material. Mining activities at Bisbee in the early 1970's encroached upon old Copper Queen workings and again provided a suite of well-crystallized minerals such as chalcoalumite, cyanotrichite, antlerite, and brochantite. These minerals are associated with basaluminite, gibbsite, and other unidentified aluminum sulfates.

At the Shattuck mine some copper silicates (in addition to chrysocolla) were formed. A mineral named for the mine, shattuckite, was described by Schaller (1915). It was noted as a replacement product of malachite. He also described bisbeeite from this mine, but in the mid-1990s bisbeeite was still not fully understood and may be an invalid species.

In areas where pyrite was abundant and acids from its dissolution were not neutralized, a variety of iron-bearing and other sulfates may have formed. Some of these minerals are still forming in old mine workings; others are older and more stable sulfates. Well-crystallized voltaite, roemerite, rhomboclase, and coquimbite have been described in the past and continue to be discovered. These minerals also formed stalactites or stalagmites and may be associated with chalcanthite. Recently, spectacular masses of epsomite crystals, partly altered to hexahydrite, have been found.

In the porphyry responsible for all the copper mined at Bisbee, there is, oddly enough, a remarkable paucity of interesting or well-crystallized oxidation products. By far the most common mineral is jarosite, which formed in veinlets or as warty crusts lining cavities left by leaching of the pyrite. Some turquoise has been recovered from the porphyry and nearby rocks.

Two notable mineral occurrences have been discovered in Bisbee during the past decade. The more remarkable was a pipelike ore shoot in the Campbell mine. Samples of this ore submitted by Keith Coke were found to be incredibly rich in silver and tin. Polished-section and X-ray studies identified stannoidite and canfieldite, but the mineralogy seen in polished section was so complex that the samples were turned over to Alan Criddle of the Natural History Museum in London for further work. His studies, conducted during 1982–85 with Chris Stanley and Steve Eady, led to the discovery of two new species and produced a lengthy list of newly found, very rare minerals (private communications to Phelps Dodge Corp.).

The ore pipe extends from the 2,500-ft level to the 1,800-ft level of the mine. The gangue at the lower levels is granular quartz plus pyrite and changes at the higher levels to flinty quartz and hematite. Contorted foliae of chromian muscovite streak the hematitic ores.

The ore minerals commonly formed as dull-black material that fills spaces among, and coats, the pyrite grains at the deeper levels within the pipe. They are suffused throughout quartz at higher levels and are partly oxidized. Only a few of the minerals are visible to the eye, but coarse tellurium, altaite, canfieldite, and stannoidite have been noted.

The studies conducted by A.J. Criddle and his coworkers, as well as additional work done later through the cooperation of Steve Eady, have added the following species to the list of primary ore minerals: acanthite, altaite, arsenosulvanite, bismuth, bismuthinite, bogdanovite, calaverite, cassiterite, colusite, cupropavonite, electrum, emplectite, goldfieldite, henryite, hessite, hodrushite, hubnerite, jalpaite, kesterite, kiddcreekite, kostovite, krennerite, kuramite, matildite, mawsonite, melonite, nekrasovite, petzite, rhodostannite, rucklidgeite, stannite, stannoidite, stützite, sylvanite, tellurium, tellurobismuthite, tetradymite, velikite, volynskite, wolframite, and yarrowite. Newly reported oxide minerals include bismite, bismutite, kettnerite, paratellurite, and tellurite.

More recently, Richard Graeme and his sons made a remarkable new find of cuprite. The material is fully oxidized ore of classic Bisbee character, but the abundance of halogen in the ore is unusual. Massive granular cuprite cemented by

Table 3.4. Oxide-Zone Minerals at Bisbee, Cochise County

Allophane	Cyanotrichite	Minium
Alunite	Delafossite	Mottramite
Anglesite	Descloizite	Murdochite
Anthonyite	Devilline	Nantokite
Antlerite	Dioptase	Osarizawaite
Atacamite	Embolite	Paramelaconite
Aurichalcite	Epsomite	Paratacamite
Azurite	Ferrimolybdite	Paratellurite
Basaluminite	Ferrocopiapite	Pharmacosiderite
Bayldonite	Fibroferrite	Pickeringite
Bayleyite	Fornacite	Plancheite
Beaverite	Gibbsite	Plattnerite
Beudantite	Goethite	Plumbojarosite
Bianchite	Goslarite	Powellite
Bilinite	Graemite	Pyrolusite
Bindheimite	Greenockite	Pyromorphite
Bisbeeite	Groutite	Ralstonite
Bismite	Gypsum	Ransomite
Bismutite	Halloysite	Rhomboclase
Bixbyite	Halotrichite	Römerite
Botallackite	Hausmannite	Rosasite
Botryogen	Hematite	Rozenite
Braunite	Hemimorphite	Sengierite
Braunite II	Hetaerolite	Shattuckite
Brochantite	Hexahydrite	Siderotil
Bromargyrite	Hisingerite	Silver
Carbonate cyanotrichite	Hydrobasaluminite	Smithsonite
Cerussite	Hydrocerussite	Spangolite
Cesarolite	Hydrohetaerolite	Spertiniite
Chalcanthite	Hydrozincite	Stibiconite
Chalcoalumite	Ilsemannite	Stolzite
Chalcophanite	Iodargyrite	Sulfur
Chalcophyllite	Jarosite	Szomolnokite
Chalcosiderite	Kettnerite	Teineite
Chlorargyrite	Kornelite	Tellurite
Chrysocolla	Ktenasite	Tenorite
Claringbullite	Langite	Tilasite
Clinoclase	Leadhillite	Tolbachite
Conichalcite	Lepidocrocite	Turquoise
Connellite	Lime	Tyuyamunite
Copiapite	Linarite	Uraninite
Copper	Malachite	Vanadinite
Coquimbite	Manganite	Variscite
Coronadite	Melanterite	Voltaite
Crednerite	Metavoltine	Willemite
Cryptomelane	Miersite	Wulfenite
Cuprite	Mimetite	Zincobotryogen

massive paraffinlike nantokite is typical of the occurrence. The nantokite is seamed with a new yellow copper halide and is surficially altered in places to tolbachite, which, in turn, alters to pulverulent paratacamite almost immediately on exposure. Vugs not filled with nantokite are apt to contain superb crystals of atacamite, paratacamite, connellite, and claringbullite.

This discovery has added the following minerals to the oxide assemblage at Bisbee: botallackite, claringbullite, iodargyrite, miersite, nantokite, spertiniite, and tolbachite. Ralstonite, an unknown HgI phase, cassiterite, and a Cu-Hg intermetallic compound were also found.

The mineralogy of Bisbee cannot be given full justice here. The interested reader is urged to consult Graeme's (1981, 1993) comprehensive reviews of Bisbee mineralogy. Many other species have formed high-quality microcrystals, but not cabinet specimens. The oxide-zone minerals that have been found at Bisbee are listed in Table 3.4.

The Tombstone District, Cochise County*

History

The first mineral location in the area was the Bronco claim some 5 miles west of the Tombstone district proper. Located in 1857, the claim was worked by Frederic Brunckow, who was later murdered by one of his employees. In 1887, Ed Schieffelin visited the claim and noted that the veins trended to the northeast. Following these to the east, he found what he thought was rich silver ore. He took some samples to his brother Albert and an assayer, Richard Gird, at the McCracken mine in Mohave County, Arizona. Finding that they were indeed rich ore, the Schieffelin brothers and Gird returned to Tombstone as partners and quickly discovered the Lucky Cuss and Toughnut deposits. The richest lode in the area, the Grand Central, was, however, located by Oliver Boyer and Henry Williams, prospectors who arrived soon after the Schieffelin party.

Boyer and Williams had agreed to share their claims with Schieffelin and Gird in return for assays of their samples. The former ignored this agreement in staking the Grand Central claim, and Gird was incensed. He knocked down the corner monuments, reducing the claim to half its original size, and relocated the remainder as the Contention claim. Shortly thereafter Boyer killed a man in Tucson, and Gird later recalled that he had been lucky, not knowing Boyer's disposition (Underhill, 1979).

The fame of the camp spread quickly. Production peaked at over $5 million in 1882, declining steadily thereafter. A decrease in the price of silver, coupled with

*Based on an article by S.A. Williams (1980b).

formidable pumping problems at the mines worked below the water table, was a major factor in the production decline.

The Tombstone mines were no safer than any other mines of the day. Several miners, killed underground in various mishaps, are buried in the famous Boothill Cemetery. The cemetery is a tourist attraction now, along with several museums and other historical exhibits in Tombstone. The Goodenough mine has been reopened by The Rocksmiths for guided tours. (Collecting is allowed, but only from the floor areas.)

Primary Ores

Ores produced in the district formed in two types of settings. Much of the ore, and especially the rich ore, was produced from faults and fissure veins that cut both sediments and dikes. Many of these ores were richer in gold than was average for the camp. Considerable ore was produced from replacement bodies, however, especially in the upper Naco Limestone and certain beds in the Bisbee Group.

Most of the ore contained galena, sphalerite, and pyrite. This was typical of many famous silver camps. It takes very little silver, on the order of 0.005% to 0.1%, to make "silver ore" of material that contains many times as much lead or zinc. In silver ore of this type, therefore, the silver minerals may be seen but rarely or never in material that contains highly visible galena and sphalerite. All of the mines in the district contained galena and sphalerite (with pyrite), including those in limestones such as the Lucky Cuss, Bunker Hill, and Herschel mines, and those in shales and siltstones of the Bisbee Group such as the Contention and Grand Central mines.

Chalcopyrite is less common. It was perhaps most abundant in quartz veins at the Emerald mine and was found in massive alabandite at the Lucky Cuss mine. It is also commonly present as microscopic beads in sphalerite wherever that mineral has formed in the district.

Tetrahedrite is scattered throughout the district. It was once abundant in the Toughnut mine, where specimen ore is reported to have carried 85 oz of silver per ton (Butler, B.S., et al., 1938b). Tetrahedrite was also common at the Emerald, Oregon, Prompter, and State of Maine mines, where it appears to have been the major silver-bearing mineral.

Alabandite was found in considerable amounts in the Lucky Cuss mine and smaller mines nearby. Typically it formed as nearly pure masses in crystalline limestone with minor amounts of pyrite and base sulfides.

Tombstone is not noted for well-crystallized sulfides, and none of them could be said to represent potential specimen material. Possible exceptions might be alabandite and pyrite. Although alabandite formed only as massive material, very rich, handsome specimens may be found with pitchy, greenish-black alabandite set in a white calcite matrix.

Very fine pyrite crystals must have come from the district. The massive, buff to tan, adularia-opal matrix at the Grand Central mine is sprinkled in some places with perfect 1- to 1.5-cm pyritohedra. Invariably, however, they are jarosite pseudomorphs.

The very rich bonanza telluride ores that were mined were quite unlike the base-metal ores. Examples of such ores are very rare in the dumps, not only because of their limited distribution in the mines but also because they were undoubtedly mined with considerable diligence.

Hessite has been described from the West Side mine by Genth (1887a). It formed in vein quartz with supergene silver and unidentified blue to green minerals. Recent examination of dumps, especially those known to be anomalously high in tellurium, has failed to disclose hessite.

Recent collecting along the Contention ore zone has turned up small amounts of other tellurides not previously reported from the district. These generally appear in crushed vein quartz or brecciated shales intensely altered to adularia. Especially noteworthy is empressite, found as fine, granular, bright tin-white masses up to 1 in. across. The empressite is typically corroded by rickardite and anglesite. One piece was found with clusters of tiny krennerite crystals set in tellurium. This piece was unusually pyritic and also contained pockets of well-crystallized paratellurite, an uncommon mineral in the district.

In addition to the primary minerals described above, a few others have been noted, typically in microscopic studies of ores. These include stromeyerite, famatinite, and bournonite.

Oxide Ores

Gold, silver, and copper have all been reported in the district, and all three appear to have been oxidation products. Gold formed in partly or wholly oxidized telluride ores as pinhead-sized grains with goethite, lead tellurites and tellurates, and quetzalcoatlite. Although supergene silver was uncommon, the silver halides were abundant and noted in every mine in the district. They undoubtedly accounted for most of the silver produced.

Both chlorargyrite and bromargyrite are common with all possible variations in between. B.S. Butler et al. (1938b) report an analysis of nearly pure bromargyrite from the Empire mine, and it has been noted all along the Contention zone. Generally this bromine-rich mineral is vivid yellow to orange yellow and is less sensitive to light than chlorine-rich varieties. Chlorargyrite tends to be pale yellow to greenish yellow, quickly turning to lavender gray in the light. Although noted at the Comet mine in limestone, bromargyrite seems to be most abundant in ores produced from noncarbonate rock, whereas chlorargyrite has formed in all environments. The Cl:Br ratio varies whimsically, even in a single specimen. It is common to find chlorargyrite in one cavity in a specimen and embolite or bromargyrite in another cavity perhaps 1 in. away.

These halides are generally well crystallized (commonly as octahedra), with brilliant faces. The typical appearance is a perfect octahedron with rounded edges, as if the crystal were slightly melted. Chlorargyrite also commonly fills hairline fractures. When rich ores are pried apart, it is common to find waxy skins of chlorargyrite partly torn from the fresh break.

One rich piece recently found in the Contention ore zone carried bromargyrite octahedra scattered about nuggets of crystalline iodargyrite partly altered to granular miersite. This remarkable piece also contains two new silver iodides, previously known only as manmade compounds.

Of special recent interest at Tombstone is the discovery of numerous new tellurium oxysalts, although tellurites have long been found there. The first mention is by W.F. Hillebrand (1885), who described emmonsite "from near Tombstone, Arizona Territory—the exact locality of occurrence being unknown." The analytical results that were reported in Hillebrand's original paper and in a later one (Dana, E.S., and Wells, 1890) have been recast by averaging and adjustment to 100% (Table 3.5).

Three of Hillebrand's analyses were based on brownish material, undoubtedly admixed with goethite. The ratio of Fe_2O_3:TeO_2 should therefore be closer to that of rodalquilarite. In addition, the optics of emmonsite, described by Whitman Cross (in Hillebrand, W.F., 1885), are related to planes of cleavage that are characteristic of rodalquilarite, not emmonsite. The type description of emmonsite, therefore, is surely based upon rodalquilarite!

Recent work has shown that rodalquilarite is common in some ores along the Contention zone. Bright siskin-green cleavage plates up to 1 in. across formed in opalized shales with anglesite, jarosite, and lesser amounts of botryoidal (never well-crystallized) emmonsite. Rodalquilarite is also noteworthy as perfect, sharp microcrystals, up to about 5 mm, formed in vugs with jarosite and winstanleyite.

Because so much pure material was available, a partial study was undertaken to

Table 3.5. Chemical Analysis of "Emmonsite" (in wt %)

	(1)	(2)	(3)
Fe_2O_3	20.79	23.7	18.8
TeO_2	75.41	71.0	74.1
H_2O	3.80	5.3	3.1
HCl			4.2
TOTAL	100.00	100.0	100.2

(1) "Emmonsite" analysis of W. F. Hillebrand (1885)

(2) Theoretical composition of emmonsite

(3) Theoretical composition of rodalquilarite

Table 3.6. Chemical Analyses of Rodalquilarite (in wt %)

	(1)	(2)	(3)	(4)	(5)
Fe_2O_3	18.59	18.70	18.54	18.73	18.45
TeO_2	73.36	73.82	74.10	74.88	72.85
H_2O	3.34	3.36	3.13	2.11	3.42
HCl	4.09	4.12	4.23	4.28	4.94
TOTAL	99.38	100.00	100.00	100.00	99.66

(1) Average of two closely agreeing analyses on 1.824 and 4.005 mg; Marjorie Duggan, analyst

(2) Analysis of column (1) recalculated to 100%

(3) Theoretical composition of $H_3Fe_2(TeO_3)_4Cl{\cdot}0.5H_2O$

(4) Theoretical composition of $H_3Fe_2(TeO_3)_4Cl$

(5) Analysis by Lopez et al. (1968) on type material

try to resolve the problem of different formulae found by chemical and crystal-structure analyses reported by Lopez et al. (1968) in the original description of rodalquilarite. Their chemical analysis suggested the formula $H_3Fe_2(TeO_3)_4Cl{\cdot}0.5H_2O$, whereas the crystal-structure analysis supported $H_3Fe_2(TeO_3)_4Cl$. The analytical results are presented in Table 3.6, including new results on Tombstone material.

Tombstone material seems to support the formula $H_3Fe_2(TeO_3)_4Cl{\cdot}0.5H_2O$. Proof of the formula by analytical methods, however, is surely beyond the capability of chemical analysis alone because the two formulae suggested by Lopez et al. (1968) differ in absolute percentages of water by only about 1%.

Crystals were also examined by X-ray diffraction, giving a = 9.00Å, b = 5.10, c = 6.64, $\alpha = 103°22'$, $\beta = 106°38'$, $\gamma = 78°4'$; thus, for Z=1, $D_{calc.}$ = 5.08 g/cm^3. The measured specific gravity using 7.68 mg (Berman balance) is 4.97. These data also support the formula $H_3Fe_2(TeO_3)_4Cl{\cdot}0.5H_2O$.

Although a rare mineral, dugganite has been found at several mines in the district. The type specimen is unique, with abundant spherules of water-green hexagonal prisms in a sugary, vuggy quartz matrix. This piece was found at the Emerald mine embedded in the face of the dump during the time the dump was being excavated and removed for leaching operations.

A few pieces containing the rare species sonoraite were found on the dump of the Little Joe shaft. The mineral formed as tiny spicular to bladed yellow crystals in heavy goethite-jarosite gossan with emmonsite.

The type specimen of khinite was found on the dump of the Old Guard mine after the dump had been removed for cyanide leaching and was scraped clean to bedrock. The one remaining piece of oxide ore lying on the surface contained khinite, formed as corroded deep-green crystals in rings about chlorargyrite and replaced outside the rings by dugganite. This piece also contained the only quetzalcoatlite found at Tombstone. More recently, khinite has been found underground at the Empire mine. Several recovered pieces contain khinite and dugganite with at least three new tellurites.

Parakhinite, identical in composition to khinite but hexagonal rather than orthorhombic, was later found at the Emerald mine with dugganite, xocomecatlite, and a host of other tellurium salts. Only two pieces containing this species were found.

More recently several lead-tellurium minerals were found at the Grand Central mine. Not only did these prove to be rare, but they are also inconspicuous, all being white or colorless minerals. The species formed in the very richest ores (gold as well as silver) with an abundance of lead. Although fresh altaite has not been found, it seems probable that it was once present.

Tombstone has the usual suite of other oxide minerals that are common to a desert climate. Very nice wulfenite and mimetite specimens in gossany, leached quartz have been found in the Empire, Emerald, and Grand Central mines. The wulfenite crystals are invariably thin tablets of a lovely orange color. B.S. Butler et al. (1938b) described a specimen of cuprite from the Toughnut mine that, when broken open, revealed a cuprite-lined vug with connellite needles, brochantite, malachite, and two unknown species.

Perhaps most noteworthy, however, is the rich variety of well-crystallized rhombohedral sulfates. Jarosite is abundant, and some truly spectacular material has been found. The best pieces are rich in jarosite crystals that are a deep-coffee-brown color; tablets up to 1 cm have been found. Crystals of pseudocubic habit are more rare but are common in the type specimen of winstanleyite, along with rodalquilarite.

Alunite is also common as sparkling crystalline druses of clear to greenish crystals. Tan natroalunite is commonly associated with emmonsite, and green hydronium alunite has been noted at the Joe shaft. Other minerals of this group that are relatively plentiful but typically massive include plumbojarosite, argentojarosite, beaverite, hidalgoite, and osarizawaite. Beaverite and osarizawaite seem most common in oxide assemblages derived from tetrahedrite-rich ores because they are typically associated with duftite, bindheimite, conichalcite, and olivenite. Suites of these minerals were once especially common at the Emerald, Oregon, and Prompter mines.

Manganese oxides are also abundant and varied, particularly in those mines that were worked in limestone wall rocks such as the Lucky Cuss mine. It seems likely that most or all of the manganese was derived from the oxidation of alabandite. These species have been discussed by Rasor (1939), who identified hetaerolite and pyrolusite and referred other species to the generic categories, "psilomelane" and "wad." Shortly thereafter, cryptomelane was described (Richmond and Fleischer, 1942) from some of the psilomelane. Recent work has also identified manjiroite, manganite, and hydrohetaerolite, but more work needs to be done. These

Table 3.7. Minerals at Tombstone, Cochise County

Acanthite	Duftite	Microcline
Actinolite	Dugganite	Miersite
Aikinite	Dunhamite	Mimetite
Alabandite	Embolite	Mixite
Alamosite	Emmonsite	Monticellite
Allanite	Empressite	Mottramite
Alunite	Epidote	Mroseite
Andradite	Ettringite	Muscovite
Anglesite	Fairbankite	Natroalunite
Apatite	Famatinite	Natrolite
Apophyllite	Fayalite	Oboyerite
Argentojarosite	Fluorite	Olivenite
Augite	Forsterite	Opal
Aurichalcite	Frohbergite	Orthoclase
Azurite	Galena	Osarizawaite
Barite	Girdite	Parakhinite
Beaverite	Goethite	Paratellurite
Bindheimite	Gold	Periclase
Biotite	Grossular	Pigeonite
Bournonite	Gypsum	Plagioclase
Brochantite	Gyrolite	Plumbojarosite
Bromargyrite	Halotrichite	Psilomelane
Calciovolborthite	Hematite	Pyrite
Calcite	Hemimorphite	Pyrolusite
Cerussite	Hessite	Pyromorphite
Cesbronite	Hetaerolite	Quartz
Chalcocite	Hidalgoite	Queitite
Chalcopyrite	Hillebrandite	Quetzalcoatlite
Chamosite	Hisingerite	Rhodochrosite
Chlorargyrite	Hornblende	Rickardite
Choloalite	Hydrohetaerolite	Rodalquilarite
Chrysocolla	Hydrozincite	Rosasite
Clinochlore	Iodargyrite	Schieffelinite
Clinozoisite	Jarosite	Serpentine
Conichalcite	Kaolinite	Silver
Connellite	Khinite	Smectite
Copper	Krennerite	Smithsonite
Corkite	Leadhillite	Sonoraite
Covellite	Linarite	Spangolite
Cryptomelane	Mackayite	Sphalerite
Cuprite	Magnetite	Spiroffite
Descloizite	Malachite	Stromeyerite
Diaspore	Manganite	Sulfur
Diopside	Manjiroite	Tellurium
Dolomite	Mckinstryite	Tenorite

Table 3.7. (continued)

Tetrahedrite	Turquoise	Wulfenite
Thaumasite	Vanadinite	Xocomecatlite
Titanite	Vesuvianite	Yafsoanite
Tlapallite	Winstanleyite	Zircon
Tremolite	Wollastonite	Zoisite

minerals are all black or nearly so and are most amenable to study by X-ray diffraction techniques.

Silicates

Only a few localities are noteworthy. At the Grand Central mine, where veins cut shales and siltstones, considerable quantities of the rock have been converted to massive adularia. Crystal-lined voids are rare. The adularia appears to represent a transitory stage, for much of the rock is further altered to massive opal. This appears to be the rock called *novaculite* by early workers in the district.

At the Lucky Cuss mine, limestones have undergone severe metamorphism owing to their proximity to an intrusive rock to the west. Some of these limestones contain unusual silicates such as monticellite, hillebrandite, and thaumasite. These minerals are best appreciated in thin section, however.

A list of minerals found at Tombstone is presented in Table 3.7. In addition to the 150 species listed, 25 new unnamed minerals have been found in the district, bringing the total to 175. The most spectacular effect of mineralogical research on Tombstone has been to increase the number of tellurium oxysalts. Including new but undescribed species as well as older ones, 43 have been found at Tombstone, of which 20 remain to be described and 9 have been described with Tombstone as the type locality. (The list of described and undescribed tellurium oxysalts worldwide totals about 95.) Further work in the district will doubtless find more. The species list probably could also be increased by study of the manganese oxides.

Additional Comments

Although prospecting activity continues at Tombstone, it seems unlikely that serious underground mining will ever again be undertaken in the main part of the district. Mineral collecting is limited to the surface and is complicated by complex ownership of claims. Little dump material remains to be examined because almost all has been removed and piled on leaching pads, the minerals destroyed by cyanidation.

Deep workings remain flooded throughout the district and the upper levels are generally caved or in dangerous condition. Not very long ago, a rumble was heard deep in the Sulphuret shaft, followed by the appearance of a cloud of dust at the surface (Burt Devere, Jr., pers. commun., 1980).

The Mammoth–St. Anthony Mine, Tiger, Pinal County*

This complex base- and precious-metal deposit was staked by Frank Shultz in 1879–82 as a "mammoth lode gold vein," hence the Mammoth mine. The town of Shultz, Arizona, was established at the mine site in 1896, and gold alone was produced from quartz through 1912. During World War I, 1916–19, the mines were reopened primarily for molybdenum production, although gold was also recovered. The Mammoth, Collins, and Mohawk–New Years mines were consolidated in 1934 by the St. Anthony Mining and Development Co., Ltd. The town of Shultz was reestablished as Tiger in 1939. Until the mine closed in 1954, substantial amounts of gold, silver, lead, zinc, copper, molybdenum, and vanadium were mined.

The area is underlain by Oracle granodiorite, which contributed material for younger conglomerate and arkose. These younger rocks are interbedded with basalt and tuff and are collectively known as the Cloudburst Formation. Following intrusion of rhyolite and andesite in Tertiary time, this entire sequence was faulted to form the main vein structure. This fault was later filled with quartz, adularia, barite, and fluorite and became mineralized with pyrite, chalcopyrite, galena, and sphalerite. These primary sulfides later were subjected to supergene weathering in the upper portions of the vein; the sulfide minerals followed a course of alteration common in many southwestern deposits. Pyrite oxidized to goethite and hematite; secondary copper sulfides, oxides, carbonates, and silicates were developed; galena altered to anglesite and cerussite; and sphalerite formed smithsonite, hemimorphite, and willemite. The vein was then cross-faulted. The former, upper, highly oxidized part became designated as the Mammoth vein, and the lower oxide-sulfide portion became the Collins vein.

Locally, further development of additional mineral species took a remarkable direction. Suites of complex minerals were formed containing lead, copper, and silver combined with carbonate, sulfate, chloride, and water. Various hypotheses of their formation involve retention or reintroduction of some components from hydrothermal solutions, derivation of some components from supergene alteration, or possibly a supply of some components from groundwater. Deposition of quartz sheathing around these zones probably provided a closed chemical system for their formation and partly assured their survival. Metastability of some of the minerals of this suite is indicated by evidence of extensive corrosion and pseudomorphism.

This anomalous suite includes the minerals that are primarily responsible for the mine's fame among mineralogists and collectors. Although the abundance and typically large crystal sizes of these minerals are unique, their existence is not. Other deposits such as those at the Rowley, Apache, and Grand Reef mines in Arizona; at Leadhills, Scotland; and in several small districts around Anarak, Iran, display comparable parageneses.

*Based on an article by R.A. Bideaux (1980).

Finally, solutions containing molybdenum, vanadium, chromium, arsenic, and phosphorus reacted with lead and copper in the vein to form secondary molybdate, vanadate, and other minerals, as in many other Arizona deposits. Upper portions of the San Manuel copper-molybdenum porphyry deposit, which is younger and more than 1 mile away, are depleted in at least molybdenum. Other elements were probably supplied by dissolution of trace minerals in the surrounding host rocks.

A list of known minerals from Tiger, categorized into somewhat arbitrary divisions, is given in Table 3.8.

Table 3.8. Minerals at Tiger, Pinal County

GANGUE MINERALS			
Adularia	Biotite	Epidote	Plagioclase
Amesite	Calcite	Fluorite	Quartz
Antigorite	Chlorite	Heulandite	Stilbite
Barite	Clays	Magnetite	Tourmaline
PRIMARY SULFIDES			
Chalcopyrite	Galena	Pyrite	Sphalerite
SECONDARY SULFIDES			
Acanthite	Chalcocite	Djurleite	
Bornite	Covellite	Wurtzite	
OXIDIZED MINERALS: "NORMAL SEQUENCE"			
Anglesite	Devilline	Hollandite	Silver
Aurichalcite	Dioptase	Malachite	Smithsonite
Azurite	Goethite	Minium	Sulfur
Cerussite	Gold	Murdochite	Tenorite
Chrysocolla	Hematite	Plancheite	Willemite
Creaseyite	Hemimorphite	Ramsdellite	
Cuprite	Hisingerite	Rosasite	
OXIDIZED MINERALS: "ANOMALOUS SEQUENCE"			
Alamosite	Connellite	Linarite	Phosgenite
Atacamite	Diaboleite	Macquartite	Pinalite
Beaverite	Embolite	Mammothite	Plumbonacrite
Bideauxite	Hydrocerussite	Matlockite	Plumbotsumite
Boleite	Iodargyrite	Melanotekite	Pseudoboleite
Brochantite	Iranite	Paralaurionite	Wherryite
Caledonite	Leadhillite	Paratacamite	Yedlinite
OXIDIZED MINERALS: LATE STAGE			
Descloizite	Mimetite	Pyromorphite	Vanadinite
Fornacite	Mottramite	Tsumebite	Wulfenite

Anyone who examines an extensive collection of Tiger minerals gains the impression that combinations of these minerals are endless, especially on specimens with minute crystals. Outstanding cabinet specimens of white botryoidal smithsonite, azurite crystals with cerussite, or azurite altered to malachite were produced from the mine. Associations of dioptase with orange to red wulfenite, willemite, and cerussite; complexly twinned or reticulated cerussite crystals, some of which are large or water clear; blue leadhillite; cleavable masses and microcrystals of matlockite and phosgenite; and large vanadinite crystals with incrustations of descloizite-mottramite are among the best specimens of these minerals produced from any locality in the United States.

Rich-blue specimens of crystalline caledonite, diaboleite, and linarite with white hydrocerussite and yellowish paralaurionite are the finest examples of these species yet found in the world, as are the greenish-black fornacite crystals. The species wherryite, bideauxite, yedlinite, creaseyite, macquartite, mammothite, and pinalite are unique, or nearly so, to Tiger. Beyond doubt, other new species await description among the Tiger suites distributed throughout many collections.

Uranium and Vanadium Deposits

The variety and colorful appearance of the uranium and vanadium minerals make them one of the most interesting assemblages in Arizona. Although these minerals do not characteristically form coarse crystals, as do some of the oxidized copper minerals, they have, nevertheless, considerable appeal to the collector. As is true of the minerals of the base metals, the ultimate reason for the discovery and exploitation of this group of minerals is its importance to the state as a source of mineral wealth. The great number of species represented, together with the unusual nature of the deposits in which they formed, warrants a brief discussion of the geological provenance of this group of minerals.

In contrast to the porphyry copper deposits of Arizona, which are largely confined to the Basin and Range physiographic province of southern Arizona, the principal uranium and vanadium deposits are in northern Arizona, although many other lesser deposits and prospects are widely scattered throughout other parts of the state. Northeastern Arizona is the southwestern portion of the large, topographically high, Colorado Plateau, a remarkable uranium-vanadium province extending over parts of Arizona, New Mexico, Colorado, and Utah. Here the Earth's surface is underlain by thick sequences of relatively undisturbed, flat-lying sedimentary rocks, which have been strongly dissected into spectacular steep-walled canyons by the river systems draining the region. Major uranium- and vanadium-rich areas are present in Monument Valley in extreme northeastern Arizona. Other deposits are centered around Cameron, where they extend in a belt about 10 miles wide and 75 miles long along the Little Colorado River. A third important uranium deposit, and the only type that is being actively mined in Arizona, is the breccia pipe. These deposits are geologically quite different from most of the other Plateau-type deposits.

Monument Valley

The famous Monument No. 2 mine in Monument Valley has been studied more intensely than any other Arizona uranium-vanadium deposit; it is representative of the so-called Plateau-type deposits. The description that follows is primarily based on the geology of this mine and is largely drawn from the work of Witkind and Thaden (1963).

The sedimentary rocks that contain the most uranium and vanadium in Monument Valley are in the Shinarump Member of the Triassic Chinle Formation, which maintains a rather uniform thickness of about 50 to 75 ft over the area. The rocks of this unit are of continental origin and are typically light-gray, medium- to coarse-grained sandstones with subordinate yellowish-brown conglomerates and some mudstones. Shinarump sandstones are commonly cross-stratified and contain abundant scour channels. The distribution of rock types within the Shinarump Member is irregular in many places, and the lateral gradations of one rock type into another within distances of a few hundred feet are common. Mixed with the pebbles and sands of the conglomerate are large quantities of fossil plant remains, including large logs. The surface of the underlying mudstones and siltstones of the Triassic Moenkopi Formation were scoured and channeled by ancient stream action before the Shinarump rocks were deposited. The long axes of these channels have an average northwesterly trend. In places the scouring reached down through the Moenkopi rocks to incise the DeChelly Sandstone of the Permian Cutler Formation. Sands, pebbles, and fossil plant remains of the Shinarump Conglomerate filled these ancient troughs.

Fossil woody material is apparently more concentrated in the channels at the base of the Shinarump Member than elsewhere in the unit. The fossil wood has been replaced by a variety of substances: silica, which formed the well-known petrified wood, is most common, but malachite, azurite, copper sulfides, uranium minerals (especially uraninite,) and vanadium minerals (montroseite) have also been locally active in this respect. Some of the wood was converted to black coaly or carbonaceous substances, and concentrations of uranium and vanadium minerals are commonly associated with this material. Clay minerals are present in the channels, some from included mudstones derived from the underlying Moenkopi Formation, and others from the devitrification of the abundant volcanic ash in the Chinle Formation. The clay minerals appear to be unrelated to the solutions that transported uranium and vanadium into the rocks.

The ore deposits are largely confined to these channels and take several forms. One type is termed the *rod deposit* because the ore concentrations are roughly cylindrical, log-shaped masses. A second type, the *tabular orebodies,* are typically at or near the bases of the channels; these bodies are somewhat elongate parallel to the length of the channels. A third type consists of irregular masses of rock impregnated and replaced by the dark vanadium minerals of the corvusite type. The fourth ore-deposit type is the *roll deposit,* named for the characteristic curved bands of channel fill impregnated by yellow uranium minerals, which cut the bedding planes of the sandstone.

High concentrations of uranium minerals are characteristic of the rod deposits, which form the richest orebodies in the Monument No. 2 mine. The rods are annular in cross sections and typically contain an inner core of light-gray sandstone surrounded by a sheaf of tyuyamunite impregnation, outside of which is a limonite-rich zone. The transition from the high uranium-mineral concentration typical of the rods to the barren or weakly mineralized sandstone is commonly abrupt.

The tabular orebodies are irregular in outline and contain large quantities of uranium minerals impregnating conglomeratic sandstone and fossil plant matter. Rich concentrations of ore minerals may have formed in depressions in the channel floors. The bodies are moderately sized, about 60 ft long, 20 to 40 ft wide, and up to 6 ft thick.

Orebodies of the corvusite type may be large (up to 600 ft long, 100 ft wide, and 40 ft thick) and consist of irregular impregnations of sandstone by dark corvusite and associated minerals. The ore mineral distribution within these bodies is erratic, but a rude zoning has been noted: blue-black central areas, typical of high concentrations of corvusite, gradually merge into surrounding areas of high limonite and low vanadium content. Although this type of ore concentration is most abundant near the bases of the channels, it also formed in some places at and near the tops. Where these minerals have been exposed to weathering at the present surface, oxidation of the dark-colored corvusite to hewettite has pervasively colored the rocks a deep red.

Although the roll deposits are important elsewhere in the uranium-vanadium province of the Colorado Plateau, they are relatively minor in Monument Valley. These curved mineralized bands consist of impregnations of sandstone that range in thickness from a few inches to several feet and contain either yellow uranium or dark vanadium minerals. The colored bands alternate with barren or weakly mineralized zones of sandstone. Mineralization in the rolls may have been localized at the intersections of fractures and cross-stratifications in the sandstone.

Reasons for the concentration of the uranium and vanadium minerals in these kinds of orebodies are often obscure. It is thought that two factors may have been most effective in bringing about precipitation of the elements from solution: (1) chemical reaction of the transporting solutions with the abundant carbonaceous plant remains in the channel fill and (2) changes in the porosity and permeability of the host sandstone and conglomerate. Evidence suggests that each may have been instrumental in causing local precipitation. Some geologists who have studied this problem believe the rod deposits were localized at the sites of carbonaceous fossil logs. Subsequent oxidation altered primary uraninite to secondary uranium minerals such as becquerelite and uranophane; the oxidation of pyrite may have provided the limonite found in the outer parts of the rod deposits. In the vanadium-rich zones, the primary mineral was probably montroseite, which subsequently oxidized to corvusite; further oxidation converted corvusite to hewettite and other secondary minerals.

Many of the base-metal deposits are so closely related in time and space to known centers of igneous activity that these are regarded as being genetically involved with the generation of the ore fluids. Igneous intrusions that may be likely sources of the ore-bearing fluids are characteristically absent, however, near Plateau-type deposits, and the ultimate sources of these metals are conjectural. Several possible origins have been proposed, among which are hypothetical, deep-seated, igneous bodies and the devitrification of volcanic ash in the overlying Chinle Formation. It has also been suggested that the high concentrations of uranium and vanadium required to produce the deposits were attained by a reiterative process involving exposure by erosion, weathering, leaching and downward percolation, precipitation, and reconcentration of an initially low metal concentration originally derived from weathered igneous materials. Whatever the ultimate source of the elements, they were subsequently transported in aqueous solutions through the sedimentary rocks to their present sites.

A composite list of minerals (Table 3.9) found in the Monument No. 1 and No. 2 mines and the Mitten No. 2 mine is compiled from the data of D.H. Johnson and A.G. King (Witkind and Thaden, 1963), with additions from other sources.

Uraninite and montroseite were the first primary uranium and vanadium minerals to form. At the Monument No. 2 mine, they appear to have been deposited independently of one another because they are rarely in close association. Their formation was accompanied by the deposition of pyrite and small quantities of other sulfides, including bornite, galena, and sphalerite. At about this time, the host rocks were modified by the addition of silica and calcium carbonate. The valence of uranium in uraninite is +4, the lowest state known in minerals; that of vanadium in montroseite is +3, the lowest state of known vanadium minerals. Both of these minerals are readily susceptible to oxidation. Presumably it was not until the later periods of uplift and erosion of the Colorado Plateau that these primary minerals were sufficiently close to the surface to be subjected to oxidizing conditions.

Table 3.9. Minerals in Monument Valley, Navajo County

URANIUM AND VANADIUM MINERALS			
Autunite	Fourmarierite	Navajoite	Tyuyamunite
Becquerelite	Hewettite	Pascoite	Uraninite
Carnotite	Metahewettite	Rauvite	Uranophane
Coconinoite	Metatorbernite	Roscoelite	Vandendriesscheite
Corvusite	Metatyuyamunite	Schoepite	Vesignieite
Doloresite	Metazeunerite	Steigerite	Volborthite
Fernandinite	Montroseite	Torbernite	"Zippeite"
ASSOCIATED MINERALS			
Alunite	Chalcocite	Jarosite	Quartz
Apatite	Chlorite	Kaolinite	Sphalerite
Azurite	Chrysocolla	Limonite	Sulfur
Bornite	Galena	Malachite	Wad (lithium-bearing)
Calcite	Gypsum	Montmorillonite	
Chalcanthite	Hydromica	Opal	
Chalcedony	Ilsemannite (?)	Pyrite	

The great variety of secondary uranium and vanadium minerals is ultimately the product of oxidation of primary uraninite and montroseite. (In some Plateau-type deposits, the silicate coffinite is also an abundant primary uranium source.) Although the oxidation of these minerals was a complex process, a general progressive sequence has been recognized. Montroseite probably oxidized first to form corvusite, in which the vanadium is in the +4 state. Corvusite is the most abundant vanadium mineral in the Monument No. 2 mine. Its blue-black or dark-green to brown ores are accompanied by smaller amounts of rauvite, navajoite, and hewettite, together with subsidiary becquerelite, tyuyamunite, pyrite, and residual uraninite. Uraninite appears to have undergone oxidation at a somewhat slower rate than the vanadium minerals, and relicts of it are commonly scattered among these oxidation products. Uraninite typically oxidizes to becquerelite and uranophane, in which the valence state of uranium is +6.

Continued oxidation of the ores progressively yielded more and more minerals in which the valence states of uranium and vanadium were high, and minerals in which both elements are present began to appear. In the later stages of oxidation, the stable mineral tyuyamunite locally became very abundant. Rich tyuyamunite occurrences are commonly accompanied by lesser amounts of relict uraninite and many other oxidized minerals. During the middle and late stages of oxidation, secondary uranium-bearing solutions mixed with vanadium-bearing solutions to produce minerals such as carnotite, tyuyamunite, and rauvite, which contain both elements. The most thorough oxidation produced ores that consist of tyuyamunite, limonite, and some hewettite. This simple mineral assemblage is typical of the ores in the upper parts of the Monument No. 2 mine.

The Cameron Area

The economic importance of the uranium deposits near Cameron is substantially less than that of deposits in Monument Valley. The Cameron deposits are discussed here because the low vanadium and copper content of the ores has fostered a somewhat different type of mineralogy. The deposits are relatively small and widely scattered through an area about 10 miles wide and 75 miles long, extending northwest and southeast from Cameron along the Little Colorado River. The most productive part of the area lies within a few miles of Cameron. The data on which this description is based are largely drawn from the work of Austin (1964).

Although some uranium minerals are found in the Lower Triassic Moenkopi Formation and the Shinarump Member, the richest and most abundant concentrations are in the overlying Petrified Forest Member of the Upper Triassic Chinle Formation. The most productive horizon consists of soft shales and mudstones interbedded with coarse-grained sandstones and localized in scour channels. The clay content of the sands is fairly high. The clay characteristically formed pellets about the size of, or a little larger than, the quartz grains in the sandstone.

The Cameron deposits are largely composed of secondary uranium minerals, of which the most abundant are boltwoodite, uranocircite, meta-uranocircite, and the vanadium-bearing metatyuyamunite. Ore mineralization is most commonly associated with carbonaceous fossil logs, which were flattened by the weight of overlying sediments, and with sandstones adjacent to them. The most abundant primary minerals are marcasite, pyrite, and uraninite, which replaced the fossil wood and filled the interstices between grains in nearby sandy lenses. (Coffinite has been recognized locally in small amounts but is apparently not important in the Cameron area.) Other primary minerals include galena, greenockite, calcite, covellite, and smaltite. Microscopic examination of the mineralized wood reveals that its cellular structures were preserved in the finest detail, even though they were completely replaced by the primary minerals. Secondary barite and gypsum fill shrinkage cracks in the fossil logs.

Removal of overlying strata by erosion eventually brought the mineralized logs and sandstones near the surface, where oxygen in the atmosphere and in underground waters oxidized and broke down the susceptible uraninite and sulfide minerals. The paucity of vanadium in the primary ores gave rise to predominantly vanadium-free, secondary uranium minerals, with which a variety of secondary iron sulfates were deposited.

Chemical considerations suggest that the oxidation products of primary uranium minerals should be sufficiently soluble to migrate readily away from the source. Vanadium-bearing compounds, on the other hand, tend to precipitate quickly because of their low solubilities. Although there is evidence for some local redistribution of uranium, the secondary minerals in these deposits did not, as a rule, migrate far from foci of primary mineralization. Possible reasons for this fixation of the secondary uranium minerals in the absence of vanadium include (1) lack of water due to local aridity, (2) restricted movement of groundwater, and (3) geologically recent exposure of the deposits to oxidation, which may not have allowed sufficient time for migration. Several lines of evidence suggest that the formation of minerals during the limited redistribution of uranium took place as recently as 4,500 to 9,000 years ago.

The advanced degree of oxidation of the Cameron deposits makes the sequence of events during oxidation of the primary minerals difficult to establish. A partial paragenetic sequence has been worked out, however, for secondary minerals that migrated into geologically young gravels overlying some of the eroded deposits. Limestone pebbles in these gravels were progressively coated (outward) by layers of cobaltian wad; gypsum and alunite; schoepite; "betazippeite"; and a mixture of uranophane, uranophane-beta, and metatorbernite. The secondary minerals found in these deposits are listed in Table 3.10 (Austin, 1964).

Locally, the generally grayish rocks of the Petrified Forest Member have been converted to yellowish to buff colors, a phenomenon that has served as a guide to ore in the district. This so-called bleaching is partly due to the impregnation of the rock by products formed from the oxidation of primary iron sulfides, including the

Table 3.10. Secondary Minerals in the Cameron Area, Coconino County

URANIUM AND VANADIUM MINERALS			
Boltwoodite	Meta-autunite	Schoepite	Uranocircite
Carnotite	Metatorbernite	Schroeckingerite	Uranophane
Coconinoite	Metatyuyamunite	Torbernite	Uranophane-beta
Coffinite	Meta-uranocircite	Tyuyamunite	"Zippeite"
"Gummite"	Phosphuranylite	Umohoite	
Iriginite	Sabugalite	Uraninite	
	Several unidentified species		
ASSOCIATED MINERALS			
Alunite	Covellite	Hematite	Opal (uraniferous)
Atacamite	Dolomite	Ilsemannite	Pyrite
Barite (strontian)	Ferrimolybdite (?)	Jarosite	Smaltite (?)
Bieberite	Galena	Limonite	Sphaerocobaltite
Calcite	Greenockite	Malachite	Sulfur
Chalcedony	Gypsum	Marcasite	Wad (cobaltian)
Copiapite	Halotrichite	Metasideronatrite	

sulfates jarosite, copiapite, and halotrichite, and the oxides hematite and limonite. Acidic sulfate solutions released during oxidation also attacked calcareous and aluminous rocks to form gypsum and alunite, whose white colors contribute to the bleaching effect, as do illites formed by the alteration of montmorillonite clays.

Breccia Pipes

Recent uranium mining in Arizona has been restricted to the breccia pipes on the Colorado Plateau in northwestern Arizona. The Hack 1, Hack 2, Hack 3, Hermit, Pigeon, and Kanab North pipes were all brought into production as uranium mines in the 1980's, and plans are underway for the mining of additional pipes in the future. Previous mining activity of these breccia pipes included limited copper production in the late 1880's and uranium production in the 1950's and 1960's. Between 1956 and 1969, the Orphan mine produced 4.26 million pounds of uranium oxide (U_3O_8) with an average grade of 0.42% U_3O_8 (Chenoweth, 1986).

These pipes are concentrated between the Grand Wash Cliffs and the Echo Cliffs and along the north and south sides of the Colorado River. Thousands of breccia pipes exist in this area, but probably less than 8% are mineralized and less than 10% of these have economic potential (Wenrich and Sutphin, 1988). The pipes are not very large; most range from 30 to 120 m in diameter. The uranium concentrations in the ore, however, can be high: 0.3 to 0.6% U_3O_8 or higher (individual samples have contained 55% U_3O_8). Other elements that have been enriched in these deposits include antimony, arsenic, barium, cadmium, cesium, chromium, cobalt, copper, gallium, germanium, lead, mercury, molybdenum, nickel, selenium, silver, strontium, vanadium, and zinc (Wenrich, 1985). The concentration of so many elements and the subsequent oxidation of some of these deposits have resulted in the formation of many minerals. Over 90 mineral species have been reported from these deposits.

The breccia pipes in this area are collapse features that formed from solution caverns in the Redwall Limestone. Material from the overlying formations fell into the caverns, filling them and forming circular pipelike bodies. Formations from the Mississippian Redwall Limestone to the Triassic Chinle Formation are involved in the brecciation and mineralization. A set of ring fractures parallel to the sides of the pipe may also be present and mineralized.

The mineralization of the pipes occurred in four separate phases (Wenrich and Sutphin, 1989). The first phase was the deposition of the carbonate and sulfate minerals calcite, dolomite, anhydrite, and barite. The second phase was the deposition of cobalt, arsenic, iron, and nickel as sulfides, the most common of which were zoned crystals of alternating layers of pyrite and siegenite. A rarer zonal assemblage of nickeline, rammelsbergite, and pararammelsbergite may also be present. The third phase was the deposition of copper, iron, lead, and zinc sulfides as the minerals chalcopyrite, sphalerite, and galena, with lesser amounts of tennantite, enargite, lautite, molybdenite, and fluorite. The fourth phase was the deposition of uranium as uraninite with some sulfides, including digenite, chalcopyrite, bornite, djurleite, and galena. Geochemical dating of the deposition of uranium gave an age of about 200 million years; the deposition of the other minerals predates that of uranium by an undetermined period (Ludwig and Simmons, 1988). Triassic rocks associated with the pipes are mineralized; Jurassic rocks are not.

Erosion has removed a large amount of rock in the Colorado Plateau, especially along the Grand Wash Cliffs and in the Grand Canyon. The exposure of some pipes has resulted in the oxidation of the primary minerals and has given rise to many supergene minerals. Copper minerals such as malachite, azurite, and chrysocolla are very common and were the reason for the early interest in these deposits. Oxidized uranium, zinc, lead, vanadium, nickel, and cobalt minerals have also been found in the pipes. The Grand View mine in the Grand Canyon is the most famous mineral locality representing this type of deposit. Mineralization at the Grandview mine occurred in the Redwall Limestone, the lowest mineralized formation. All of the overlying formations have been eroded away, and the primary sulfide minerals have been removed or oxidized. A suite of secondary copper, zinc, iron, arsenic, and uranium minerals, including cyanotrichite, brochantite, chalcoalumite, langite, metazeunerite, scorodite, olivenite, and adamite, also formed at the mine (Leicht, 1971).

Pegmatites

Granite pegmatites are widespread throughout Arizona. They are abundant in the older Precambrian terrain of the Grand Canyon, where they make up perhaps 15 to 20% of the rocks of this age (Babcock et al., 1979). They are also abundant in the Precambrian rocks of the Arizona pegmatite belt (Jahns, 1952). This belt, which trends from the northwest corner of Arizona southeasterly for about 250 miles to the Phoenix area, encompasses part of the Transition Zone and the Basin and Range Province. Pegmatites also formed in the rest of the Basin and Range Province in Arizona, but are much less common than in the aforementioned regions.

Pegmatites formed in Arizona during at least three different times (Reynolds et al., 1986). The most common are those that developed in Precambrian time and are associated with the metamorphic and igneous rocks of that era. Most of the pegmatites in the Grand Canyon and the Arizona pegmatite belt are Precambrian, including those in the White Picacho district, the Kingman area, and the Bagdad area. Precambrian radioactive dates that have been determined on Arizona pegmatites range from 1.37 to 1.64 billion years.

A second period of pegmatite formation occurred during the Jurassic Period. These pegmatites are mainly in the southwestern part of the state, from Kitt Peak to the Trigo Mountains. They are about 160 million years old, based on age determinations from associated igneous rocks (Gordon Haxel, pers. commun., 1989). The mineralogy of these pegmatites is relatively simple, with garnet and tourmaline as accessory minerals.

A third period of pegmatite formation in the Late Cretaceous and early Tertiary was associated with Laramide intrusions common in the Basin and Range Province. Very few age dates are available for pegmatites of this group; their extent, therefore, is not well known. Two such dates are 64.6 million years for a pegmatite in the New Cornelia open-pit mine at Ajo and 52.2 million years for the Canoa pegmatite in the Twin Buttes quadrangle. This latter body contains beryl.

Pegmatites have had only limited economic importance in Arizona. The most important production has been feldspar, of which several hundreds of thousands of tons have been quarried. Quartz, mica, beryl, and bismuth have also been mined, and exploration and limited production has occurred for lithium, tantalum, and rare earth minerals.

About 120 different minerals have been reported from pegmatites in Arizona, including two for which Arizona is the type locality: bermanite and paulkerrite from the 7U7 Ranch near Bagdad. Some of the most interesting pegmatites are in the White Picacho district, Bagdad area, Aquarius Mountains, and Kingman area. All of these pegmatites are Precambrian.

The pegmatites of the White Picacho district in Maricopa and Yavapai Counties have been studied more than any other Arizona pegmatites. Jahns (1952), London (1979, 1981), and London and Burt (1982a and b) have described these pegmatites and their mineralogy in detail. Jahns lists 22 named prospects and mines in this district and many additional undeveloped deposits, 7 of which are lithium-bearing pegmatites. London concentrated his work on these bodies, describing nine in this district. Many maps, cross-sections, and descriptions of specific localities are available in these reports.

The primary lithium minerals in these pegmatites are spodumene, montebrasite, lithiophilite, and elbaite. Spodumene is the most common lithium mineral and formed in crystals up to 21 ft long and 4.5 ft across (Jahns, 1952). Most of the spodumene has been entirely or partially altered, first to eucryptite plus albite, then, in some crystals, to albite plus muscovite or lepidolite, and finally, in a few places, to muscovite or lepidolite (the latter are soft, waxy pseudomorphs of mica after spodumene; London and Burt, 1982a).

Montebrasite, which Jahns (1952) called amblygonite, formed large irregular masses and crudely faceted, equant crystals that range from a few inches to 6 ft in length, with aggregates of crystals approaching 15 ft across. The montebrasite also shows alteration, first to a low-fluorine montebrasite, then to a complex series of minerals, including the phosphates augelite, brazilianite, crandellite, kulanite, scorzalite, and wyllieite (London and Burt, 1982a).

Lithiophilite is not as common as spodumene and montebrasite. It formed crude crystals and clusters up to 24 in. in diameter (Jahns, 1952), as well as several alteration products. London and Burt (1982a) gave two different replacement series, depending on whether the lithiophilite was embedded in quartz or albite. The alteration minerals include hureaulite, triploidite, fillowite, dickinsonite, wyllieite, eosphorite, fairfieldite, and robertsite. Other alteration phosphates found in this district include sicklerite, purpurite, stewartite, and strengite.

Elbaite has only been found in a few pegmatites and formed pink, green, and yellow crystals up to 7 in. long (Jahns, 1952). The elbaites are typically altered to muscovite or lepidolite. Most of the lepidolite in this area is probably secondary, formed from the alteration of the aforementioned primary lithium minerals. Other lithium-bearing pegmatites have been found in the Wickenburg area (Norton, 1969), but their mineralogy has not been studied.

The Bagdad area contains many pegmatites, including some with unusual minerals. These pegmatites are dispersed over a larger area and are smaller than the pegmatites of the White Picacho district; they have neither been economically important nor studied in detail. C.A. Anderson et al. (1955) described the general mode of occurrence of pegmatites in this area, including some that contain the lithium-bearing minerals lepidolite and amblygonite. Many pegmatites also contain beryl.

The most interesting pegmatite in the Bagdad area, one whose location is somewhat mysterious, is the type locality of bermanite and paulkerrite. This pegmatite is on the 7U7 Ranch, the location of which has been described as 25 miles west of Hillside (Hurlbut, 1936); 40 miles west of Hillside, near the Bagdad copper mine (Peacor et al., 1984); and 7 miles southeast of Bagdad (Anderson, C.A., et al., 1955). The exact location of the 7U7 Ranch remains unknown; many collectors have searched for this mineral locality without luck. Recent studies have been made on material from collections. The bermanite and paulkerrite are associated with leucophosphite, phosphosiderite, strengite, hureaulite, and switzerite as alteration products of triplite (Leavens, 1967; Peacor et al., 1984).

Triplite was also found at three other localities within a 7-mile radius of the 7U7 Ranch (Hurlbut, 1936). One of these, "the granites," also contains bismutite (Frondel, C., 1943). This mineral locality is described as "the granites, near the Bagdad copper mine, 30 miles west of Hillside, Yavapai Co., Arizona. Mostly as pseudomorphs after bismuthinite." The exact relationship of "the granites" location to the 7U7 Ranch is unknown.

About 20 miles to the northwest of the Bagdad area, on the west side of the

Aquarius Mountains, several pegmatites contain rare-earth-bearing minerals. The largest of these is the Rare Metals mine, which Heinrich (1960) reported as having "yielded seven to eight tons of yttrotantalite ore, six tons of beryl, some bismuth minerals, and small amounts of monazite and gadolinite." Other prospects in this area, e.g., the Columbite prospect, contain similar minerals as well as xenotime and allanite. Chevkinite has also been found in the Aquarius Mountains, but the specific locality is unknown (Kauffman and Jaffe, 1946).

Farther north in the Kingman area are two interesting pegmatites. The Kingman Feldspar mine, about 5 miles north of Kingman, is "the largest and most continuous commercial pegmatite operation in Arizona" (Heinrich, 1960). It has been mined for crude and ground feldspar, and several hundred thousand tons have been recovered. Here microcline formed large, white masses up to 10 or 12 ft thick. Another interesting mineral in this mine is allanite, of which several hundred pounds were recovered. Heinrich (1960) presented some chemical and X-ray data for this allanite, which has a high rare earth content. Another pegmatite about 5 miles south of Kingman has yielded large crude crystals of thalenite (Fitzpatrick and Pabst, 1986). The thalenite also contains considerable amounts of rare earth elements, particularly dysprosium, erbium, and ytterbium.

"Mine Fire" Minerals, United Verde Mine, Jerome

A mine fire that started in 1894 in the massive sulfide orebody in the United Verde mine at Jerome burned for several decades, despite concerted efforts to extinguish it. The fire was thought to have been caused by spontaneous combustion of unstable sulfide minerals on exposure to air. Surface stripping operations later exposed rocks above the fire area and revealed a suite of newly formed hydrated sulfate minerals. Of the 11 minerals formed by the mine fire, 7 were previously unknown species. Of these seven, all but one are unique products of the local conditions in the United Verde mine.

The geology and mineralogy of the Jerome area have been described in the papers of Reber (1922), C.A. Anderson (1927), Lausen (1928), Palache (1934), C.A. Anderson and Creasey (1958), Hutton (1959a), and C.A. Anderson and Nash (1972). The main United Verde orebody in which the fire burned is a northtrending, steeply plunging, pipelike, massive sulfide deposit composed of fine-grained pyrite and lesser amounts of chalcopyrite in a matrix of quartz and carbonate gangue. Minor amounts of arsenopyrite, sphalerite, galena, bornite, and tennantite are also present. The country rocks enveloping the orebody are metamorphosed bedded volcanic tuffs, into which a gabbro mass was intruded. Unlike most metallic mineral deposits in Arizona, both the country rocks and the sulfide orebody of the United Verde mine are Precambrian.

After reinterpreting the geology of the mine, C.A. Anderson and Nash (1972) believed that the massive sulfides were deposited contemporaneously with the volcanic tuffs that enclose them. The sulfides probably came from hydrothermal emanations fed into a submarine basin floored by volcanic tuffs and were soon buried beneath accumulating volcanic materials. The ores and enclosing rocks were later deformed structurally by folding, metamorphosed, and modified by hydrothermal activity. These postdepositional events probably mobilized some of the copper sulfides, which migrated to form veins, and also created the rich chlorite mineral assemblages of the local "black schist."

The burning stopes were sealed off by bulkheads, and the fire was partially contained by the use of air introduced under pressure. Later, when the bulkheads were removed, the exposed rocks were red hot (Talley, 1917). Unsuccessful methods used to contain the fire included the injection of water, carbon dioxide, and steam under pressure into the affected areas. The introduced water was probably gasified by the high temperatures in the mine and reacted with the abundant iron and copper sulfide ores. Lausen (1928) thought the gases contained, in addition to water vapor and sulfur dioxide, small amounts of ferrous and ferric iron, copper, sodium, potassium, and aluminum. Their upward migration through fractures in the overlying rocks led to the precipitation of the unusual suite of secondary minerals.

Lausen (1928) reported that copious quantities of gas and smoke were issuing from natural vents in the floor of the mine pit when he collected samples. Study of the chemistry of these gases convinced him that the new minerals could not have formed from them. He concluded that the minerals were directly precipitated from gas phases of quite different composition, which were generated immediately after the introduction of water into the mine. Lausen's paragenetic observation also demonstrated that the sulfate minerals could not have been coprecipitated, but must have been formed during several distinct periods of sulfate precipitation.

The secondary sulfates were most abundant on the north and west sides of the massive sulfide pipe and were deposited in fractures in areas of abundant, fine-grained, iron-oxide-stained quartz (jasper), as well as in cracks in pyrite. Lausen recognized nine sulfate compounds in material he collected from the pit floor, five of which he proposed as new species. One of these, louderbackite, was later shown by Pearl (1950) to be identical with roemerite. The new minerals were named *butlerite, guildite, ransomite,* and *rogersite.* Rogersite was renamed *lausenite* because the name *rogersite* was used previously (Butler, G.M., 1928). To our knowledge, only two of these minerals have been recognized elsewhere. Butlerite has been reported from the Santa Elena mine, La Alcaparrosa, San Juan, Argentina, and from Chuquicamata, Chile. Ransomite was found at Bisbee.

Lausen also described an amorphous dark-reddish material largely composed of arsenic, sulfur, and selenium, which formed as thin films and globules on the interior of large iron hoods placed around active gas vents in the pit to protect the miners. He gave the name *jeromite* to the substance, whose standing as a mineral species, although formerly questioned, is reported by Fleischer and Mandarino (1991).

Other sulfates that Lausen found include alunogen, copiapite, coquimbite, and voltaite. The voltaite occurrence had been previously described by C.A. Anderson in 1927 as the first U.S. and the seventh world occurrence of the species.

In 1934 Charles Palache added to the list of mine fire minerals the rare species claudetite (As_2S_3), whose dimorph, arsenolite, was later identified at the United Verde mine. He also reported the first natural occurrence of elemental selenium. Hutton (1959a) later described the new species yavapaiite ($KFe[SO_4]_2$) from material collected in the mine fire area. Seven new mineral species were thus formed under these unusual circumstances.

Arizona Meteorites

Data on Arizona meteorites were obtained from Charles Lewis of the Center for Meteorite Studies, Arizona State University; the *Catalogue of Meteorites* (Hey, 1966; Graham et al., 1985); the Mineral Museum, University of Arizona; and the cited literature. Arizona meteorites in the collections of Arizona State University (ASU), the University of Arizona (UA), and the Museum of Northern Arizona are noted.

The following meteorites are no longer regarded as representing distinct falls because they have been shown by chemical and mineralogical evidence to be transported fragments of the Canyon Diablo meteorite (Buchwald, 1975): Apache County, *Ganado* and *Houck;* Coconino County, *Monument Rock;* Maricopa County, *Wickenburg* (iron); Yavapai County, *Bloody Basin, Camp Verde,* and *Fair Oaks;* and Yuma County, *Ehrenberg.* The classification type for each chondritic and iron meteorite (H, H5, L6, IA, IIB, etc.) is included with the meteorite's description.

A total of 23 minerals have been found in meteorites in Arizona and, with the

Table 3.11. Arizona Minerals Found Only in Meteorites

Barringerite	Daubreelite	Lawrencite	Roedderite
Brezinaite	Diamond	Lonsdaleite	Schreibersite
Carlsbergite	Haxonite	Mackinawite	Taenite
Cliftonite (a variety of graphite)	Kamacite	Moissanite	Tetrataenite
Cohenite	Kosmochlor	Richterite	Troilite
	Krinovite	Roaldite	Wüstite

exception of wüstite, are not known from any other localities in the state (Table 3.11). Of these, brezinaite, haxonite, krinovite, lonsdaleite, and moissanite were first described from Arizona meteorites. Ureyite, included in the last edition, is now named *kosmochlor.*

Apache County: Navajo (iron, coarsest octahedrite, IIB). A large 1,500-kg mass was found in 1921 buried with Indian beads in talus (Merrill, 1922). A 683-kg mass was found in 1926 only 48 m northwest of the original find (Buchwald, 1975). 4 g are in the ASU collection.

Coconino County: Canyon Diablo (iron, coarse octahedrite, IA). Found in 1891. Over 30 tons have been collected around Meteor Crater, just east of Canyon Diablo. Over 250 kg are in the UA collection, and 1,200 kg are in the ASU collection (Foote, A.E., 1891a,b; Nininger, 1949). This is probably the most widely distributed of all meteorites. As noted above, several Arizona meteorites are now considered to be transported fragments of the Canyon Diablo meteorite (Buchwald, 1975). *Coon Butte* (stone, olivine-hypersthene chondrite, L6). A stone weighing 2.75 kg was found in 1905 about 1 mile west of Coon Butte. (*Coon Butte* was the name for Meteor Crater at that time; Mallet, 1906); 625 g are in the ASU collection. *San Francisco Mountains* (iron, fine octahedrite, IVA). A beautifully preserved mass of 1.65 kg was found by a shepherd in 1920 on the northern slope of the San Francisco Mountains near Flagstaff (Perry, S.H., 1934); 30 g are in the ASU collection. *Seligman* (iron, coarse octahedrite, IA). A fresh 2.2-kg iron was found near Seligman in 1949. 16 g are in the UA collection (UA 8375), and 274 g are in the ASU collection. *Winona* (stone, anomalous chondrite). A very weathered, 24-kg mass was found in 1928 in a stone cistern in the ruins of the Elden Pueblo (Brady, 1929; Heineman and Brady, 1929; Buddhue, 1940). Eleven fragments totaling 885.8 g are in the UA collection (UA 818), 230 g are in the ASU collection, and 4.5 kg are in the Museum of Northern Arizona.

Gila County: Clover Springs (stony-iron, mesosiderite). In 1954 a 7.7-kg mass was found 13 miles southwest of Clover Springs; 425 g are in the ASU collection. *Gun Creek* (iron, medium octahedrite, anomalous). A 22.7-kg mass was discovered by

Anwell Lafave in 1909 about 70 miles northeast of Globe in the Sierra Anchas (Palache, 1926); 42 g are in the ASU collection.

La Paz County: Kofa (iron, plessitic octahedrite, anomalous). A 490-g mass was found in 1893; 55 g are in the ASU collection.

Maricopa County: Chandler (stone, olivine-bronzite chondrite, H). A 102-g fragment of what must have been a much larger stone was found in 1988 by 13-year-old David Bustoz in a horse pasture near his home in Chandler. It is in the ASU collection (C.F. Lewis, pers. commun., 1988). *El Mirage* (iron, hexahedrite, IIA). A single 598-g iron was found in the spring of 1972 by 8-year-old Steven Schuetz while he was walking in the desert. The main mass is in the ASU collection (*Meteoritics,* 1975, v. 10, p. 145). *Hassayampa* (stone, olivine-bronzite, H). A 16-kg stone was discovered sometime before 1963 (Mason, 1963). *Maricopa* (stone, olivine-bronzite chondrite, H). A single 50-g mass was found near Maricopa in the spring of 1980. An 18-g slice is in the ASU collection (*Meteoritics,* 1981, v. 16, p. 195). *Weaver Mountains* (iron, ataxite, IVB). This 38.8-kg iron was discovered in 1898 (Henderson, E.P., and Perry, 1951). The main mass of 28.5 kg is in the UA collection (UA 5628); 2.6 kg are in the ASU collection. *Wickenburg* (stone, olivine-hypersthene chondrite, L6). This 9.2-kg stone was found in 1940, about 3 miles west of Wickenburg (Nininger, A.D., 1940); 2.88 kg are in the ASU collection.

Mohave County: Bagdad (iron, medium octahedrite, IIIA). A 2.2-kg mass was found in 1959 by Donald Stout on Burro Creek (Moore, C.B., and Tackett, 1963). The main mass is in the ASU collection. *Wallapai* (iron, fine octahedrite, IID). Two masses of 306 and 124 kg were found in 1927 by Richard Grover on the Hualpai Indian Reservation (Merrill, 1927). The main mass (123 kg) is in the UA collection (UA 7638 and 8351); 527 g are in the ASU collection. *Wikieup* (stone, olivine-bronzite chondrite, H5). A 372-g stone was found by A.B. Walker on the eastern slope of McCracken Peak in the spring of 1965; 334 g are in the ASU collection.

Navajo County: Holbrook (stone, olivine-hypersthene chondrite, L6). In the early evening of July 19, 1912, a very large shower of stones, estimated to have numbered at least 14,000, fell at Aztec Siding east of Holbrook. Nearly 225 kg have been recovered, the largest weighing 14.5 lb (Foote, W.M., 1912; Gibson, 1970). Several specimens are in the UA (about 8 kg) and ASU (about 10.8 kg) collections.

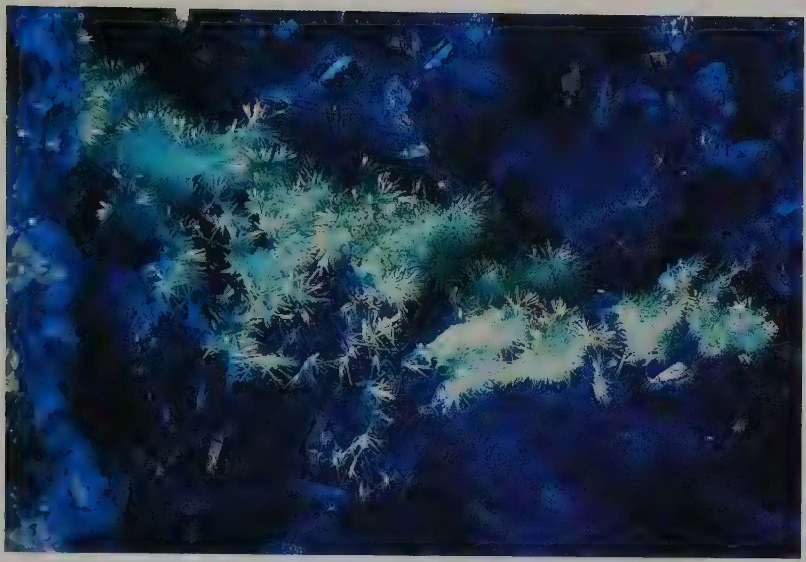
Pima County: Cat Mountain (stone, olivine-hyperthene chondrite, impact melt breccia). A 2.7-kg stone was found in 1980 or 1981 by William Goldups near Cat Mountain in the Tucson Mountains. A slice is in the UA collection, 1.7 kg are in the Robert Haag collection, and 784 g are anonymously held. *Hickiwan* (stone, olivine-bronzite chondrite, H5). A 1.928-kg stone was found about 4 miles east of Hickiwan in March 1974 (Lange and Keil, 1977). *Pima County* (iron, hexahedrite, IIA). A 210-g mass was reportedly found near Tucson before 1947 (Henderson, E.P., and Perry, 1949). *Silver Bell* (iron, coarsest octahedrite, IIB). Mining geologist Harrison Schmidt (appropriately, the father of a U.S. astronaut) found a 5.1-kg iron near the town of Silver Bell before 1939. The main mass (3.3 kg) is in the UA collection; 300 g are in the ASU collection. *Tucson* (iron, ataxite, anomalous). Two huge masses, the Signet (Ring) or Irwin-Ainsa Iron, weighing 688 kg, and the Carleton Iron, weighing 287 kg, had been known for some years before 1850, when they were first described. Both of the main masses are in the Smithsonian Institution; 1.1 kg are in the ASU collection.

Pinal County: Arizona City (stone, olivine-bronzite chondrite, H). A weathered, 97-g individual stone was found in the spring of 1988 by Mike Yeatts about 1 mile south of Arizona City. The specimen is in the ASU collection (C.F. Lewis, pers. commun., 1988).

Southern Arizona (iron, coarse octahedrite, IA). A 266-g slice of the 622-g iron was exchanged to the Smithsonian Institution in 1947. The only available information indicated that the mass had been found in the southern part of Arizona before that date. 46 g are in the ASU collection.

Yavapai County: Ash Fork (iron, coarse octahedrite, IA). A 27-kg mass was found in 1901 by Charles Quitzow in Cedar Glade, about 25 miles southwest of Ash Fork (Reeds, 1937). This was thought to have been a transported portion of *Canyon Diablo* (Buchwald, 1975), but a subsequent study showed that it is not (J.T. Wasson, pers. commun., 1989). *Cottonwood* (stone, olivine-bronzite chondrite, H5). An 800-g stone was found in 1955. The main mass is in the ASU collection.

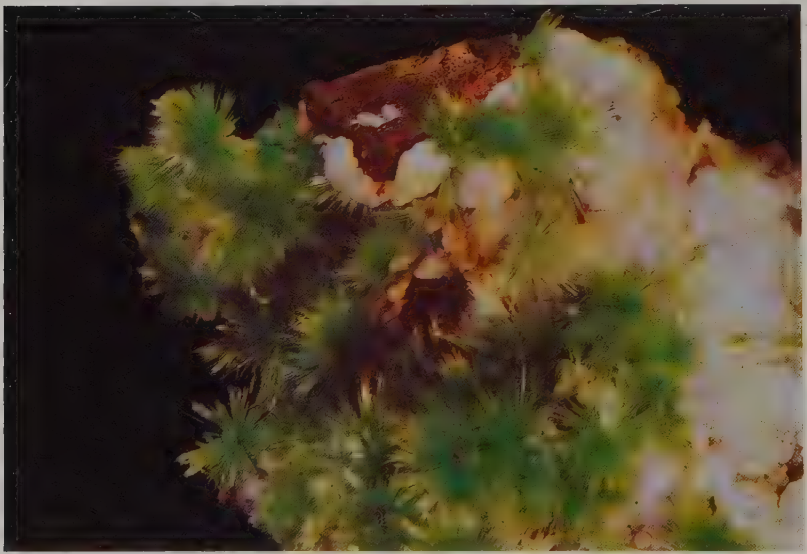
ARIZONA MINERAL SPECIMENS



Ajoite and papagoite. Ajo, Pima County. Gibbs collection. 1.3-cm-wide image. Wendell E. Wilson photo.

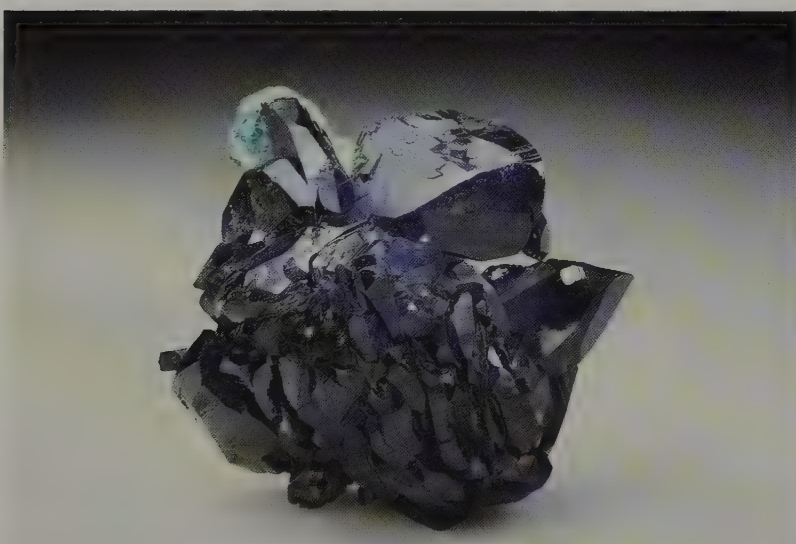
Amethyst scepter quartz. Fat Jack mine, Yavapai County. Wagner collection. 3.8-cm-long crystal. Jeff Scovil photo.

Aragonite, twisted. Bisbee, Cochise County. Graeme collection. 7.5-cm-long crystal. Monica Graeme photo.

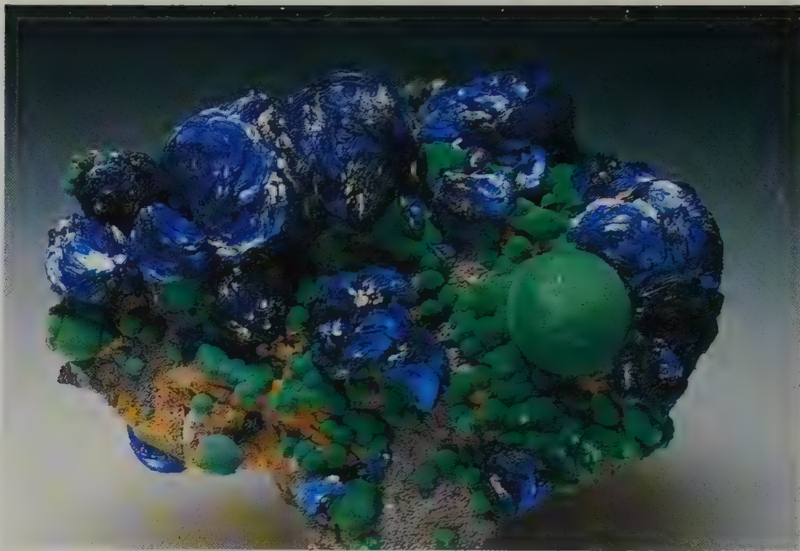


Aurichalcite. Bisbee, Cochise County. University of Arizona Mineral Museum. 5-cm-wide specimen. Jeff Kurtzeman photo.

Azurite and cuprite. Bisbee, Cochise County. Arizona-Sonora Desert Museum. 4.8-cm-wide specimen. Wendell E. Wilson photo.

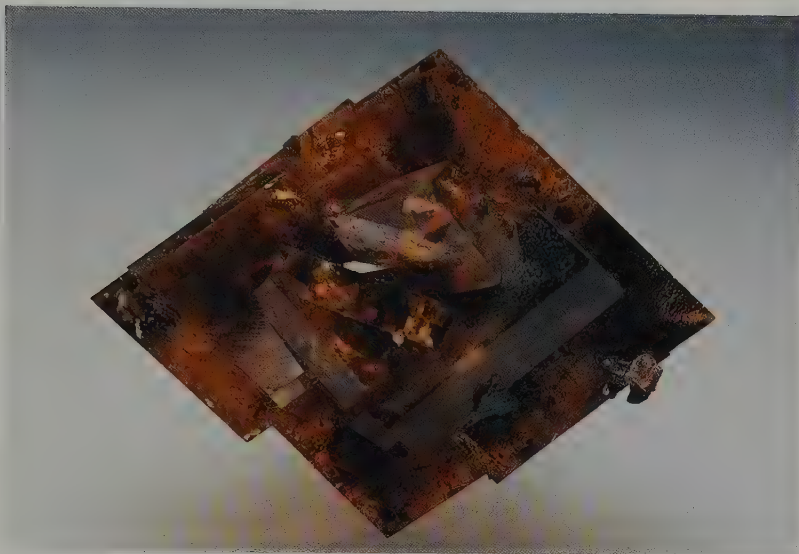


Azurite and malachite. Ajo, Pima County. Arizona-Sonora Desert Museum. 3-cm-wide specimen. Monica Graeme photo.

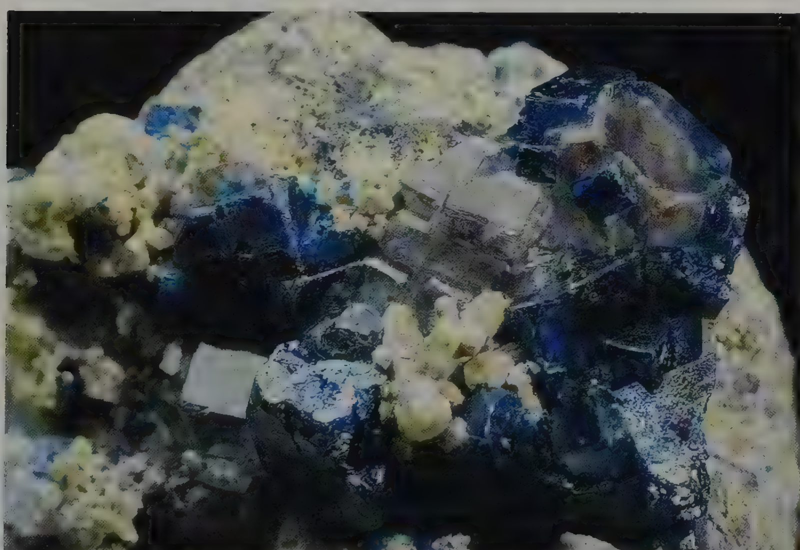


Azurite and malachite. Morenci, Greenlee County. Presmyk collection. 6.2-cm-wide specimen. Wendell E. Wilson photo.

Azurite and malachite. Morenci, Greenlee County. 3-cm-wide specimen. Jeff Kurtzeman photo.

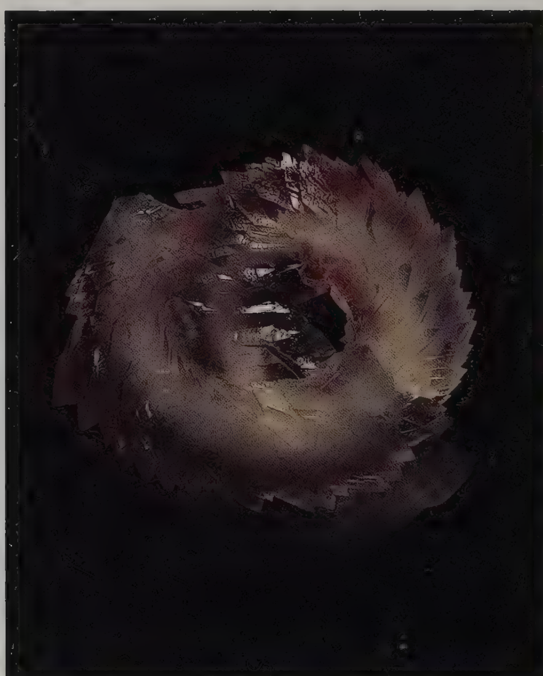


Barite. Magma mine, Gila County. Presmyk collection. 3.3-cm-crystal. Wendell E. Wilson photo.



Bideauxite. Tiger, Pinal County. Arizona-Sonora Desert Museum. 4 mm wide, largest crystal. Wendell E. Wilson photo.

Calcite. Bisbee, Cochise County. Arizona-Sonora Desert Museum. 7-cm-wide specimen. Wendell E. Wilson photo.

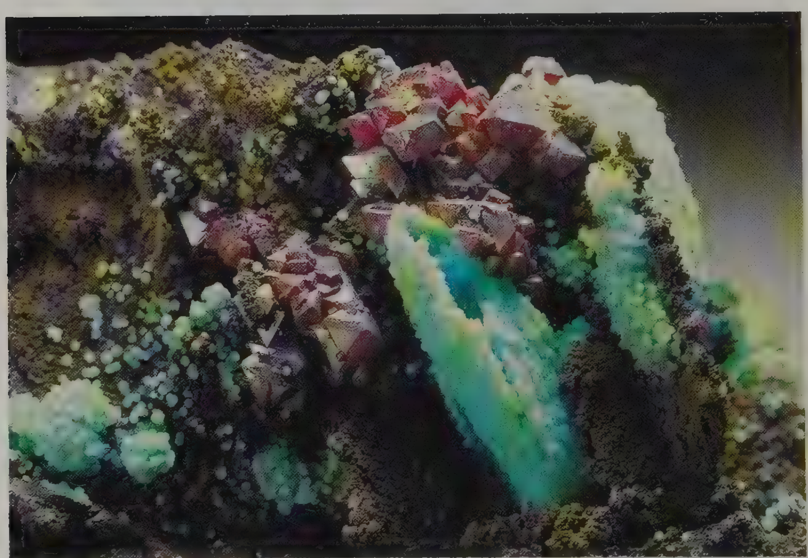


Calcite. Bisbee, Cochise County. Graeme collection. 2-cm-wide specimen. Monica Graeme photo.

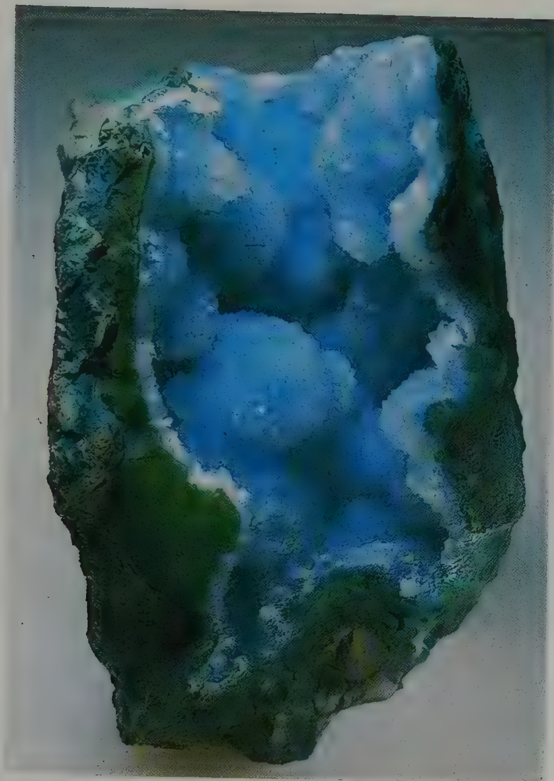
Calcite enclosing cuprite. Bisbee, Cochise County. Arizona-Sonora Desert Museum. 11.1-cm-high specimen. Jeff Scovil photo.

Caledonite. Tiger, Pinal County. Arizona-Sonora Desert Museum. Micromount. Art Roe photo.

Cerussite and dioptase. Tiger, Pinal County. Arizona Department of Mines and Mineral Resources Mineral Museum. 1.5-cm-wide image. Jeff Scovil photo.

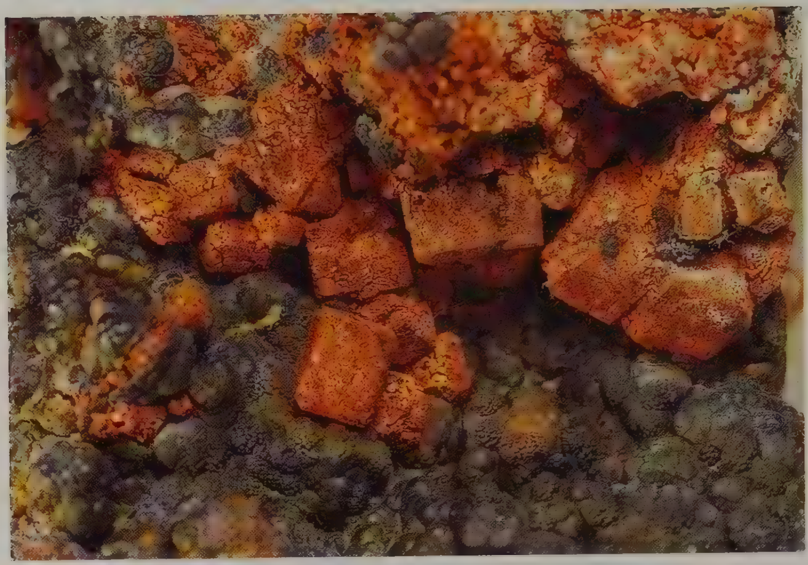


Chalcoalumite after azurite with cuprite. Bisbee, Cochise County. Bideaux collection. 3.6-cm-wide image. Wendell E. Wilson photo.



Chrysocolla. Inspiration mine, Gila County. University of Arizona Mineral Museum. 11.5-cm-wide specimen. Wendell E. Wilson photo.

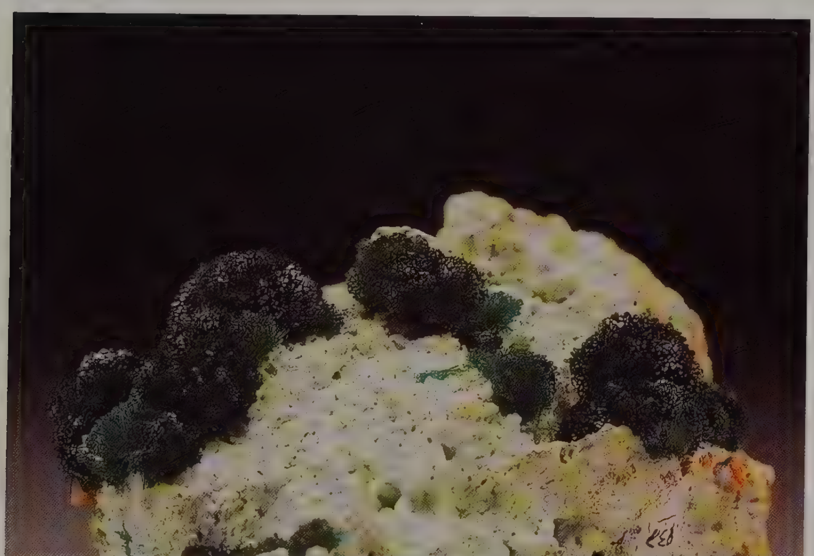
Copper. Bisbee, Cochise County. Presmyk collection. 12.3-cm-wide specimen. Wendell E. Wilson photo.



Copper after cuprite. Bisbee, Cochise County. Bideaux collection. 5 mm wide, largest crystal. Wendell E. Wilson photo.

Cuprite. Bisbee, Cochise County. Graeme collection. 2.6-cm-wide crystal. Monica Graeme photo.

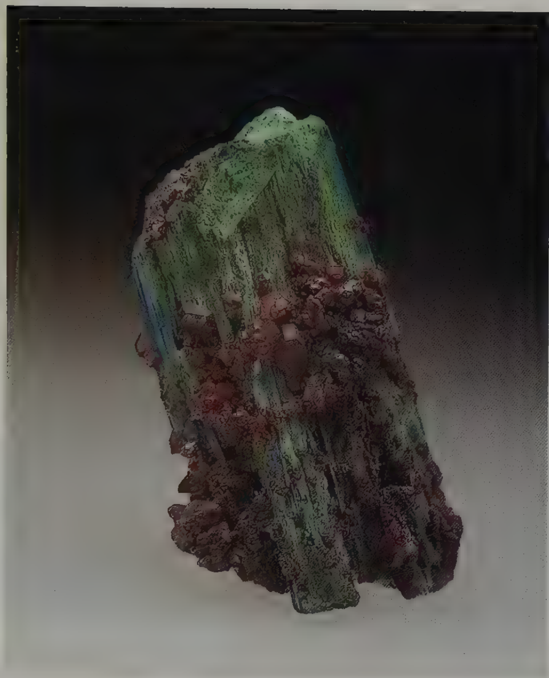
Cuprite var. chalcotrichite. Bisbee, Cochise County. University of Arizona Mineral Museum. 8-cm-wide specimen. Wendell E. Wilson photo.



Dioptase and wulfenite. Tiger, Pinal County. Arizona-Sonora Desert Museum. 5-cm-wide specimen. Jeff Scovil photo.

Fluorite on dioptase. Tiger, Pinal County. Arizona-Sonora Desert Museum. Micromount. Art Roe photo.

Gold. Near Quartzsite. La Paz County. University of Arizona Mineral Museum. 2.4-cm-high specimen. Wendell E. Wilson photo.

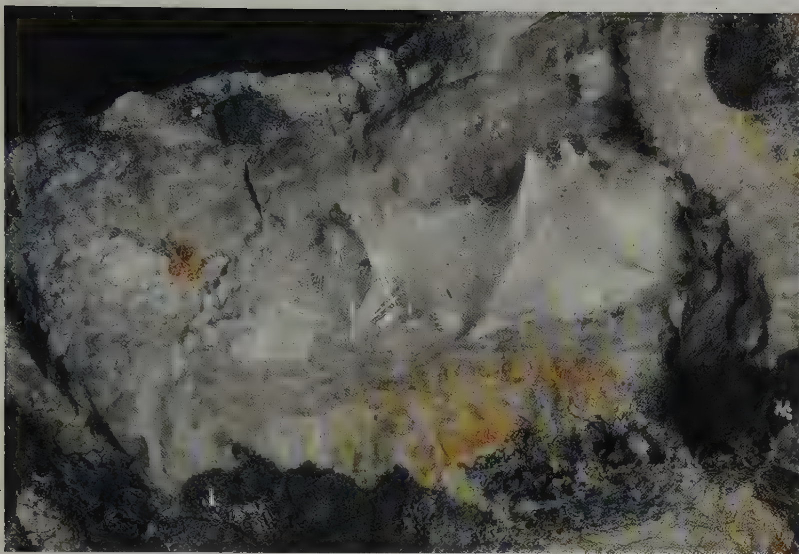


Graemite and cuprite. Bisbee, Cochise County. Arizona-Sonora Desert Museum. 1-cm-wide specimen. Jeff Scovil photo.

Groutite. Holbrook, Navajo County. Behnke collection. Micromount. Dan Behnke photo.

Hemimorphite. 79 mine, Gila County. Godas collection. 3.7-cm-wide specimen. Wendell E. Wilson photo.

Kinoite. Christmas, Gila County. Behnke collection. Micromount. Dan Behnke photo.



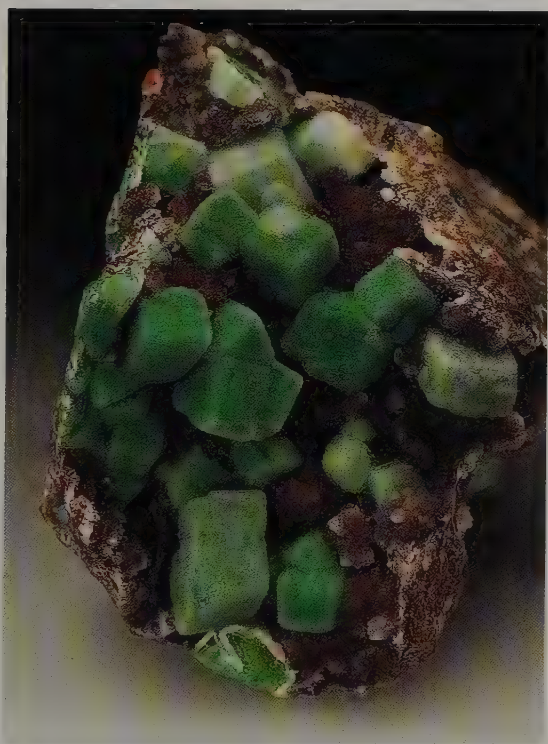
Laurelite. Grand Reef mine, Graham County. Presmyk collection. 2-cm-wide image. Les Presmyk photo.

Leadhillite. Grand Reef mine, Gila County. University of Arizona Mineral Museum. 6 mm wide, largest crystal. Wendell E. Wilson photo.

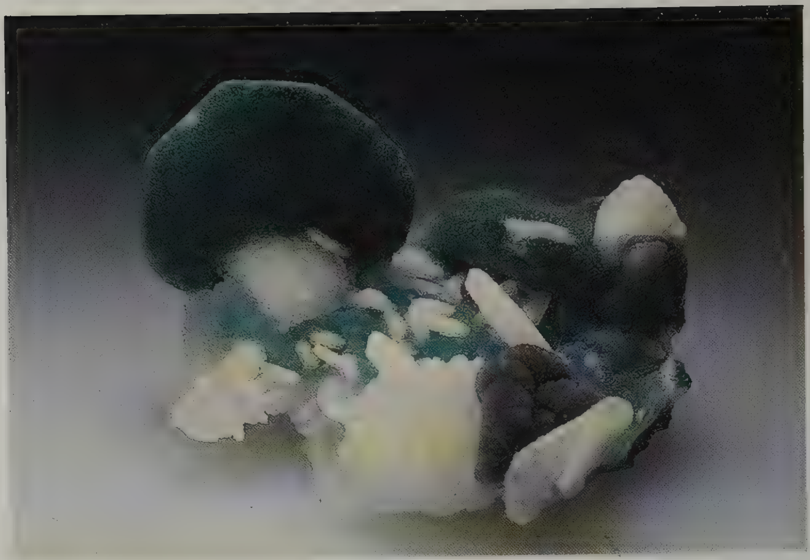
Linarite. Grand Reef mine, Gila County. Bideaux collection. 7 mm long, largest crystal. Wendell E. Wilson photo.

Malachite. Bisbee, Cochise County. Arizona-Sonora Desert Museum. 4.3-cm-high specimen. Jeff Scovil photo.

Malachite. Bisbee, Cochise County. Graeme collection. 3.5-cm-wide image. Wendell E. Wilson photo.

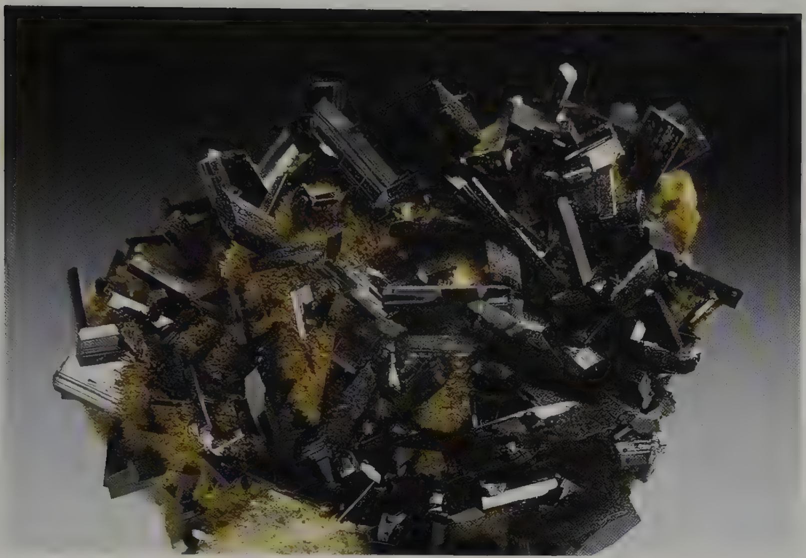


Malachite after azurite. Piedmont mine, Yavapai County. Arizona-Sonora Desert Museum. 10.1-cm-high specimen. Jeff Scovil photo.



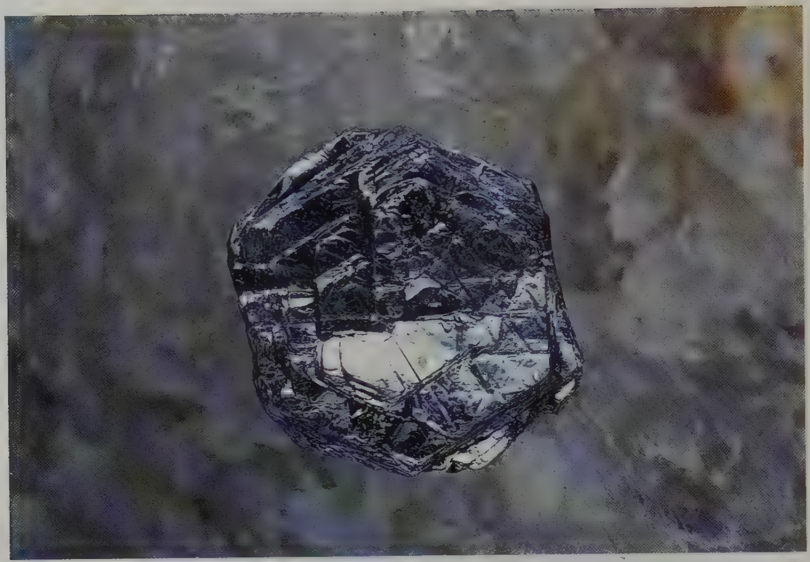
Malachite after azurite. Globe, Gila County. Presmyk collection. 2.9-cm-wide specimen. Wendell E. Wilson photo.

Malachite after azurite. Silver Bill mine, Cochise County. Knudsen collection. 1.6-cm-high specimen. Wendell E. Wilson photo.

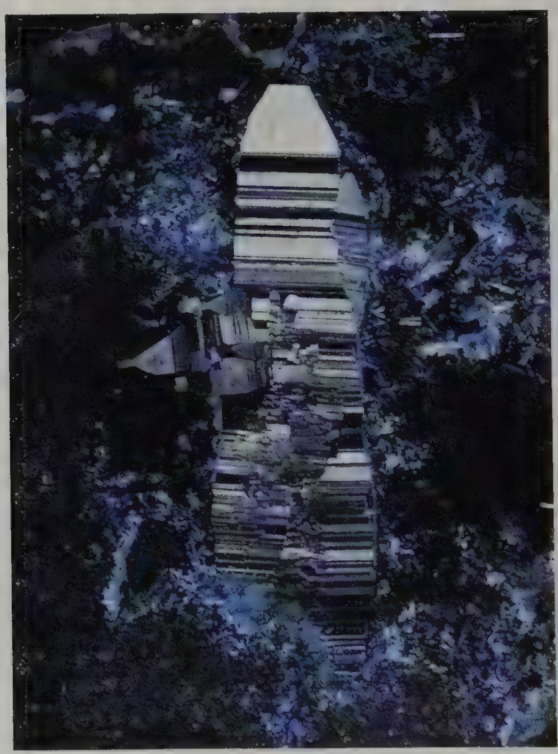


Manganbabingtonite. Iron Cap mine, Gila County. Godas collection. 2-cm-wide specimen. Wendell E. Wilson photo.

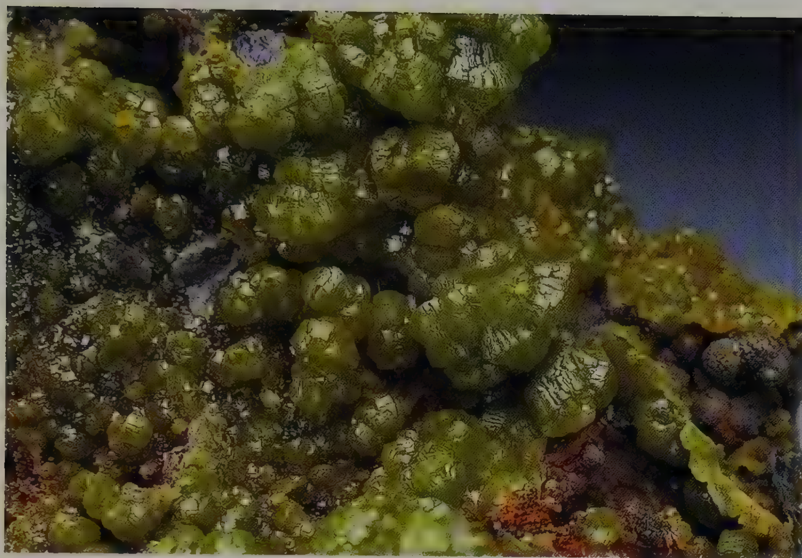
Metatorbernite. Silver Bell mine, Pima County. Bladh collection. Micromount. Art Roe photo.



Molybdenite. Near Cleator, Yavapai County. Arizona Department of Mines and Mineral Resources Mineral Museum. 1.6-cm-wide crystal. Jeff Scovil photo.



Paramelaconite. Bisbee, Cochise County. Smithsonian Institution. 5-mm-long crystal. Monica Graeme photo.



Pyromorphite. Hardshell mine, Santa Cruz County. Arizona Department of Mines and Mineral Resources Mineral Museum. Micromount. Jeff Scovil photo.

Quartz, Japan-law twin. Holland mine, Santa Cruz County. Smithsonian Institution. 17.5-cm-high specimen. Wendell E. Wilson photo.

Rosasite. Silver Bill mine, Cochise County. Godas collection. 3.2-cm-wide specimen. Wendell E. Wilson photo.

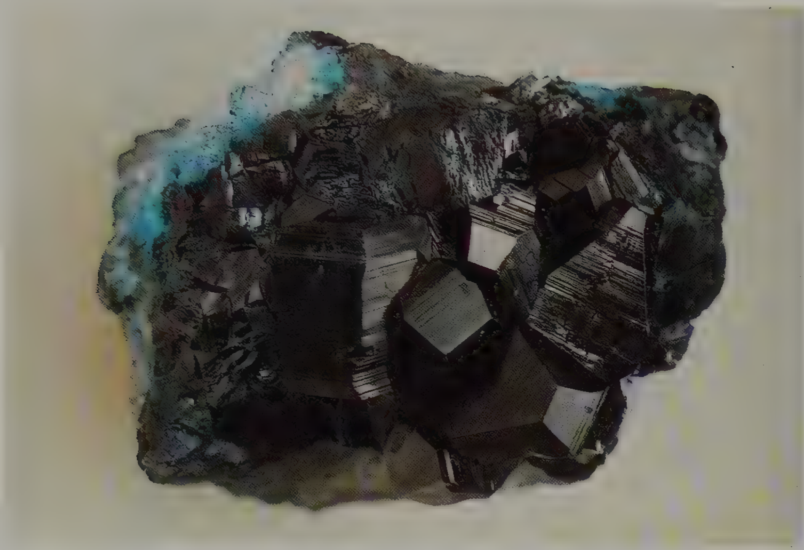
Scheelite. Cohen mine, Cochise County. Arizona Department of Mines and Mineral Resources Mineral Museum. 6.1-cm-high specimen. Jeff Scovil photo.

Shattuckite. Bisbee, Cochise County. Behnke collection. Micromount. Dan Behnke photo.

Silver. Silver King mine, Pinal County. McCarty collection. 7-cm-high specimen. Wendell E. Wilson photo.

Silver. Silver King mine, Pinal County. Presmyk collection. 7.6-cm-high specimen; 4-cm-long wires. Wendell E. Wilson photo.

Smithsonite. Tiger, Pinal County. Cureton collection. 2.7-cm-wide specimen. Wendell E. Wilson photo.



Spangolite. Bisbee, Cochise County. Harvard University. 3.6-cm-wide specimen. Wendell E. Wilson photo.

Sphalerite and galena. Iron Cap mine, Gila County. Presmyk collection. 1.2-cm-wide green crystal. Wendell E. Wilson photo.

Stolzite on quartz. Fat Jack mine, Yavapai County. Godas collection. 1-cm-wide yellow crystal. Wendell E. Wilson photo.

Stringhamite on xonotlite. Christmas, Gila County. Behnke collection. Micromount. Dan Behnke photo.

Turquoise. Various Arizona localities. 1 cm wide, largest specimen. Jeff Kurtzeman photo.

Vanadinite. Hamburg mine, La Paz County. Shannon collection. 2 mm long, largest crystal. Wendell E. Wilson photo.

Vanadinite. Western Union mine, Mohave County. Godas collection. 1.9 cm, largest crystal. Wendell E. Wilson photo.

Vanadinite after wulfenite. Rowley mine, Maricopa County. Behnke collection. Micromount. Dan Behnke photo.

Volborthite. Monument Valley, Navajo County. Behnke collection. Micromount. Dan Behnke photo.

Wulfenite. Hilltop mine, Cochise County. Arizona-Sonora Desert Museum. 7.3-cm-wide specimen. Jeff Scovil photo.

Wulfenite. Rowley mine, Maricopa County. Godas collection. 2.5 cm, largest crystal. Wendell E. Wilson photo.

Wulfenite and cerussite. Old Yuma mine, Pima County. Arizona-Sonora Desert Museum. 1.3-cm-wide orange crystal. Wendell E. Wilson photo.

4

CATALOG OF ARIZONA MINERAL OCCURRENCES

EDITORIAL NOTE

The Meanings of Heading Styles Used in Part Four

ACANTHITE—Names in capital letters indicate mineral species accepted as valid by most authorities. In this matter we have been guided by Michael Fleischer's and Joseph Mandarino's (1991) *Glossary of Mineral Species,* as well as corrections and additions to this volume made through 1993. A letter-and-number code in parentheses, e.g., (UA 1091), listed under "ACANTHITE, *Mohave County,*" specifies the museum catalog number of the specimen. (See Table 1.1 for museum codes.)

Chrysoprase (see QUARTZ); adularia (a variety of ORTHOCLASE); ripidolite (see Chlorite group)—Names in lowercase indicate that the mineral (or substance) is not a distinct species but may be a variety; an explanation typically follows in parentheses. A number of obsolete and generally discarded varietal names (e.g., ripidolite) have been included to assist the interested reader in interpreting older literature. Other examples of obsolete names are among the apatite, amphibole, chlorite, and kaolinite-serpentine groups.

Bisbeeite(?)—Names whose validity is questioned by some mineralogists, but not by all, are followed by a query in parentheses.

#BOKITE—Minerals added to the Arizona mineral list since the revised first edition of *Mineralogy of Arizona* was published in 1982 are preceded by #.

Arizona Mineral Occurrences

A

ACANTHITE

Silver sulfide, monoclinic Ag_2S. Dimorphous with the isometric argentite. Argentite, which may form in hydrothermal veins at elevated temperatures, inverts upon cooling, creating the monoclinic dimorph, acanthite. An important silver ore mineral; commonly associated with other silver minerals, as well as galena, tetrahedrite, and nickel-cobalt ores. Also formed as a secondary mineral in the zone of sulfide enrichment, with chalcocite, silver, and silver halogen minerals.

Cochise County: Bisbee, Warren district, Campbell orebody. Tombstone district, in oxidized ores formed from alteration of argentiferous tetrahedrite (Butler, B.S., et al., 1938b; Romslo and Ravitz, 1947; Graeme, 1993). Pearce district, Commonwealth mine, with chlorargyrite, bromargyrite, embolite, and iodargyrite, in quartz veins (Endlich, 1897). Chiricahua Mountains, California district, El Tigre mine, with cubanite in black-banded quartz (Tsuji, 1984).

Gila County: Richmond Basin, as the chief primary silver mineral, in masses up to several pounds in weight; Stonewall Jackson mine (Guild, 1917).

Graham County: Aravaipa district, in veins of the Grand Reef system (Ross, C.P., 1925a). Copper Creek district, Blue Bird mine (Simons, 1964).

La Paz County: Silver district, said to have been mined in important quantities in the Princess and other veins (Wilson, E.D., 1933); Padre Kino mine, massive with galena.

Mohave County: Cerbat Mountains, Mineral Park district, Keystone, Golden Star, and Queen Bee mines (Bastin, 1925). Stockton Hill district, Prince George mine and veins of the Banner group. Cerbat district, at various properties (Schrader, 1909). McConnico district, Rawhide mine, altering to chlorargyrite (UA 1091).

Pima County: Santa Rita Mountains, Helvetia-Rosemont district, Blue Jay mine (Schrader and Hill, 1915). Sierrita Mountains, Papago district. Quijotoa Mountains, Morgan mine. Reymert mine, with jalpaite, and silver in quartz and calcite veins (Wilson, K.S., 1984).

Pinal County: Pioneer district, Silver King mine, in large quantities on the upper levels (Romslo and Ravitz, 1947). Belmont property, as small blebs in galena. Dripping Spring Mountains, Saddle Mountain district, Little Treasure mine. Mammoth district, Mammoth–St. Anthony mine, as rare, minute, monoclinic crystals on leadhillite and silver. Silver Reef Mountains, Nugget Fraction mine, with cerussite (David Shannon, pers. commun., 1986). Vekol mine, as pods with chlorargyrite.

Santa Cruz County: Santa Rita Mountains, Tyndall district, Alto, Eureka, Ivanhoe, Montezuma, and Empress of India mines; Wrightson district, Augusta, Happy Jack, and Anaconda mines. Patagonia Mountains, Red Rock district, La Plata and Meadow Valley mines; Harshaw district, January, Blue Eagle, Flux, and American mines (Schrader and Hill, 1915; Schrader, 1917).

Yavapai County: Bradshaw Mountains, Hassayampa district, Dos Oris mine, with silver and chlorargyrite. Wickenburg Mountains, Monte Carlo mine, in primary ores with silver, skutterudite, and proustite (Bastin, 1922). Big Bug district, Hillside mine, with arsenopyrite, chalcopyrite, galena, sphalerite, pyrite, and tetrahedrite (Axelrod et al., 1951); Arizona National mine, in galena with freibergite and in cavities with wire silver (Lindgren, 1926).

Acmite (see AEGIRINE)

ACTINOLITE

Calcium magnesium iron silicate hydroxide, $Ca_2(Mg,Fe^{2+})_5Si_8O_{22}(OH)_2$. An iron-rich member of the amphibole group of rock-forming minerals. Forms a continuous solid-solution series with the iron-free tremolite. Formed in both thermally metamorphosed gneisses, schists, and marbles and in contact-metamorphosed rocks, particularly limestones.

Cochise County: Little Dragoon Mountains, Johnson district, in metamorphosed limestones.

Graham County: Aravaipa and Stanley districts, as gangue of contact-metamorphosed ores (Ross, C.P., 1925a). Galiuro Mountains, Ash Peak.

Greenlee County: Northern part of the Clifton-Morenci district, where Paleozoic limestones are in contact with the main intrusion, with garnet, diopside, epidote, tremolite, and other calc-silicate minerals (Moolick and Durek, 1966).

La Paz County: Harcuvar Mountains, Yuma Copper and Cabrolla properties, as a replacement of limestone beds.

Mohave County: Black Mountains, Oatman district, Big Jim vein, as thin sheets between layers of quartz.

Pima County: Sierrita Mountains, Twin Buttes district, abundant in contact rocks; Twin Buttes mine, in skarns and tactites (Stanley B. Keith, pers. commun., 1973). Helvetia–Rosemont district, in contact-metamorphosed sedimentary rocks at several mines (Creasey and Quick, 1955).

Pinal County: Globe district, Old Dominion mine, along bedding planes in Mescal Limestone.

Santa Cruz County: Patagonia Mountains, Westinghouse property.

Yavapai County: Bradshaw Mountains, Iron Queen mine, in country rock; Big Bug district, Boggs mine, as the fibrous variety, with bournonite (Lindgren, 1926).

Yuma County: Cemetery Ridge area, east of Deadman Tank, as bladed green crystals in amphibolite dikes with an asbestiform texture, developed in schist (Wilson, E.D., 1933).

ADAMITE

Zinc arsenate hydroxide, orthorhombic $Zn_2(AsO_4)(OH)$. Dimorphous with paradamite. A rare secondary mineral found in the oxidized portion of some base-metal deposits.

Coconino County: Grand Canyon National Park, Horseshoe Mesa, Grandview (Last Chance) mine, in very small amount associated with zeunerite, scorodite, and olivenite (Leicht, 1971).

Yavapai County: Mayer area (sec. 17, T. 12 N., R. 2 W.), at a small prospect, as pale-green crystalline crusts in vein quartz, associated with alloclasite.

Adularia (a variety of ORTHOCLASE)

AEGIRINE (Acmite)

Sodium iron silicate, $NaFe^{3+}Si_2O_6$. A rock-forming mineral of the pyroxene group, which is primarily produced by late crystallization of alkaline magmas.

Apache County: Monument Valley, Garnet Ridge, with diopsidic jadeite and pyrope-almandine garnet in eclogite inclusions from kimberlite pipes (Watson, K.D., and Morton, 1969).

Pima County: Northern Sierrita Mountains, Gunsight Mountain, with sphene and scapolite in a pulaskite dike (Bideaux et al., 1960).

#AENIGMATITE

Sodium iron titanium silicate, $Na_2Fe_5^{2+}TiSi_6O_{20}$. A constituent of syenites, syenitic pegmatites, certain granites, alkali-rich rocks such as phonolites, and trachytes.

Navajo County: Identified by X-ray diffraction on material from a dike; the mineral was not visible to the naked eye (Laughlin et al., 1986).

Agate (see QUARTZ)

AIKINITE

Lead copper bismuth sulfide, $PbCuBiS_3$. A rare mineral found at few localities in the world; may be associated with gold and galena.

Cochise County: Black Prince claims, as blebs and veinlets between garnet crystals in limestone. Unnamed locality, about 15 miles northeast of Tombstone (UA 3572). Warren district, 2,200-ft level of the Campbell shaft (Graeme, 1993).

Gila County: Globe-Miami district, Miami mine, in veinlets cutting chalcopyrite, with tennantite and enargite (Legge, 1939).

Pima County: Roskruge Mountains, Roadside mine, in small quantities (S 12049).

AJOITE

Potassium sodium copper aluminum silicate hydroxide hydrate, $(K,Na)Cu_7AlSi_9O_{24}(OH)_6 \cdot 3H_2O$. A rare mineral intimately associated with shattuckite in the oxidized zone of copper deposits. Ajo is the type locality.

Maricopa County: At several localities south of Wickenburg, including the Moon Anchor mine and Potter-Cramer property, associated with wickenburgite, mimetite, willemite, and phoenicochroite (Williams, S.A., 1968).

Pima County: Ajo district, New Cornelia open-pit mine, as pale aquamarine tufts and crystals filling interstices between radiating spherulitic, dark-blue crystalline shattuckite (Schaller and Vlisidis, 1958; Hutton and Vlisidis, 1960; Sun, 1961; Newberg, 1964). On material from Ajo, a chemical analysis (Chao, G.Y., 1981) that is superior to the original analysis of impure type material gave the following results (wt %):

SiO_2	41.2	Al_2O_3	3.81	CuO	42.2
MnO	0.02	FeO	0.11	CaO	0.04
Na_2O	0.84	K_2O	2.50	H_2O	8.35
				TOTAL	99.07

Specific gravity: 2.96

AKAGANEITE

Beta iron oxide hydroxide chloride, β-$Fe^{3+}O(OH,Cl)$. A rare secondary mineral thought to have formed by the alteration of pyrrhotite at the type locality, the Akagané mine, Iwate Prefecture, Japan.

Mohave County: Mineral Park district, reported as possibly present at the Ithaca Peak mine (Eidel et al., 1968).

Santa Cruz County: Small prospect north of the Santo Niño mine, as thin, warty, reddish-brown films on fractured vein quartz containing partly leached pyrite and molybdenite.

ALABANDITE

Manganese sulfide, MnS. An uncommon primary mineral found in vein deposits, commonly associated with sphalerite, galena, pyrite, rhodochrosite, rhodonite, quartz, and calcite.

Cochise County: Tombstone district, Lucky Cuss mine (Moses and Luquer, 1892; Blake, W.P., 1903; Hewett and Rove, 1930; Butler, B.S., et al., 1938b); Oregon-Prompter mine (Hewett and Fleischer, 1960). Warren district, Higgins and Copper Queen mines, in veinlets in limestone (UA 954). Chiricahua Mountains, Humboldt mine (Hewett and Rove, 1930); Hilltop mine (UA 5417).

Santa Cruz County: Northern Patagonia Mountains, Harshaw district, Trench mine, with sphalerite, galena, and rhodochrosite (Hewett and Rove, 1930). Patagonia district, World's Fair mine, with rhodonite (UA 9924).

ALAMOSITE

Lead silicate, $PbSiO_3$. A rare secondary mineral, associated with wulfenite and leadhillite at the type locality near Alamos, Sonora, Mexico.

Cochise County: Tombstone, Lucky Cuss mine, as spectacular crystal groupings with queitite and zeolites.

Mohave County: Base-metal prospect near Artillery Peak, as euhedral tabular crystals 10 to 12 mm across, in quartz druses with luddenite and leucoxene (Williams, S.A., 1982).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, on a single specimen, as white crystalline sprays and balls up to 5 mm, associated with diaboleite and willemite.

ALLANITE (Orthite)

Cerium calcium yttrium aluminum iron silicate hydroxide, $(Ce,Ca,Y)_2(Al,Fe^{3+})_3$-$Si_3O_{12}(OH)$. A member of the epidote group. Commonly formed as an accessory mineral in granites; also found in pegmatites, schists, and as a detrital mineral.

Cochise County: Tombstone district, as microscopic crystals in granodiorite (Butler, B.S., et al., 1938b).

Maricopa County: Estrella Mountains, southwest of Phoenix, in very coarse granite as phenocrysts up to 1 × 0.25 in.

Mohave County: Aquarius Mountains, Rare Metals mine and Columbite prospect, in pegmatite with gadolinite (Heinrich, 1960). McConnico district, Consolidated Spar mine, in granite pegmatite (Frondel, J.W., 1964). Cerbat Mountains, Kingman Feldspar quarry. Greenwood Mountains near Signal (Robert O'Haire, pers. commun.).

Pima County: Oracle Junction, near Willow Springs Ranch, in pegmatite with schorl (Robert O'Haire, pers. commun., 1972). Cottonwood Ranch, 11 miles southwest of San Xavier Mission, sparingly distributed in black sands over an area several miles across (Adams, J.W., and Staatz, 1969). Southeast of Covered Wells, as spectacular masses in a vein with tourmaline, actinolite, and calcite (Williams, S.A., 1960).

Yavapai County: Eureka district, 7U7 Ranch near Bagdad, in pegmatite knots, with triplite and bermanite (Hurlbut, 1936; Leavens, 1967). White Picacho district, as a rare accessory mineral in crystals up to 4 in. long (Jahns, 1952). Locality 3 miles west of Congress Junction (UA 6638). Reported near Yarnell.

#ALLOCLASITE

Cobalt iron arsenide sulfide, (Co,Fe)AsS. Formed in calcite or quartz veins of apparently low-temperature, late hydrothermal origin.

Yavapai County: Prospect in the Mayer quadrangle, in bull quartz veins, as massive to crudely crystalline, coarse-grained material; the same material contains a small amount of adamite.

ALLOPHANE

Amorphous aluminum silicate hydrate, perhaps near $Al_2SiO_5 \cdot nH_2O$. A widespread constituent of clays; amorphous to X-rays because of minute particle size or disordered structure. Allophane clays are certainly more abundant in Arizona than the few documented localities suggest.

Cochise County: Warren district, Sacramento Hill, in a hydrothermally altered granite porphyry stock with sericite, hydromuscovite, kaolinite, and alunite (Schwartz, 1947). Turquoise district, Maid of Sunshine mine, as blue glassy material with azurite.

Gila County: Globe-Miami district, Inspiration mine, as a hydrothermal alteration product in granite porphyry (Schwartz, 1947, 1956); Castle Dome mine, a product of hydrothermal alteration of quartz monzonite (Peterson, N.P., et al., 1951); Van Dyke claim (AM 30585).

Greenlee County: Copper Mountain district (Morenci), as pseudomorphs after plagioclase, with halloysite, in altered porphyry copper ore and in granite porphyry (Schwartz, 1947, 1958), especially around the periphery of the orebody (Moolick and Durek, 1966).

Mohave County: Hualapai Mountains, Antler mine, in gangue (Romslo, 1948).

Pinal County: Mammoth district, San Manuel mine, in hydrothermally altered monzonite and quartz monzonite porphyries (Lovering et al., 1950; Schwartz, 1953). Ray district, in a hydrothermally altered porphyry stock and in sericitized veins (Schwartz, 1947, 1952).

ALMANDINE

Iron aluminum silicate, $Fe_3^{2+}Al_2(SiO_4)_3$. A member of the garnet group. Typically formed in regionally metamorphosed argillaceous sediments, but also in the contact metamorphic environment and in some igneous rocks.

Coconino County: Grand Canyon, Inner Gorge, in Archean rocks; Phantom Creek, as crystals over 1 in. in diameter.

Mohave County: Southern Aquarius Mountains, as crystals up to 2.5 cm, in light-colored volcanic rock (Henderson, R., 1941; Burt et al., 1981; Moyer, 1982); the manganese content of these garnets is variable, and some are spessartine in composition. Cerbat Mountains, as pink material in migmatite (Thomas, B.E., 1953).

Pima County: Santa Catalina Mountains, front range and crestal portions of the main range, in gneiss and granite complexes and in pegmatite; the garnets contain varying amounts of the end-member components almandine, spessartine, and pyrope (Pilkington, 1961). Helvetia-Rosemont district, Peach-Elgin copper deposit, with grossular and diopside in bedded replacement deposits (Heyman, 1958).

ALTAITE

Lead telluride, PbTe. Formed in hydrothermal veins with other tellurides, tellurium, pyrite, and other sulfides.

Cochise County: Warren district, Campbell mine, in a pod of unusual pyritic ore, as cleavable patches up to 8 mm across; in calcite gangue with galena and sphalerite in an otherwise nearly massive pyrite.

ALUNITE

Potassium aluminum sulfate hydroxide, $KAl_3(SO_4)_2(OH)_6$. A common mineral formed in the wall rocks of sulfide orebodies by processes related to hydrothermal activity.

Apache and Navajo Counties: Monument Valley, with uranium-vanadium ores in channels at the base of the Shinarump Conglomerate and below channels in the Moenkopi Formation and DeChelly Member of the Cutler Formation (Mitcham and Evensen, 1955).

Cochise County: Warren district, Sacramento Hill, in the hydrothermally altered granite porphyry stock, as an alteration product of feldspar (Schwartz, 1947); Cole mine, as large masses resembling variscite.

Coconino County: Cameron area, in uranium ores as white powdery crusts and masses; near the Black Peak breccia pipe, as small prismatic crystals in sandstone (Barrington and Kerr, 1961); Black Point–Murphy mine, in close association with gypsum and secondary uranium minerals in Pleistocene gravels (Austin, 1964).

Gila County: Globe district, Old Dominion mine, as veins in diabase (Lausen, 1923). Dripping Spring Mountains, Banner district, Apex mine.

Graham County: Gila Mountains, Lone Star district, intimately associated with jarosite and turquoise in the oxidized zone of the Safford porphyry copper deposit (Robinson, R.F., and Cook, 1966).

Greenlee County: Clifton-Morenci district, Ryerson mine, as grains, irregular masses, and fibrous aggregates in altered porphyry (Lindgren, 1905; Reber, 1916); on fractures in the Candelaria breccia pipe, with turquoise and wavellite (Bennett, K.C., 1975).

La Paz County: Sugarloaf Butte, about 5 miles west of Quartzsite and 1 mile south of U.S. Highway 60, as branching, irregular veins that constitute a substantial deposit within dacite; unusual in containing up to 4.3% Na_2O (Heineman, 1935; Thoenen, 1941; Wilson, E.D., 1944; Omori and Kerr, 1963; H 108800). The composition (wt %), based on a partial analysis by F.S. Wartman, is as follows:

Al_2O_3	36.5	K_2O	4.85	Na_2O	4.3
SO_3	38.1			SiO_2	1.2

Maricopa County: Eastern Vulture district, about 3 miles west of Morristown on the west side of Hassayampa River, as a major constituent of a hydrothermally altered rhyolite in an area of about 0.5 square mile, associated with kaolinite (Sheridan and Royse, 1970).

Mohave County: Mineral Park district, Ithaca Peak mine, as nodules in a clay-turquoise-sulfide vein that traverses an igneous host rock (Field, 1966; Eidel et al., 1968).

Pima County: Silver Bell mine, Oxide pit, associated with jarosite in veins (Kerr, 1951). At Ajo, in innumerable narrow veins that cut the Concentrator Volcanics (Gilluly, 1937; Hutton and Vlisidis, 1960). Pima district, Esperanza mine, in veinlets with or without turquoise, in the oxidized capping over the predominantly chalcopyrite-chalcocite orebody (Loghry, 1972).

Pinal County: Mammoth district, San Manuel mine, abundant in hydrothermally altered monzonite and quartz monzonite porphyries with kaolinite and quartz (Schwartz, 1947, 1953, 1958, 1966). Rare in the Ray area, associated with the oxidation of sulfides (Ransome, 1919).

Santa Cruz County: Patagonia Mountains, Palmetto district, Evening Star prospect and Three-R mine, disseminated in an altered granite porphyry (Schrader, 1913, 1914, 1917; Wilson, E.D., 1944). Red Mountain copper prospect, where it is thought to be of both primary and secondary origin (Loghry, 1972). Kunde Mountain, North Saddle Mountain, and Saddle Mountain, about 2.5 miles northeast of Red Mountain, in mineralized zones (Hall, 1978).

ALUNOGEN

Aluminum sulfate hydrate, $Al_2(SO_4)_3{\cdot}18H_2O$. A water-soluble secondary mineral commonly formed by the decomposition of pyrite or under fumarolic conditions. May be associated with a variety of other secondary sulfates. Probably more widespread in the state than suggested by the single locality noted below.

Yavapai County: United Verde mine, as a by-product of the burning of pyritic ore (Lausen, 1928).

AMBLYGONITE

Lithium sodium aluminum phosphate fluoride hydroxide, $(Li,Na)Al(PO_4)(F,OH)$. Formed in lithium- and phosphate-rich granite pegmatites. Commonly associated with spodumene, lithiophilite-triphylite, lepidolite, and tourmaline.

Maricopa County: Mitchell's Wash, northeast of Morristown (UA 5623). San Domingo district, near San Domingo Wash, northeast of Wickenburg, in several pegmatite bodies, as rough crystals up to 4 or 5 ft in diameter (Jahns, 1953).

Maricopa and Yavapai Counties: White Picacho district, in pegmatites, associated with spodumene and zinnwaldite; Midnight Owl mine (Jahns, 1952; UA 2675). London (1981) and London and Burt (1982a) determined that most of the material from the mines of the White Picacho district formerly identified as amblygonite is actually montebrasite.

AMESITE

Magnesium iron aluminum silicate hydroxide, $(Mg,Fe)_4Al_4Si_2O_{10}(OH)_8$. A member of the septachlorite group, related chemically to the chlorites and structurally to the kaolinite group. Produced under conditions similar to those under which the chlorites form.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as a white powdery matrix on which wulfenite has been deposited in some places.

Amethyst (See QUARTZ)

Amphibole

A large group of rock-forming, double-chain silicates that are abundant in certain igneous and metamorphic rocks. Refer to the alphabetical listing of individual species.

ANALCIME

Sodium aluminum silicate hydrate, $NaAlSi_2O_6 \cdot H_2O$. A fairly common mineral similar in chemistry and mode of occurrence to members of the zeolite group. Found in some igneous rocks of intermediate and mafic composition; also formed as a result of hydrothermal processes.

Apache County: Near Nutrioso, associated with clinoptilolite, as cement in Tertiary sandstone (Wrucke, 1961). Hopi Buttes volcanic field, widespread in the mafic volcanic rocks (Williams, H., 1936).

Cochise County: Along the San Simon River, associated with chabazite, clinoptilolite, erionite, and herschelite in late Cenozoic tuffs (Sand and Regis, 1966; Regis and Sand, 1967). Willcox Playa, in Pleistocene mudstone, of authigenic origin (Pipkin, 1967).

Coconino County: Near Cameron, in the baked border zone of the Tuba monchiquite dike, associated with chlorite and illite (Barrington and Kerr, 1962).

Maricopa County: One mile south of Horseshoe Dam, as small, transparent, trapezohedral crystals (Shannon, D.M., 1983b).

Mohave County: Near Wikieup, where it composes the bulk of a friable green "sandstone" formerly thought to be mostly glauconite; glauconite merely coats the analcime grains (Wilson, E.D., 1944; Robert O'Haire, pers. commun., 1972). East of Big Sandy Wash, in the east half of T. 16 N., R. 13 W., in Pliocene tuff, associated with chabazite, clinoptilolite, erionite, and phillipsite (Ross, C.S., 1928, 1941). Maggie Canyon, in sec. 30, T. 12 N., R. 13 W., as cement in sandstone of the Chapin Wash Formation (Lasky and Webber, 1949).

Pima County: Santa Rita Mountains, Rosemont area, in cavities in amygdaloidal basalts.

Pinal County: Near Eloy, in sec. 25, T. 7 S., R. 8 E., in a diamond-drill hole in silty claystone (Sheppard, 1969). About 5.5 miles south of Superior in a wash east of State Highway 177, as small crystals in vugs in basalt, with chabazite, mordenite, and thomsonite (William Hunt, pers. commun., 1985).

Yavapai County: The composition (wt %) of material from the Aquarius Cliffs, based on an analysis by J.G. Fairchild (Wells, R.C., 1937), is as follows:

SiO_2	60.61	MgO	0.05	K_2O	1.02
Al_2O_3	18.03	CaO	0.04	$H_2O(-)$	0.34
Fe_2O_3	1.01	Na_2O	10.98	$H_2O(+)$	8.36
				TOTAL	100.44

ANATASE

Titanium oxide, TiO_2. Trimorphous with rutile and brookite. An uncommon secondary mineral found in veins and cavities in schists and gneisses; formed from titanium derived through leaching of country rock by hydrothermal solution.

Gila County: Reported in the Diamond Butte quadrangle, in the suite of authigenic heavy minerals in Precambrian quartzites (Gastil, 1958).

Graham County: Stanley district, Friend mine.

Pima County: Ajo district, as tiny, well-formed, pyramidal crystals present in minor amounts, associated with papagoite in altered rock (Hutton and Vlisidis, 1960).

Santa Cruz County: Patagonia Mountains, around the Santo Niño mine near Duquesne, with brookite, chalcopyrite, wulfenite, and molybdenite, all as microcrystals in interstices between adularia crystals (collected by William Hunt).

ANDALUSITE

Aluminum silicate, orthorhombic Al_2SiO_5. Trimorphous with kyanite and sillimanite. Commonly associated with kyanite or sillimanite in regionally metamorphosed rocks such as slates, schists, and gneisses; also typically found in thermally altered rocks, where it may be associated with cordierite. Rarely found in granites.

Cochise County: Cochise district, near the Texas Canyon stock, as square prismatic porphyroblasts up to 2 in. long in schist, locally as the variety chiastolite (Cooper and Silver, 1964). Dos Cabezas Mountains, Apache Pass, as metacrysts in Mesozoic metamorphosed mudstones. Chiricahua Mountains, as the variety chiastolite (UA 8166).

Gila County: Banner district, Christmas mine, in small amounts in metamorphosed siltstones of the Naco Formation, associated with muscovite, biotite, quartz, and orthoclase (Perry, D.V., 1969).

Gila and Pinal Counties: Locally abundant in the Pinal Schist near post-Cambrian granitic rocks (Ransome, 1919).

La Paz County: Near La Paz, in sec. 34, T. 4 N., R. 21 W., as small crystalline masses in granite (David Shannon, pers. commun., 1971). Granite Wash Mountains, west and south flank of Salome Peak, as thin prismatic crystals up to 3 cm (Stephen Reynolds, pers. commun., 1989). About 3 miles southeast of Quartzsite, with kyanite, sillimanite, and dumortierite, as prismatic crystals in schist (Wilson, E.D., 1929, 1933; Duke, 1960).

Maricopa County: Southwest slope of Squaw Peak in Phoenix, as a common mineral in quartz muscovite schist; appears as bright- to dark-green, blocky porphyroblasts up to 1 cm in diameter; chemical composition varies from almost pure andalusite to the manganese-rich end member, kanonaite; most of the andalusite is manganese rich (Thorpe, 1980).

Mohave County: Grand Wash Cliffs, Red Lake district, in pegmatite. Hualapai Mountains, Cedar district, 11 miles east of Yucca, in quartz veins in schist.

Pima County: Ajo district, in small quantities in the Cardigan Gneiss (Gilluly, 1937).

Pinal County: Gila River Indian Reservation, Sacaton Mountains, about 10 miles north of Casa Grande, in metamorphosed sediments encased in granodiorite, as the variety titanandalusite, associated with sillimanite, corundum, and cordierite (Bideaux et al., 1960).

Yavapai County: Bradshaw Mountains, as scattered lenses and disseminations in schist; near Middleton, on the Crown King Road, as large, pinkish crystals; also reported near Cleator. Near Granite Mountain in extensive veins. Santa Maria Mountains, near Camp Wood, as flakes and nodules in schist. At Bagdad.

ANDERSONITE

Sodium calcium uranyl carbonate hydrate, $Na_2Ca(UO_2)(CO_3)_3{\cdot}6H_2O$. A very rare, water-soluble secondary mineral, which forms as efflorescences with gypsum and other secondary oxidized minerals. The Hillside mine deposit is the type locality.

Coconino County: Cameron area (Bollin and Kerr, 1958).

Yavapai County: Eureka district, Hillside mine, with gypsum, schröckingerite, bayleyite, swartzite, johannite, and uraninite; as an efflorescence on the walls of mine workings in crusts about 1/8 in. thick on gypsum (Axelrod et al., 1951). The composition (wt %), based on a chemical analysis by F.S. Grimaldi on 3.8 mg, is as follows:

MgO	0.5	UO_3	43.4	SO_3	1.6
CaO	8.9	CO_2	19.6	(H_2O)	16.7
Na_2O	9.3			TOTAL	100.0

Specific gravity: 2.8

ANDRADITE

Calcium iron silicate, $Ca_3Fe_2^{3+}(SiO_4)_3$. A common member of the garnet group. Typically found in contact-metamorphosed deposits and skarns formed in impure limestones.

Cochise County: Dragoon Mountains, Turquoise district, common in the wall rocks of pyritic ores in the Abrigo Limestone (Perry, D.V., 1964).

Gila County: Dripping Spring Mountains, Banner district, Christmas mine, in large massive beds; 79 mine, as an abundant silicate in contact-metamorphosed limestones (Keith, 1972). Harrington's claims, near the East Verde River, intergrown with epidote, calcite, and chalcopyrite (Ross, C.P., 1925a). Sierra Ancha Mountains, near Workman Creek, as black crystals up to 2 cm, in a contact zone with diabase.

Graham County: Stanley district; at Stanley Butte, as massive material and as crystals up to 2 in. in diameter; crystals are generally brown, but some display greenish hues because of platy inclusions distributed in layers just beneath their surfaces and are almost metallic in luster (Sinkankas, 1964, 1966). Reported in the Aravaipa district.

Greenlee County: Clifton-Morenci district, in layered limestone, forming masses from 50 to 100 ft thick (Lindgren, 1905; Guild, 1910; Reber, 1916; Moolick and Durek, 1966).

Pima County: Empire Mountains, as zones of massive material at contacts between Paleozoic limestones and quartz monzonite intrusives. Helvetia-Rosemont district, King mine, in contact-metamorphosed limestones (Michel, 1959). Santa Rita Mountains, Rosemont district, as the most common silicate mineral in limestones (Schrader and Hill, 1915; Schrader, 1917). Sierrita Mountains, Twin Buttes mine, as zones up to 200 ft wide in limestone (Stanley Keith, pers. commun., 1973). Pima district, Mission mine, as the primary constituent of tactite formed in Paleozoic limestones (Kinnison, 1966).

Santa Cruz County: Patagonia Mountains, Westinghouse property, as crystals up to 2 in. in diameter, in metamorphosed limestone (Schrader and Hill, 1915; Schrader, 1917).

ANGLESITE

Lead sulfate, $PbSO_4$. Abundant in oxidized lead deposits, most commonly as masses surrounding galena and altering, in turn, to cerussite. Only a few of the many localities in Arizona are listed here.

Cochise County: Tombstone district, Tombstone Extension mine (Butler, B.S., et al., 1938b). Warren district, Shattuck mine, and 1,800-ft level of the Campbell mine, as glassy, spear-shaped crystals with leadhillite (S 114586). Turquoise district, Silver Bill mine. Huachuca Queen mine (UA 7777). Gunnison Hills, Texas Arizona mine (Cooper and Silver, 1964). Hilltop mine (William Kurtz, UA x3686)

Gila County: Globe district, Lost Gulch and Defiance mines (Wilson, E.D., et al., 1950; Peterson, N.P., 1962); Castle Dome mine (Peterson, N.P., et al., 1951); Apache mine (Wilson, E.D., et al., 1950).

Graham County: Stanley district (Ross, C.P., 1925a). Aravaipa district (Simons, 1964), Grand Reef mine, where a few well-formed, translucent crystals up to 1 in. long are associated with linarite in quartz-lined vugs (Richard L. Jones, pers. commun., 1969; Jones, R.W., 1980).

Maricopa County: In dumps of the Montezuma and Prodigal mines, west of Morristown, as nodules 1 to 3 in. in diameter. Painted Rock Mountains, and Rowley mine near Theba (Wilson, W.E., and Miller, 1974). Tonopah-Belmont mine (Robert O'Haire, pers. commun.; Allen, G.B., and Hunt, 1988).

Mohave County: Cerbat Mountains, Wallapai district, Tennessee-Schuylkill mine (Thomas, B.E., 1949). Mineral Park district, in several properties.

Pima County: Empire Mountains, at several mines of the Hilton group. Santa Rita Mountains, King mine (UA 7776). Sierrita Mountains, abundant at the Paymaster mine, Olive Camp. Quijotoa Mountains, Morgan mine (Ransome, 1922). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963).

Pinal County: Galiuro Mountains, Saddle Mountain group. Mammoth district, Mammoth–St. Anthony mine, as spear-shaped crystals up to about 0.25 in. (Fahey et al., 1950; Bideaux, 1980; H 98082). Nugget Fracture mine (David Shannon, UA x4345).

Santa Cruz County: Patagonia Mountains, Westinghouse and Mowry mines (Schrader and Hill, 1915). Santa Rita Mountains, Tyndall district, Cottonwood Canyon, Glove mine, associated with cerussite and wulfenite in oxidized lead ore (Bideaux et al., 1960; Olson, H.J., 1966). Flux mine, as clear-yellow crystals up to 1 cm long in goethite vugs.

Yavapai County: Bradshaw Mountains, Castle Creek district, Copperopolis mine (Lindgren, 1926). Eureka district, Hillside mine (Axelrod et al., 1951). Big Bug district, Iron King mine (Anderson, C.A., and Creasey, 1958). Jerome (UA 7711).

Yuma County: Castle Dome Mountains, Castle Dome district (Foshag, 1919;

Wilson, E.D., 1933); Brush (1873) chemically analyzed a compact variety of anglesite from the district.

ANHYDRITE

Calcium sulfate, $CaSO_4$. Formed in extensive sedimentary deposits with halite, gypsum, and other salts from evaporation of oceanic waters of inland seas. A common gangue mineral in some sulfide mineral deposits.

Apache and Navajo Counties: In the subsurface of the southern portions of the counties, in the Supai Salt Basin, which embraces about 2,300 square miles; with halite, dolomite, and clastic red beds (Peirce, H.W., and Gerrard, 1966; Peirce, H.W., 1969).

Gila County: Dripping Spring Mountains, Christmas mine, between the 1,000- and 1,200-ft levels, as a fairly abundant constituent of diamond-drill cores (Peterson, N.P., and Swanson, 1956); in orebodies replacing dolomite, in veinlets and interbanded with layers of magnetite (Perry, D.V., 1969).

Pima County: Ajo district, New Cornelia mine, sparingly as minute crystals of hypogene origin in the orebody (Gilluly, 1937) and as large, lilac pieces up to 1.5 in. across (Sinkankas, 1964; H 107494). Pima district, Twin Buttes mine, as a hypothermal mineral (Stanley B. Keith, pers. commun., 1973).

Pinal County: Mammoth district, San Manuel and Kalamazoo orebodies, in the inner alteration zone of mineralized monzonite and quartz monzonite porphyry, associated with quartz, sericite, and sulfides (Lowell, J.D., 1968). A drill hole sunk by the Humble Oil and Refining Co. in 1972 penetrated 80 ft of halite and about 6,000 ft of anhydrite just west of the Picacho Mountains, in sec. 5, T. 8 S., R. 8 E. The lateral extent of this enormous salt body is unknown (H. Wesley Peirce, pers. commun., 1973).

ANKERITE

Calcium iron magnesium manganese carbonate, $Ca(Fe^{2+},Mg,Mn)(CO_3)_2$. A member of the dolomite group of minerals in which there is extensive substitution among iron, magnesium, and manganese. Probably widely distributed in metamorphosed limestones and metallic veins in the state, but few localities have been noted.

Gila County: Globe-Miami district, Ramboz deposit, as a manganoan variety, with rhodochrosite (Peterson, N.P., 1962). Payson district, Silver Butte mine, with tetrahedrite (Lausen and Wilson, 1925). Along the Salt River, between Cibecue Creek and Salt River Draw, Tomato Juice and Rock Canyon deposits, as drusy coatings on walls of the central fracture (Granger and Raup, 1969). Sierra Ancha district, Sorrel Horse and Horse Shoe deposits.

Pima County: Pima district, Esperanza mine (UA 9371). Ajo district, New Cornelia orebody, in veins or as druses coated by calcite (Gilluly, 1937).

Yavapai County: United Verde mine, in pyritic ore. Bradshaw Mountains, Big Bug district, Arizona National mine; Iron King mine, where it was formed during the alteration of a massive sulfide deposit, as disseminated grains and in veinlets (Creasey, 1952). Black Canyon district, Howard Copper and Kay Copper properties. Tiger district, M and M veins. Hassayampa district, Tillie Starbuck mine, as small rhombs associated with dolomite in cavities.

Yuma County: Northern Mohawk Mountains, as thin brownish-gray veins cutting schist and gneiss (Wilson, E.D., 1933).

#ANORTHOCLASE

Sodium potassium aluminum silicate: the triclinic, sodic end member of the alkali feldspar group, $(Na,K)AlSi_3O_8$. Characteristic of certain igneous rocks. Probably common in volcanic flow rocks in the state.

Apache County: Buell Park diatreme, in lherzolite nodules, with enstatite and olivine.

Gila County: Peridot Mesa and Soda Springs, as crystals in volcanic flow rocks (Garcia et al., 1980).

ANTHONYITE

Copper hydroxide chloride hydrate, $Cu(OH,Cl)_2 \cdot 3H_2O$. A rare, water-soluble secondary species. This occurrence is one of only four known in the world.

Cochise County: Warren district, 1,300-ft level of the Cole mine, as large (5 mm or more), vividly violet, corroded crystals. These encrust crumbly pyritic ores and are associated with an unknown copper hydroxide. Chemical analysis shows this anthonyite to be virtually halogen-free in contrast to the type-locality mineral. Its presence at the Cole mine may, in some way, be related to the burning of sulfide ores in a nearby stope. After the first few specimens were found, the area was washed before a collecting trip; any remaining anthonyite was inadvertently dissolved.

ANTHOPHYLLITE

Magnesium iron silicate hydroxide, $(Mg,Fe^{2+})_7Si_8O_{22}(OH)_2$. An orthorhombic member of the amphibole group. A metamorphic mineral common in schists and gneisses; less common in contact-metamorphosed rocks.

Cochise County: Cochise district, Johnson Camp, asbestiform, in a narrow vein cutting Horquilla Limestone (Cooper and Silver, 1964).

Coconino County: Grand Canyon, in anthophyllite-bearing rocks scattered throughout the older Precambrian metamorphic rocks; e.g., in cordierite-anthophyllite schists and paragneisses at mile 229, Travertine Canyon (Clark, M.D., 1979).

Mohave County: Hualapai Mountains, Antler mine (Romslo, 1948). Kingman area, with phlogopite (UA 1193).

Pima County: Santa Rita Mountains, Blue Jay mine (UA 5233). Santa Catalina Mountains, Kielberg's Iron Mountain claim (UA 5288).

Yavapai County: Reported in the Eureka district.

ANTIGORITE (see Serpentine)

ANTLERITE

Copper sulfate hydroxide, $Cu_3(SO_4)(OH)_4$. A rare secondary mineral formed in the oxidized zone of copper deposits; easily mistaken for brochantite, which it resembles. The mineral takes its name from the Antler mine in Mohave County, which is the type locality.

Apache County: Monument Valley, Monument No. 2 mine (UA 2279).

Cochise County: Warren district, unspecified mine (probably the Copper Queen), as small crystals of excellent quality, implanted on brochantite (S 95724; Palache, 1939a); Holbrook pit, west side.

Gila County: Banner district, 79 mine, as pale-green crusts in the 31 stope area (Thomas Trebisky, pers. commun., 1975).

Graham County: Lone Star district, in small amounts in veins in metamorphosed latites and andesites (Hutton, 1959b).

Greenlee County: Morenci district, Clay orebody (UA 6259).

Mohave County: Hualapai Mountains, Antler mine, on material from which W.F. Hillebrand (1889a) originally described it as a new species (Romslo, 1948), as soft-green lumps (S 6075, part of the type material). The original analyses by W.F. Hillebrand gave the following results (wt %):

(1)

CuO	68.19	CaO	0.05	H_2O	11.11
ZnO	0.29	SO_3	20.46	TOTAL	100.10

(2)

CuO	67.64	CaO	0.04	H_2O	10.76
ZnO	0.04	SO_3	21.49	TOTAL	99.97

Specific gravity: 3.93

Yavapai County: Jerome, as highly perfect crystals up to 3 mm long on fracture surfaces in chlorite schist that contains chalcopyrite; abundant in the lower part of the oxidized zone, with cyanotrichite and brochantite.

APACHITE

Copper silicate hydrate, $Cu_9Si_{10}O_{29}\cdot 11H_2O$. A retrograde metamorphic or mesogene mineral. Christmas is the type locality.

Gila County: Banner district, as minute, blue-matted fibers or blades that resemble shattuckite; fills fractures (with calcite) and has replaced grossular and diopside in some areas; alters to gilalite; first noted by R.A. Jenkins in one fine specimen; later found in relative abundance only along an ill-defined structure that cuts tactites in the southwestern part of the open-pit mine at Christmas. The composition (wt %), based on analyses by Marjorie Duggan (Cesbron and Williams, 1980), is as follows:

CuO	43.6*	CaO	1.8	SiO_2	40.8
FeO	0.3	MnO	—	H_2O	13.8
MgO	1.7			TOTAL	102.0

*This value represents the average of two closely agreeing analyses.

APATITE

A group name, the most common members of which have this general composition: calcium phosphate fluoride hydroxide chloride, $Ca_5(PO_4)_3(F,OH,Cl)$. Members of the group are the most common of the phosphorus-bearing minerals in igneous rocks. The name *apatite* is frequently used synonymously with *fluorapatite,* the most common member of the group. The particular species has apparently seldom been determined for the apatite minerals of the state.

Apache County: Garnet Ridge, as an accessory mineral in ejection boulders of garnet gneiss, associated with zircon and muscovite (Gavasci and Kerr, 1968). Monument Valley, Monument No. 2 mine, as carbonate apatite, $Ca_{10}(PO_4)_6(CO_3)\cdot H_2O$, probably related to bone material (Witkind and Thaden, 1963).

Apache and Navajo Counties: Monument Valley, as one of the most common heavy minerals in uranium-bearing Shinarump Conglomerate, associated with barite, leucoxene, tourmaline, and zircon (Young, R.G., 1964).

Gila County: Globe-Miami district, as a common accessory mineral in igneous rocks; Castle Dome area, as veinlets of hydrothermal origin that cut the Scanlan Conglomerate and arkoses of the Pioneer Formation (Peterson, N.P., 1962). Dripping Spring Mountains, Banner district, Christmas mine, as remnant euhedral grains in metamorphosed diorite (Perry, D.V., 1969).

Graham County: Turnbull Mountain, Aravaipa district, Fisher prospect, in micropegmatite. Lone Star district near Safford, as a minor constituent in metasomatized volcanic rocks (Hutton, 1959b).

Greenlee County: Clifton-Morenci district, as a primary mineral in green mica-bearing rock, as small rods embedded in green mica, with pyrite and magnetite (Reber, 1916).

Maricopa County: Mazatzal Mountains, Four Peaks amethyst mine, as 1.5-cm tabular crystals (Lowell, J., and Rybicki, 1976).

Mohave County: Hualapai Mountains, as white fluorapatite crystals, which exhibit golden-yellow fluorescence under ultraviolet light, associated with muscovite. Aquarius Mountains, in pegmatite in a granite dike, with sphene, chevkinite, monazite, and cronstedtite (Kauffman and Jaffe, 1946).

Pima County: Ajo district, in minor amounts in altered rock (Hutton and Vlisidis, 1960). Silver Bell area, as an accessory mineral (Kerr, 1951). Twin Buttes mine (William Hefferon, UA x 740).

Pinal County: Bunker Hill district, Copper Creek, Childs-Aldwinkle mine, as a gangue mineral in a breccia pipe; one crystal on the 820-ft level was 5 in. long (Kuhn, 1941; UA 535); Old Reliable mine, with rutile (UA 9606). Mammoth district, in the potassium silicate phase of hydrothermal alteration of monzonite and quartz monzonite porphyries, and in the argillic phase of alteration (Creasey, 1959). Ajax mine (William Kurtz, UA x4401).

Santa Cruz County: Patagonia Mountains, Four Metals mine, as large crystals (UA 9298). Palmetto district, as an accessory mineral in granite porphyry (Schrader, 1913).

Yavapai County: Pine Grove district, Springfield group, as large crystals in granodiorite. Eureka district near Bagdad, as an accessory mineral in titaniferous magnetite bodies (Ball and Broderick, 1919; Schwartz, 1947; Anderson, C.A., 1950). White Picacho district, in pegmatites (Jahns, 1952). Copper Basin district, as an accessory mineral in several igneous rocks (Johnston, W.P., and Lowell, 1961). Big Bug district, Iron King mine, introduced during hydrothermal alteration of the massive sulfide deposit; as disseminated grains and needlelike crystals (Creasey, 1952).

APOPHYLLITE (a group name)

Potassium calcium silicate fluoride hydroxide hydrate, $KCa_4Si_8O_{20}(F,OH)\cdot 8H_2O$. The apophyllite minerals compose a group; insufficient chemical information precludes identifying particular species in the following localities. Minerals of the apophyllite group primarily form as secondary minerals in amygdules in basalts and are commonly associated with zeolites. They are also found in contact-metamorphosed limestones bordering intrusive rocks.

Cochise County: Tombstone district, as subhedral grains with idocrase and wollastonite in tactite (Bideaux et al., 1960).

Gila County: Banner district, Christmas open-pit mine, coating kinoite.

Maricopa County: One mile south of Horseshoe Dam, as clear tabular crystals up to 10 mm, with natrolite (Shannon, D.M., 1983b). See also hydroxyapophyllite.

Pima County: Santa Rita Mountains near Helvetia, in a drill core that penetrated skarn developed in Paleozoic limestones and dolomites; as vuggy, crystalline masses in which copper and kinoite are embedded (Anthony and Laughon, 1970).

ARAGONITE

Calcium carbonate, orthorhombic $CaCO_3$. Trimorphous with calcite and vaterite. Metastable under standard conditions, tending to revert to the stable calcite. Formed in spring deposits and from sulfate-bearing saline solutions, in beds with gypsum, in cavities in lavas, and in limestone caverns.

Cochise County: Warren district, as magnificent coralloidal groups of the variety flos ferri, in limestone caverns. Dragoon Mountains, Turquoise district, as stalactites and stalagmites lining solution cavities in silver-lead deposits.

Coconino County: Grand Canyon, as part of the travertine common along the canyon where it formed from seeps and streams. Most of the travertine is apparently calcite, but aragonite has been identified at a large travertine cone at mile 62.4 and at Christmas Tree Cave, mile 135.5.

La Paz County: Sheeps Tank mining district, as part of black-banded calcite veins (Cousins, 1972).

Mohave County: 35 miles southeast of Hackberry, in granite pegmatite, with gadolinite (Palmer, 1909).

Pima County: Santa Rita Mountains, Onyx Cave, as flos ferri; Cave of the Bells, as large, snow-white flos ferri and corallike groups. Pima district, as fine crystals from the San Xavier West mine (Arnold, 1964; UA 5782) and Mineral Hill (UA 7630, H 89687); Sierrita Mountains, copper-stained in fissures. Silver Bell Mountains, Silver Bell mine (UA 6466). Catalina Mountains, Oracle Ridge (Dewey Wilkins, pers. commun., 1989).

Yavapai County: Jerome, United Verde Extension mine (UA 7626). Castle Hot Springs, as pseudohexagonal crystals (UA 220). Northeast of Camp Verde, in basalts (E.R. Brenizer, pers. commun., 1974; UA 10185). Camp Verde salt mine, as ball-like aggregates of pseudohexagonal crystals and pseudomorphs after glauberite (Thompson, J.R., 1983).

Yuma County: Castle Dome district, in channels and vugs with smithsonite, hydrozincite, wulfenite, vanadinite, and mimetite.

#ARAVAIPAITE

Lead aluminum fluoride hydrate, $Pb_3AlF_9 \cdot H_2O$. Associated with galena and fluorite from which it is thought to have formed by interaction with supergene fluids. The Grand Reef mine is the type and, at the time of this writing, only known locality.

Graham County: Aravaipa district, Grand Reef mine, as thin, colorless crystal plates, invariably twinned, in quartz-lined vugs, associated with galena, quartz, fluorite, and anglesite, together with the rare species grandreefite, pseudograndreefite, and laurelite (Kampf et al., 1989).

Argentite (see ACANTHITE)

#ARGENTOJAROSITE

Silver iron sulfate hydroxide, $AgFe^{3+}_3(SO_4)_2(OH)_6$. Except for rarity, in most respects similar to the far more common jarosite.

Cochise County: Tombstone district, associated with other oxide-zone minerals (Williams, S.A., 1980b).

#Arizonite(?)

A mineral first described by Palmer (1909) on material collected by F.L. Hess of the U.S. Geological Survey from a pegmatite about 25 miles southeast of Hackberry in Mohave County, where it was associated with gadolinite (H 86617). Type material is represented by S 86973. Palmer decided that the material was an iron titanium oxide and ascribed to it the formula $Fe_2Ti_3O_9$. Subsequently Overholt et al. (1950) and Ernst (1943) reported that the material was a mixture of hematite, anatase, ilmenite, and rutile, and concluded that it was a weathering product of ilmenite, findings with which Bolfa et al. (1961) generally agreed.

The experimental work of Karkhanavala (1959), however, led him to state that arizonite is "a specific and unique, though rare and unstable chemical compound." Flinter (1959) also believed that the material has validity as a distinct mineral species. Arizonite was accepted as a valid species in the *Glossary of Mineral Species* (Fleischer and Mandarino, 1991) but identified as a mixture in the 1993 update (Fleischer and Mandarino, 1993), without reference to any additional work or official decision.

ARSENIC

Arsenic, As. Found in hydrothermal veins, most commonly associated with cobalt, nickel, and silver ores but also in other sulfide deposits.

Santa Cruz County: Patagonia district, Washington Camp, Double Standard mine, as reniform masses, some weighing more than 50 lb, in metamorphosed dolomitic limestone (Warren, C.H., 1903; Struthers, 1904; Guild, 1910; Schrader and Hill, 1915).

#ARSENIOSIDERITE

Calcium iron arsenate oxide hydrate, $CaFe^{3+}_3(AsO_4)_3O_2{\cdot}3H_2O$. An uncommon oxide product of arsenopyrite in carbonate-hosted ores. Typically associated with carminite and beudantite.

Yavapai County: Venus prospect, as clusters of deep-red, interlocking, platy crystals, occupying pseudomorphs after arsenopyrite. The deposit is confined to a narrow shear zone in a large xenolith of Precambrian metavolcanic rocks, which is suspended in a granitic intrusive host.

ARSENOLITE

Arsenic oxide, As_2O_3. The dimorph of claudetite. A secondary mineral formed by alteration of primary arsenides or arsenic-bearing sulfides or as a product of mine fires. A very toxic substance.

Yavapai County: United Verde mine, Jerome, as octahedral crystals on "burned ore" matrix; formed during the mine fires (UA 6708).

ARSENOPYRITE

Iron arsenic sulfide, FeAsS. The most common of the arsenic-bearing minerals. Formed under a wide variety of conditions: in high-temperature gold-quartz veins, in contact-metamorphosed sulfide deposits, and less commonly in pegmatites and low-temperature veins.

Maricopa County: White Picacho district, sparingly in pegmatites (Jahns, 1952). Unspecified locality near Tempe, as the cobaltian variety, danaite (UA 6193).

Mohave County: Cerbat Mountains, in some mines of the Chloride and Mineral Park districts, notably the Minnesota-Connor, Windy Point, and Queen Bee properties (Schrader, 1909).

Pima and Santa Cruz Counties: Santa Rita and Patagonia Mountains, Patagonia district, especially the Duquesne and Washington Camp areas, in several contact-metamorphosed deposits; Mowry mine (Schrader, 1917).

Yavapai County: Verde district, sparingly at the United Verde mine (Lausen, 1928) and Shea property. Bradshaw Mountains, as crystals in the Boggs mine. Big Bug district, Iron King mine, abundant in the massive sulfide ores of *en echelon* vein deposits, as subhedral grains up to 1.5 mm showing diamond-shaped sections (Creasey, 1952). Eureka district, near the Hillside mine, in a vein with bismuthinite (Axelrod et al., 1951). White Picacho district, sparingly in pegmatites (Jahns, 1952). Near Prescott, as the cobaltian variety, danaite (UA 6193). Old Dick mine, as the cobaltian danaite, in vein quartz with pyrite; these danaite-bearing quartz veins may cut earlier massive arsenopyrite.

#ARSENOSULVANITE

Copper arsenic vanadium sulfide, $Cu_3(As,V)S_4$. Formed in quartz veins cutting limestone and in a porphyry copper deposit.

Cochise County: Warren district, Campbell orebody, as granular, yellowish-gray masses that resemble bornite in color (Graeme, 1993).

#ARTROEITE

Lead aluminum fluoride hydroxide, $PbAlF_3(OH)_2$. Associated with galena and fluorite from which it is thought to have formed by interaction with supergene fluids. The Grand Reef mine is the type and, at the time of this writing, only known locality.

Graham County: Aravaipa district, Grand Reef mine, as crystals in a quartz-lined vug, associated with galena, quartz, fluorite, and anglesite, together with an as-yet undescribed mineral, a lead calcium aluminum fluoride hydroxide (Kampf and Ford, 1995).

Asbestos (see Serpentine)

Attapulgite (see PALYGORSKITE)

ATACAMITE

Copper chloride hydroxide, $Cu_2Cl(OH)_3$. A secondary mineral formed from the oxidation of other secondary copper minerals, especially under arid, saline conditions. Commonly associated with malachite, cuprite, chrysocolla, brochantite, gypsum, and limonite. Probably more widely represented in Arizona than indicated by the number of localities reported here.

Cochise County: Bisbee, Warren district, associated with connellite (Gene Wright, UA x1201). On the fifth level of the Southwest mine, as fine crystals up to 2 cm long (Graeme, 1993).

Gila County: Globe-Miami district, Castle Dome mine (H 108296); Inspiration mine (Olmstead and Johnson, 1966).

Maricopa County: Painted Rock Mountains, Rowley mine near Theba, in very small amounts, associated with caledonite and thought to have formed by the alteration of caledonite or linarite (Wilson, W.E., and Miller, 1974).

Pima County: Cerro Colorado Mountains, Cerro Colorado mine. South side of Saginaw Hill, about 7 miles southwest of Tucson, associated with other oxidized minerals, including brochantite, pseudomalachite, malachite, libethenite, cornetite, and chrysocolla (Khin, 1970). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963).

Pinal County: Galiuro Mountains, Copper Creek district, on the main level of the Old Reliable mine, as small green crystals, with olivenite. Mammoth district, Mammoth–St. Anthony mine, 400-ft level of the Collins vein, as deep-green, coarse, granular aggregates; San Manuel mine, as laths in chrysocolla and cornuite (a variety of chrysocolla) and along fractures (Bideaux et al., 1960; Thomas, L.A., 1966; UA 3180 and others). Lakeshore mine, 900-ft level, as an isolated occurrence in the brochantite zone (Cook, 1988a). Santa Cruz porphyry copper deposit west of Casa Grande, as the major supergene copper mineral. This may be the largest atacamite deposit in the world. The data are from drill-hole studies (Cook, 1988b).

Yavapai County: Black Hills, in small quantities at the United Verde Extension mine (Guild, 1910).

#AUGELITE

Aluminum phosphate hydroxide, $Al_2(PO_4)(OH)_3$. Found in granite pegmatites with other phosphate minerals and with silicates.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites (London, 1981).

AUGITE

Calcium sodium magnesium iron titanium aluminum silicate, $(Ca,Na)(Mg,Fe^{2+},Fe^{3+},Ti,Al)(Si,Al)_2O_6$. A common rock-forming mineral of the pyroxene group, which is present in a wide variety of mafic igneous rocks such as gabbro, diabase, and basalt. Only a few localities are mentioned.

Apache County: Monument Valley, Garnet Ridge, in a breccia dike associated with loose garnets and as fragments in sand and soil (Gavasci and Kerr, 1968).

Cochise County: Tombstone district, in diorite porphyry dikes and basaltic rocks (Butler, B.S., et al., 1938b).

Gila and Pinal Counties: Abundant in diabase sills that intrude rocks of the Apache Group over large areas in central Arizona. Dripping Spring Mountains, with olivine and iddingsite in Tertiary basalts.

La Paz County: Reported to be abundant in metamorphosed limestones; this mineral, however, may well be misidentified diopside.

Navajo County: North of Bidahochi Butte, as loose crystals in an unnamed diatreme (Bideaux et al., 1960).

Pinal County: Arnett Creek, as microcrystals in volcanic rocks.

Santa Cruz County: Patagonia Mountains, Duquesne and Washington Camp, in metamorphosed limestones (Schrader and Hill, 1915).

Yavapai County: Copper Basin district, as an accessory mineral in igneous rocks (Johnston, W.P., and Lowell, 1961). Big Bug district, Iron King mine, as phenocrysts in porphyritic basalt flows, with olivine (Creasey, 1952).

AURICHALCITE

Zinc copper carbonate hydroxide, $(Zn,Cu)_5(CO_3)_2(OH)_6$. An uncommon secondary mineral associated with other oxidized minerals in the oxidized zones of lead and copper deposits.

Cochise County: Warren district, in the upper portions of the Copper Queen orebody (Ransome, 1904; Guild, 1910), "in beautiful tubes lining cavities" (Kunz, 1885); 1,200- to 1,300-ft levels of the Cole shaft, with hemimorphite and calcite. Tombstone district, on the west side of the Quarry "roll," as plumose aggregates of pale-blue crystals (Butler, B.S., et al., 1938b). Turquoise district, as incrustations and drusy linings of cavities in oxidized lead-silver deposits; Mystery mine (UA 8942); Silver Bill mine, with hemimorphite, rosasite, and smithsonite (H. Peter Knudsen, UA x852).

Little Dragoon Mountains, Cochise district, Johnson Camp, with chrysocolla, malachite, tenorite, copper, and hemimorphite, in the oxidized portions of pyrometasomatic sulfide deposits (Cooper and Huff, 1951; Cooper and Silver, 1964).

Coconino County: Grand Canyon National Park, Horseshoe Mesa, Grandview (Last Chance) mine, on or near the Redwall Limestone, as greenish-blue, lathlike crystals that form tufted incrustations (Leicht, 1971).

Gila County: Banner district, 79 mine, among the finest specimens in the world, rivaling those from Mapimi, Mexico. The most notable occurrence is on the fourth level of the mine, where the mineral formed delicate sprays of acicular and lathlike crystals that range in color from pale sky-blue to deep sea-blue-green. The sprays typically grew on hemimorphite, smithsonite, and wulfenite and may, in turn, be covered with cerussite, calcite, plattnerite, or murdochite; formed contemporaneously with rosasite (Keith, 1972; UA 1201); a specimen described by its collector (W.E. Wilson) as perhaps the world's finest was recovered from the mine in about 1970 (see Wilson, W.E., 1987b, for illustration).

La Paz County: Plomosa Mountains, Black Mesa mine, in sec. 16, T. 3 N., R. 17 W., as well-formed small crystals with crystalline malachite in limonite gangue with small brilliant hexagonal willemite crystals (David Shannon, pers. commun., 1972).

Pima County: Empire Mountains, Lone Mountain mine, as small radiating, fibrous masses and seams with smithsonite and hemimorphite. Helvetia district, King in Exile mine, with malachite, azurite, and smithsonite (Dan Helm, pers. commun., 1978); Omega mine, with rosasite and calcite (Brian Bond, UA x2511); Chief mine, as abundant acicular clusters. Sierrita Mountains, Pima district, in fissures in garnetized limestone at the Queen mine at Twin Buttes (UA 5565) and at the San Xavier West mine (Arnold, 1964). Waterman Mountains, Silver Hill mine, with plattnerite and murdochite (Bideaux et al., 1960). South Comobabi Mountains, Cababi district, east Silver-Lead claim, as small (up to 1 mm long) crystals on quartz (Williams, S.A., 1962).

Pinal County: Vekol Mountains, Reward mine. Mammoth district, Mammoth–St. Anthony mine, as rare radiating sprays of crystals. Mineral Mountain area (Robert Mudra, UA x173).

Santa Cruz County: Patagonia district, Flux mine, as light-blue clots of thick acicular crystals on limonite, with hemimorphite (Thomas Trebisky, pers. commun., 1972).

#AURORITE

Manganese silver calcium oxide hydrate, $(Mn,Ag,Ca)Mn_3^{4+}O_7{\cdot}3H_2O$. An associate of black calcite crystals, as small black crystals or massive, with other manganese oxide minerals, including todorokite, pyrolusite, and cryptomelane.

Cochise County: Defiance mine, as small black crystals with calcite (Hidemichi Hori, pers. commun., 1985).

Greenlee County: Morenci, southern part of the open-pit mine, as small black crystals on goethite in the oxidized zone (Hidemichi Hori, pers. commun., 1982; UA 12297). Ash Peak mine near Duncan, as massive material.

La Paz County: Sheep Tanks mining district, as one of several manganese minerals in black calcite veins (Cousins, 1972).

Yuma County: Kofa district, King of Arizona mine, with todorokite, groutite, chalcophanite, and pyrolusite (Hankins, 1984).

AUSTINITE

Calcium zinc arsenate hydroxide, $CaZn(AsO_4)(OH)$. A rare secondary mineral found in the oxidized zones of some base-metal deposits.

Pinal County: Galiuro Mountains, Table Mountain mine, as intergrowths with conichalcite (Bideaux et al., 1960).

AUTUNITE

Calcium uranyl phosphate hydrate, $Ca(UO_2)_2(PO_4)_2 \cdot 10\text{-}12H_2O$ (water content variable between about 10 and 12 molecules). The most common of the secondary uranium minerals. Widely distributed; commonly formed in the oxidized zones of hydrothermal mineral deposits.

Apache County: Monument Valley, Monument No. 2 mine, associated with a wide variety of oxidized uranium and vanadium minerals (Witkind and Thaden, 1963).

Gila County: Red Bluff prospect, with uranophane and uraninite (R. Robinson, pers. commun., 1954).

Maricopa County: Lucky Find group, in a mafic dike cutting Precambrian granite (Robinson, R.L., 1956).

Mohave County: Chapel district, Chapel prospect, with uranophane and torbernite (Wenrich and Sutphin, 1989).

Navajo County: Monument Valley, Monument No. 1 and Mitten No. 2 mines (Witkind, 1961; Witkind and Thaden, 1963).

Santa Cruz County: Near Alamo Spring, with uranophane in a vein with lead ore. Santa Rita Mountains, Duranium claims, in arkosic sandstone with kasolite and uranophane (Robinson, R.L., 1954).

Axinite (a group name; see also MANGANAXINITE and TINZENITE)

Calcium manganese magnesium iron aluminum borosilicate hydroxide, $(Ca,Mn,Mg,Fe^{2+})_3Al_2BSi_4O_{15}(OH)$. Typically formed in contact metamorphic aureoles where intrusive rocks have invaded sediments, especially limestones; commonly associated with other calcium silicate minerals.

AZURITE

Copper carbonate hydroxide, $Cu_3(CO_3)_2(OH)_2$. A widely distributed secondary mineral in the oxidized zones of copper deposits; commonly associated with malachite (to which it alters), cuprite, copper, and limonite. Widespread but typically sparse in the copper deposits of the state.

Cochise County: Warren district, as magnificent crystallized specimens of extraordinary size (up to 4.5 in.) at the Copper Queen mine, one of the world's premier localities (Kunz, 1885; Douglas, 1899; Ransome, 1903b, 1904; Bideaux, 1973; UA 79, 177, 736, 1153, etc.). Excellent crystallized specimens were noted from the deeper workings of the mine "implanted as a secondary growth in parallel position upon well-formed pseudomorphs of malachite after azurite of longer dimensions (length parallel to *b* axis, 7 cm)" (Palache and Lewis, 1927); some crystals exhibit a blue exterior but have green cores (Schwartz and Park, 1932); Junction mine (Mitchell, 1920). Tombstone district, Lucky Cuss and Toughnut mines (Butler, B.S., et al., 1938b). Turquoise district, Maid of Sunshine mine, as large crystallized masses. Little Dragoon Mountains, Cochise district, Johnson Camp area (Kellogg, 1906).

Coconino County: Kaibab Plateau, as extensive impregnations in chert beds; Apex copper property (Tainter, 1947a). Grand Canyon National Park, Horseshoe Mesa, Grand View (Last Chance) mine, as short prismatic crystals on clay and in vugs in sandstone; some crystals of azurite altering to malachite are up to 1 × 3 cm (Leicht, 1971). Cameron area, with malachite, anhydrite, and pyrite in mineralized silica plugs (Barrington and Kerr, 1963).

Gila County: Globe-Miami district, as a common secondary mineral in many deposits (Woodbridge, 1906; Schwartz, 1921, 1934); Bluebird mine, as radiating crystal aggregates up to 15 cm; Castle Dome mine (Peterson, N.P., 1947); Copper Cities deposit, associated with malachite and turquoise (Peterson, N.P., 1954); Sleeping Beauty mine (UA 9707). Summit district, Blue Ball mine, as nodular concretions of considerable size (Sinkankas, 1964), commonly with a central cavity containing malachite crystals (Grant, 1989). Banner district, 79 mine (Kiersch, 1949; Keith, 1972). Payson district, as crystallized masses at the Silver Butte, Golden Wonder, and Bishops Knoll mines.

Greenlee County: Clifton-Morenci district, where thousands of specimens of azurite and malachite have been recovered from the Morenci open pit, including some azurite stalactites up to 15 cm long; as large bodies in the Longfellow, Detroit, Manganese Blue, and Shannon mines; sheaflike and spherical masses up to 40 lb were found in kaolinized shale (Kunz, 1885; Farrington, 1891; Lindgren, 1903, 1904, 1905; Reber, 1916; Schwartz, 1934; Bideaux, 1973).

Maricopa and Gila Counties: Mazatzal Mountains, at Pine Mountain, near Mount Ord and Saddle Mountain, on Alder and Slate Creeks, associated with malachite and chalcopyrite in mercury deposits in a schist belt (Lausen, 1926).

Mohave County: Cerbat Mountains, Wallapai district, as a sparse but widely distributed mineral, associated with sulfide vein deposits and disseminations (Thomas, B.E., 1949). Bentley district, Grand Gulch, Bronze L, and Copper King mines (Hill, 1914b).

Pima County: Santa Rita Mountains, widely distributed at mining properties throughout the range, primarily those in the Old Baldy district (Schrader, 1917); Copper Mountain prospect of the Anaconda group, as fine crystalline specimens (Schrader and Hill, 1915); Helvetia, as massive material and crystals and as pseudomorphs of malachite after azurite, up to about 0.5 in., with rosasite (Peter Megaw, UA x2918). Sierrita Mountains, common in the Pima district; Banner mine, as fine rosettes (UA 6759). Santa Catalina Mountains, Cañada del Oro (UA 4126). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Ajo district, as granular aggregates that have concentric structures, with malachite and quartz, and as pseudocubic crystals (Schwartz, 1934). Waterman Mountains, Silver Hill mine (UA 1646); Indiana-Arizona mine, as crystalline material with cerussite in goethite; with rosasite. Silver Bell Mountains, Silver Bell mine, with cuprite and malachite in orebodies in limestone (Engineering Mining Journal, 1904).

Pinal County: Pioneer district, in the open cut of the Silver King mine, as small but beautifully crystallized groups. Galiuro Mountains, Copper Creek district, Childs-Aldwinkle mine (Kuhn, 1941). Mineral Creek district, northeast of Ray Hill and near the Ray deposit, as crystals up to 3 mm long, one of several oxidized minerals, including malachite, cuprite, tenorite, jarosite, and goethite, in Holocene gravels, locally replacing a fossil log (Phillips et al., 1971). Mammoth district, San Manuel mine, in small amounts in the oxidized portion of the orebody, with chrysocolla, malachite, and cuprite (Schwartz, 1949); Mammoth–St. Anthony mine, as deep-blue crystals up to 2 in. long, associated with reticulated cerussite, and as pseudomorphs of malachite after azurite (Bideaux, 1980; UA 9239, 8549).

Santa Cruz County: Patagonia district, Duquesne and Washington Camp (Schrader, 1917). Tyndall district (Schrader, 1917).

Yavapai County: Black Hills, Black Hills district, Yeager mine, as fine-quality specimens (Anderson, C.A., and Creasey, 1958). Copper Basin district, in the oxidized zones of several sulfide ore deposits (Johnston, W.P., and Lowell, 1961); in T. 13 N., R. 3 W., secs. 20 and 21, as botryoidal specimens (David Shannon, pers. commun., 1971). Jerome, United Verde Extension mine, as crystals lining vugs and as small, radiating, spherical aggregates irregularly distributed with malachite in limonitic clay in the replacement orebody (Schwartz, 1938).

Yuma County: Muggins district, Red Knob claims, associated with weeksite, opal, vanadinite, carnotite, gypsum, and calcite (Outerbridge et al., 1960). Gila Mountains, Blue Butte vein (Wilson, E.D., 1933).

B

BARITE

Barium sulfate, $BaSO_4$. A widespread, relatively common mineral that forms under low- to moderate-temperature conditions in hydrothermal veins; also in sedimentary rocks as replacements, veins, and cavity fillings formed by hypogene or meteoric solutions. L.A. Stewart and Pfister (1960) have summarized barite deposits in the state.

Apache and Navajo Counties: Monument Valley, with the uranium-vanadium ores in Shinarump Conglomerate–filled channels at the base of the Chinle Formation (Mitcham and Evensen, 1955; Young, R.G., 1964).

Cochise County: Tombstone district, Ground Hog mine as a vein, and near the Lucky Cuss mine as white crystals (Butler, B.S., et al., 1938b; Stewart, L.A., and Pfister, 1960). Western slope of the Dragoon Mountains, Johnnie Boy No. 1 claim, as veins and replacements in limestone (Stewart, L.A., and Pfister, 1960). Warren district, in places associated with manganese ores (Palache and Shannon, 1920; Taber and Schaller, 1930). Hopeful claim, north of the Mule Mountains, in NW¼ sec. 4, T. 22 S., R. 23 E., as strong veins of nearly pure barite that cut Cretaceous sedimentary rocks (Tenney, 1936; Funnell and Wolfe, 1964). Foothills of the northern Mule Mountains, north side of Gadwell Canyon, Ramirez group of claims, in veins of nearly pure barite up to 3 ft wide that cut Cretaceous sedimentary rocks (Stewart, L.A., and Pfister, 1960).

Coconino County: Grand Canyon National Park, Horseshoe Mesa, Grandview (Last Chance) mine, in a fault zone in Redwall Limestone, associated with aurichalcite (Leicht, 1971); Orphan mine (UA 7098).

Gila County: Richmond Basin, abundant in veins. Castle Dome mine, in small amounts with fluorite (Peterson, N.P., et al., 1946, 1951). Reported near Coolidge Dam, in a vein about 500 ft long, associated with galena. South of Payson, "barite occurs sporadically in more or less parallel fractures for about 15 miles along an east-west zone in granitic rocks" in the Top Hat, Gilmore Spring, and Lone Pine claims (Stewart, L.A., and Pfister, 1960).

Graham County: Stanley district, near Stanley Butte, abundant in veins (Ross, C.P., 1925a). Southeast of Klondyke, Marcotte group of claims, in veins (Stewart, L.A., and Pfister, 1960). About 5 miles east of Turnbull Mountain, Barium King group of claims, in sec. 19, T. 4 S., R. 20 E., and sec. 24, T. 4 S., R. 19 E. (Funnell and Wolfe, 1964).

Greenlee County: Ash Peak district, Luckie mine, associated with fluorite and psilomelane in a vein in andesite porphyry (Hewett, 1964).

La Paz County: Planet mine, as golden-yellow crystals up to 2 cm long on malachite and chrysocolla, and as white sheaves up to 2.5 cm long. Trigo Mountains, Mendevil claims, in veins; Padre Kino mine (Peter Megaw, UA x2966). East slope of the Plomosa Mountains, Bouse district, at several deposits, in veins that form an arc around veins of manganese oxides, in layered volcanic host rock (Stewart, L.A., and Pfister, 1960; Hewett, 1964). Red Chief prospect near Bouse, with fluorite (UA 2716). Cottonwood Pass near Salome (Wilson, E.D., 1944).

Maricopa County: Goldfield Mountains, 14 miles north of Mesa, in secs. 4 and 5, T. 2 N., R. 7 E., as veins at the Granite Reef (Arizona Barite) mine (Wilson, E.D., 1944; Stewart, L.A., and Pfister, 1960; UA 5955). Painted Rock Mountains, Rowley mine near Theba, as colorless crystals up to 2 cm long and 2 to 4 mm thick, commonly lining cavities in massive barite (Wilson, W.E., and Miller, 1974). Aguila district, Valley View mine, as layers of crystals with fluorite that alternate with black calcite in a hypogene vein cutting an andesite flow (Hewett, 1964). Horseshoe Dam area (Arthur Roe, pers. commun., 1989).

Mohave County: Reported in the Aquarius Mountains, as veins. Cerbat Mountains, Wallapai district (UA 4925). Near Alamo Crossing, as veins. Artillery Mountains, with fluorite in veins with manganese oxides that cut the Artillery Formation. Rawhide Mountains, Barbee vein, in sec. 1, T. 11 N., R. 14 W., associated with chalcedony and mammillary layers of psilomelane(?) in basalt (Hewett and Fleischer, 1960). McCracken Mountains, McCracken mine, about 8 miles west of Signal, in large quantities in veins with quartz, carbonates, and galena (Bancroft, H., 1911; Funnell and Wolfe, 1964). About 30 miles east of Kingman, Rucker group of claims, in sec. 2, T. 20 N., R. 12 W., as sporadic pods, segregations, and stringers, and as veins up to 8 ft wide, in granitic rocks (Stewart, L.A., and Pfister, 1960).

Navajo County: Monument Valley, Starlight No. 3 mine, as druses of minute brown crystals on fracture surfaces in sandstone (AEC mineral collection).

Pima County: Ajo district, sparingly in veins cutting Concentrator Volcanics and quartz monzonite (Gilluly, 1937). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Picacho de Calera Hills. One-half mile east of Colossal Cave, Heavy Boy mine, as cleavable white masses (Stewart, L.A., and Pfister, 1960). Silver Bell Mountains, House Canyon, as large, bladed crystals (Kerr, 1951); Silver Bell mine, coating fractures. Santa Rita Mountains, as an abundant gangue mineral in some sulfide deposits (Schrader and Hill, 1915; Schrader, 1917). Quijotoa Mountains, Quijotoa district, White Prince claims (Stewart, L.A., and Pfister, 1960), Morgan mine (UA 7036), and Quijotoa mine, in sec. 33, T. 15 S., R. 2 E. (Stewart, L.A., and Pfister, 1960; Funnell and Wolfe, 1964), as bladed crystals that form the matrix for galena crystals; Welden mine, as large, pink rosettes of crystals up to 15 cm (Shannon, D.M., 1981; MM N 474). Northwest ridge of the Santa Catalina Mountains, as large, quartz-encrusted, bladed crystals (UA 9601); Santa Catalina Mountain foothills, north of Campbell Avenue, Tucson. Coyote Mountains (UA 1145).

Pinal County: Superior district, Magma mine, as brilliant, tabular (up to 2 × 0.5 in.) crystals in a variety of colors: black, brown, maroon, gray, white, yellow, and golden (Barnes and Hay, 1983; UA 2015). Mammoth district, west side of Tucson Wash, in a vein with calcite and some psilomelane (Schwartz, 1953); Mammoth–St. Anthony mine, as groups of large, tabular crystals (Peterson, N.P., 1938b). Galiuro Mountains, Copper Creek district, Old Reliable mine, as tabular crystals and crystal groups. Gonzales Pass deposit, in secs. 16 and 17, T. 2 S., R. 11 E., in a vein following a fault in Pinal Schist (Stewart, L.A., and Pfister, 1960).

Santa Cruz County: Santa Rita and Patagonia Mountains, notably in the Tyndall, Old Baldy, and Patagonia districts, as one of the principal gangue minerals in base- and precious-metal deposits, commonly associated with quartz, fluorite, rhodochrosite, and other carbonates (Schrader, 1917).

Yavapai County: Bradshaw Mountains, as a gangue mineral in several properties; French Creek deposit, in sec. 29, T. 9 N., R. 1 W. (Stewart, L.A., and Pfister, 1960). Eureka district, Bagdad mine (Anderson, C.A., 1950). Bullard district, Hatton mine (Hewett and Fleischer, 1960; Hewett, 1964). Monte Cristo mine near Wickenburg, with silver, chalcopyrite, and nickel arsenides (Bastin, 1922); MGM claims, a few miles northeast of Wickenburg, as filling and replacement in a brecciated zone in volcanic breccia and granite (Stewart, L.A., and Pfister, 1960).

Yuma County: Castle Dome Mountains, Castle Dome mines, in many veins and as large, clear crystals with wulfenite and fluorite (Foshag, 1919). Mohawk Mountains, Barite mine, as white to pink, radiating crystal aggregates in calcite veins.

#BARRINGERITE

Iron nickel phosphide, $(Fe,Ni)_2P$. In meteorites.

Coconino County: Meteorites found in Canyon Diablo, near Meteor Crater, contain small seams and pods of barringerite partly altered to schreibersite, followed in sequence by wüstite and lawrencite (material provided by David Shannon).

BASALUMINITE

Aluminum sulfate hydroxide hydrate, $Al_4(SO_4)(OH)_{10}\cdot H_2O$. A rare secondary mineral associated with other sulfates.

Cochise County: Warren district, Holbrook mine, as white, earthy masses with hydrobasaluminite and other aluminum sulfates encrusting silicified limestones, and as microcrystals (Richard Thomssen, UA x4504).

BASSANITE

Calcium sulfate hydrate, $2CaSO_4{\cdot}H_2O$. An uncommon mineral formed as pseudomorphs after gypsum in cavities in volcanic rocks and as a result of fumarolic activity. Also an alteration product in porphyry copper deposits.

La Paz County: Several small prospects near Bouse, in veins in andesite with chrysocolla and tenorite.

Pima County: Sierrita Mountains, Sierrita open-pit mine, as tiny, subhedral, fibrous crystals in veinlets filled with quartz, calcite, and chlorite in hydrothermally altered diorite and quartz diorite porphyry (Roger Lainé, pers. commun., 1972).

BASSETITE

Iron uranyl phosphate hydrate, $Fe(UO_2)_2(PO_4)_2{\cdot}H_2O$. A secondary mineral commonly associated with uraninite.

Gila County: Northwestern part of the county, common in the uranium deposits in Dripping Spring Quartzite; Sue mine, associated with saleeite and locally with metanovacekite (Granger and Raup, 1969). Sierra Ancha Mountains, Red Bluff mine (Granger and Raup, 1962).

BAYLDONITE

Lead copper arsenate hydroxide, $PbCu_3(AsO_4)_2(OH)_2$. A rare oxide-zone mineral found only in a few localities.

Cochise County: Bisbee, Warren district (AM 21,475); Southwest mine, sixth level, as spongy, resinous, greenish-yellow linings of small voids in a quartz breccia (Graeme, 1993).

Pima County: Santa Rita Mountains, Frijole prospect, in sec. 24, T. 18 S., R. 15 E.; common in coarse, milky vein quartz; derived from sulfosalts; associated with bindheimite, cerussite, wulfenite, and mimetite.

BAYLEYITE

Magnesium uranyl carbonate hydrate, $Mg_2(UO_2)(CO_3)_3{\cdot}18H_2O$. A rare, water-soluble, secondary mineral associated with other secondary uranium minerals and gypsum as an efflorescence in a tunnel at the Hillside mine at Bagdad, which is the type locality.

Cochise County: Warren district, Cole mine (Richard Graeme, pers. commun., 1973; UA 10078).

Yavapai County: Hillside mine, as a 1/8-in.-thick efflorescence on the walls, associated with schröckingerite, andersonite, swartzite, gypsum, johannite, and uraninite; locally present as well-formed crystals (Axelrod et al., 1951). Chemical analyses by F.S. Grimaldi gave these results (wt %):

(1)

MgO	9.03	UO_3	30.80	Acid Insol. Ignited	2.27
CaO	3.42	CO_2	14.60		
Na_2O	—	SO_3	4.43		
K_2O	—	H_2O	35.19	TOTAL	99.74

(2)

MgO	8.97	UO_3	32.42	Acid Insol. Ignited	0.45
CaO	2.75	CO_2	15.36		
Na_2O	0.19	SO_3	3.95		
K_2O	0.09	H_2O	36.60	TOTAL	100.78

Specific gravity: 2.05

BEAVERITE

Lead copper iron aluminum sulfate hydroxide, $Pb(Cu,Fe,Al)_3(SO_4)_2(OH)_6$. An uncommon secondary mineral formed in the oxidized portion of lead-copper deposits in arid regions. Commonly associated with plumbojarosite.

Cochise County: Tombstone district, Empire and Toughnut mines, in small quantities with cerussite (Butler, B.S., et al., 1938b). Warren district, Southwest mine, sixth level (Graeme, 1993).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, rarely as shining golden-yellow scales around the bases of linarite crystals (Bideaux, 1980).

BECQUERELITE

Calcium uranium oxide hydrate, $CaU_6O_{19} \cdot 11H_2O$. A secondary mineral typically closely associated with uraninite, from which it is commonly derived; associated with other secondary uranium minerals such as schoepite, fourmarierite, and curite.

Apache County: Monument Valley, Monument No. 2 and Cato Sells mines, where it is an important ore mineral; associated with uraninite (Frondel, C., 1956; Finnell, 1957; Witkind and Thaden, 1963).

BEIDELLITE

Sodium calcium aluminum silicate hydroxide hydrate, $(Na,Ca_{0.5})_{0.33}Al_2(Al,Si)_4$-$O_{10}(OH)_2 \cdot nH_2O$. Some authorities (e.g., Grim, 1968) question the propriety of the name *beidellite* because the purity of the original material used to describe the species is uncertain. Fleischer and Mandarino (1991), however, retained the name. Beidellite is a member of the montmorillonite (smectite) group of clay minerals. It is a component of bentonitic clays and is common in hydrothermally altered areas associated with mineral deposits.

Coconino County: Along the base of the Echo Cliffs, north of Cameron, as a clay mineral in the Chinle Formation.

Gila County: Globe-Miami district, Castle Dome mine, in veinlets and fine aggregates, and as scattered flakes in the altered quartz monzonite (Peterson, N.P., et al., 1946, 1951).

Greenlee County: Morenci district, in less altered zones near intense hydrothermal alteration of porphyry copper ores, associated with kaolinite, montmorillonite, and allophane (Schwartz, 1947, 1958).

Pima County: Ajo district, New Cornelia mine, commonly formed as pseudomorphic replacement of plagioclase phenocrysts in the outlying parts of the mineralized area (Gilluly, 1937).

Pinal County: Mammoth district, San Manuel mine, as a minor constituent of hydrothermally altered quartz monzonite and monzonite porphyries, associated with kaolinite, hydromuscovite, leucoxene (titanian products of the alteration of ilmenite), and rutile in a quartz-sericite-pyrite-chalcopyrite aggregate (Schwartz, 1947).

BEMENTITE

Manganese silicate hydroxide, $Mn_8Si_6O_{15}(OH)_{10}$. An uncommon mineral formed in contact-metamorphosed manganiferous limestones.

Pinal County: Mineral Creek district, Ray mine, near the Emperor tunnel, as minute, clear, platy crystals with hematite in oxidized capping in the Granite Mountain porphyry (Loghry, 1972).

BERLINITE

Aluminum phosphate, $AlPO_4$. A very rare mineral, first identified at the Westanå iron mine, Kristianstad, Sweden, where it is associated with other phosphate minerals.

Gila County: Globe-Miami district, Inspiration mine, as a single, light-brown, hollow pod less than 2 mm in size, completely enclosed by hematite in oxidized and leached capping (Loghry, 1972).

BERMANITE

Manganese phosphate hydroxide hydrate, $Mn^{2+}Mn_2^{3+}(PO_4)_2(OH)_2 \cdot 4H_2O$. A rare mineral formed in granite pegmatites. The 7U7 Ranch is the type locality.

Yavapai County: 7U7 Ranch near Bagdad, in narrow veins cutting a spherical mass of triplite, which formed as a segregation in pegmatite lenses in granite; as single crystals and subparallel aggregates with fan-shaped or rosettelike appearance

(Hurlbut, 1936); associated with phosphosiderite, leucophosphite, hureaulite, and other phosphate minerals (Leavens, 1967; Hurlbut and Aristarian, 1968). Analysis (by Jun Ito) of bermanite from the type locality (Hurlbut and Aristarian, 1968) gave the following results (wt %):

Al_2O_3	0.19	MnO	12.8	Na_2O	—
Fe_2O_3	3.2	MgO	1.05	H_2O	20.2
Mn_2O_3	30.6	CaO	0.75	P_2O_5	31.4
				TOTAL	100.19

BERTRANDITE

Beryllium silicate hydroxide, $Be_4Si_2O_7(OH)_2$. Formed in granite pegmatites, typically as an alteration product of beryl.

Maricopa County: White Picacho district, Independence claim.

BERYL

Beryllium aluminum silicate, $Be_3Al_2Si_6O_{18}$. An important ore mineral of beryllium, typically embedded in granites and pegmatites as a magmatic mineral; also associated with tin ores and mica schists.

Cochise County: Swisshelm Mountains, east of Elfrida, as euhedral crystals in vugs with fluorite and as beryl-muscovite masses in veins (Diery, 1964; Staatz et al., 1965). Dragoon Mountains, Boericke tungsten property, as small, colorless crystals with fluorite; Gordon and Abril mines, in garnet tactite (Balla, 1962; Shawe, 1966); Beryl Hill claims; Tungsten Blue Bird mines, in scheelite-bearing quartz veins; Texas Canyon stock near Dragoon; Little Lulu and Silver Drip claims, the latter as aquamarine in aplite dikes in granite; Thompson Beryl claims (Meeves, 1966).

Graham County: Goodwin Wash (Shawe, 1966).

Maricopa County: Near Aguila (UA 6664).

Mohave County: Aquarius Mountains, Rare Metals mine and Columbite prospect, as crystals in pegmatite (Heinrich, 1960). Beryl Wash near Kingman, as greenish-blue crystals up to 12 × 4 in. Groom Peak, G and M pegmatite, 15 miles southwest of Wikieup, as bluish-green crystals up to 9 ft long and 18 in. in diameter. Boriana mine (Hobbs, 1944). About 15 miles south of Peach Springs, 4 miles east-southeast of Wright Creek Ranch, in several irregular pegmatite dikes in schist and gneissic granite, with microcline, albite, quartz, fluorite, schorl, sphene, and muscovite; locally, as well-formed prismatic crystals (Schaller et al., 1962). This beryl is quite unusual in its chemical composition and has been assigned the formula $(Na,Cs)Be_3Al(Fe^{2+},Mg)Si_6O_{18}$. Its composition (wt %), based on the average of several analyses, is as follows:

SiO_2	59.52	FeO	2.24	K_2O	0.16
BeO	12.49	MnO	0.29	Cs_2O	6.68
Al_2O_3	10.63	MgO	2.16	CaO	0.11
Fe_2O_3	2.08	TiO_2	0.05	BaO	—
Cr_2O_3	0.09	Li_2O	0.23	H_2O	1.62
Sc_2O_3	0.10	Na_2O	1.16	P_2O_5	0.27
				TOTAL	99.88

At the time, this was the lowest silica content recorded for beryl.

Cerbat Mountains, in pegmatite (UA 6309). Chloride district, with gadolinite in pegmatite (Thomas, B.E., 1953). Virgin Mountains, Hummingbird claims, where it locally constitutes up to 3% of quartz-muscovite pegmatite; in crystals up to 15 in. long (Olson, J.C., and Heinrichs, 1960). Hualapai Mountains, Kingman district (Meeves et al., 1966).

Pima County: Sierrita Mountains, Bella Donna claim, near the Frielinger feldspar property, as massive material and beautiful blue-green crystals, in quartz veins in granite; pegmatites have contained gem-quality aquamarine crystals affording stones up to 40 carats. Baboquivari Mountains (Shawe, 1966). Agua Verde, in a vein in granite (Staatz et al., 1965). Santa Catalina Mountains, Apache Peak, in quartz veins (Robert O'Haire, pers. commun., 1972).

Yavapai County: Eureka district, Black Pearl mine, in veins that traverse biotite granite (Brownell, 1959; Dale, 1961; Staatz et al., 1965), and as blue crystals with pyrite and bismuthinite (MM 1062). Near Bagdad. Bradshaw Mountains, 4 miles southeast of Wagoner, in pegmatite veins; Peck mining district, 3 miles east of the Crown King post office, in a pegmatite dike. White Picacho district, as crystals up to 11 in. long in pegmatites; associated with lithium minerals (Jahns, 1952; Meeves et al., 1966). Lawler Peak area, in tabular masses of quartz. Weaver Mountains, 7 miles northwest of Yarnell, Monte Cristo pegmatite, as green crystals up to 2 ft long and 14 in. in diameter, associated with albite, muscovite, and quartz; also as honey-brown euhedral and anhedral crystals, and aquamarine crystals up to 6 in. long (Mohon, 1975).

Yuma County: Gila Mountains, Fortuna district, about 1.5 miles east of the Fortuna mine, as small, lavender- and rose-colored crystals in a matrix of yellowish quartz, associated with small masses of an unidentified black mineral containing niobium.

BEUDANTITE

Lead iron arsenate sulfate hydroxide, $PbFe_3(AsO_4)(SO_4)(OH)_6$. A rare secondary mineral formed in the oxidized portions of mineralized veins.

Cochise County: Warren district, abundant in the Southwest mine (Graeme, 1993).

Gila County: In the northeast workings of the Kullman-McCool (Finch, Barking Spider) mine, as brown, earthy, massive material associated with descloizite (Hidemichi Hori, pers. commun., 1984).

Maricopa County: Vulture district, Moon Anchor mine, from a trench on the north side of the hill, with mimetite (William Hunt, pers. commun., 1985).

Pima County: Silver Hill mine (UA 10474).

Yavapai County: Pine Grove district, Crown King mine, as greenish crusts in vein matter, with jarosite and iron oxides.

BEYERITE

Calcium lead bismuth carbonate oxide, $(Ca,Pb)Bi_2(CO_3)_2O_2$. A secondary mineral formed by the alteration of bismutite or other primary bismuth minerals, typically in pegmatites.

Maricopa and Yavapai Counties: White Picacho district, as grayish green films on bismutite and bismuth(?) and as dense masses and pearly-white flakes in small cavities (Jahns, 1952).

#BIANCHITE

Zinc iron sulfate hydrate, $(Zn,Fe)(SO_4)\cdot 6H_2O$. Associated with other soluble secondary sulfates as an efflorescence in mine openings.

Cochise County: Bisbee, Warren district (Graeme, 1981).

Graham County: Pinaleño Mountains, at a prospect on the east end of Willow Spring Canyon, as white, earthy to botryoidal films on sphalerite; the sphalerite is associated with galena in a quartz vein along a strongly chloritized fault zone.

BIDEAUXITE

Lead silver chloride fluoride hydroxide, $Pb_2AgCl_3(F,OH)_2$. An extremely rare secondary mineral originally discovered at the Mammoth–St. Anthony mine in the oxide zone with other secondary lead minerals. It has since been found in Chile.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as colorless crystals, 2 to 7 mm in maximum dimension, that enveloped and replaced boleite in the oxide zone of the Collins vein(?); associated with cerussite and galena, from which it was ultimately derived, and with leadhillite, matlockite, and anglesite. The type specimen is S 114583 (Williams, S.A., 1970a). Chemical analysis gave the following results (wt %):

Pb	62.66	Cl	14.74	OH	(2.78)
Ag	15.74	F	3.26	TOTAL	99.18

Specific gravity: 6.274 ± 0.008

BIEBERITE

Cobalt sulfate hydrate, $CoSO_4 \cdot 7H_2O$. A moderately soluble, uncommon mineral formed through oxidation of cobalt-bearing sulfide and arsenide ores.

Coconino County: Cameron area, in most of the mines in the Petrified Forest Member of the Chinle Formation, as pink to rose efflorescences (Austin, 1964). Huskon No. 1 mine, where the powdery mineral stains cross-vein, fibrous gypsum or halotrichite (H, unnumbered specimen).

Pima County: Ajo district, as a pink efflorescence in a ditch draining the approach to the New Cornelia open-pit mine (Gilluly, 1937).

#BILINITE

Ferrous ferric iron sulfate hydrate, $Fe^{2+}Fe^{3+}(SO_4)_4 \cdot 22H_2O$. An uncommon secondary sulfate mineral of the halotrichite group, formed from the oxidation of iron sulfides.

Cochise County: Bisbee, Warren district, Higgins mine, 100-ft level, where massive pyritic ore was encrusted and corroded by thick layers of finely fibrous, white to tan bilinite (Graeme, 1993); no other sulfates were identified in the specimens.

BINDHEIMITE

Lead antimony oxide hydroxide, $Pb_2Sb_2O_6(O,OH)$. An uncommon secondary mineral generally in small quantities in oxidized antimonial lead ores; commonly replaces tetrahedrite.

Cochise County: Tombstone district, as yellowish-gray spots in siliceous ores (Butler, B.S., et al., 1938b). Johnny Lyon Hills, in a prospect on the bank of Tres Alamos Wash, as a chalky, green mixture pseudomorphous after tetrahedrite, associated with partzite, lewisite, and stibiconite.

Pima County: Santa Rita Mountains, Frijole prospect. Tucson Mountains, Snyder Hill mine, with cerussite. Silver Hill mine, as microcrystals (Bruce Maier, UA x3058)

Santa Cruz County: Patagonia Mountains, Mowry mine, in small amounts (Schrader and Hill, 1915; Schrader, 1917).

BIOTITE

Potassium magnesium iron aluminum silicate hydroxide fluoride, $K(Mg,Fe)_3(Al,Fe)Si_3O_{10}(OH,F)_2$. An important and abundant rock-forming mineral; the most common of the mica minerals. Formed under a wide variety of conditions and found in rocks of nearly all types. Also a product of hydrothermal alteration in mineral deposits. Widespread throughout the state.

BIRNESSITE

Sodium calcium manganese oxide hydrate, $(Na,Ca)_4Mn_{14}O_{27}\cdot 9H_2O$. An uncommon mineral apparently of secondary origin formed by the breakdown of primary manganese minerals. May be associated with other manganese oxide minerals, rhodonite, and rhodochrosite.

Cochise County: Turquoise district, several prospects immediately north of Courtland, as a constituent of black, scummy crusts on altered quartz monzonite; todorokite is the other major component of these crusts.

Bisbeeite(?)

Copper silicate hydrate, $CuSiO_3\cdot H_2O$(?). A rare, poorly defined, secondary mineral. Defined by Schaller (1915) from the Shattuck mine at Bisbee, the species has been reviewed by Laurent and Pierrot (1962), who studied type material and compared it with African occurrences at Kambove, Katanga, Zaire, and Renéville, Congo Republic. Their studies confirmed that bisbeeite was a distinct species identical to material from the African localities, to which they assigned the formula $(Cu,Mg)SiO_3\cdot nH_2O$. After studying material from the Azurite mine (see *Pinal County,* below) and reviewing the literature, Oosterwyck-Gastuche (1967), however, concluded that the validity of bisbeeite was doubtful.

Cochise County: Warren district, Shattuck mine, as pseudomorphs after shattuckite, which is, in turn, pseudomorphous after malachite (Schaller, 1915; H 87653 includes part of the type material). Chemical analyses by W.T. Schaller (Wells, R.C., 1937) gave the following results (wt %):

(1)

SiO_2	36.71	CaO	0.48	$H_2O(+)$	8.32
Fe_2O_3	1.31	$H_2O(-)$	4.37	CuO	49.45
				TOTAL	100.64

(2)

SiO_2	36.93	CaO	0.39	$H_2O(+)$	7.46
Fe_2O_3	—	$H_2O(-)$	8.56	CuO	46.66
				TOTAL	100.00

Specific gravity: (1) 3.05; (2) 2.88

Greenlee County: Morenci-Metcalf district, in fractures in the Candelaria breccia pipe, with conichalcite, wavellite, turquoise, and alunite (Bennett, K.C., 1975).

Pima County: Ajo district, in veins at the New Cornelia mine.

Pinal County: Tortolita Mountains, Azurite mine, associated with plancheite, shattuckite, malachite, and chrysocolla in quartz (Bideaux et al., 1960; UA 6342).

Santa Cruz County: Patagonia district, Hardshell mine. High-quality specimens have been carefully studied as possible candidates for bisbeeite. These are blue, fibrous, hydrous copper silicates that have one good cleavage, which follows the length of the crystals. The crystals are orthorhombic: a = 19.06Å, b = 20.10, and c = 8.86. The strongest powder diffraction lines are 10.06(4)(020), 6.916(5)(220), 4.857(5)(140), 3.937(4)(340,150), and 3.299(5)(160). These data are very close to those for plancheite, but powder films of the two minerals—held side by side—are clearly dissimilar. The composition (wt %) of the Hardshell material, based on analysis by Marjorie Duggan, is as follows:

SiO_2	43.64	CuO	47.19	ZnO	1.00
$H_2O(+)$	5.0	$H_2O(-)$	3.6	TOTAL	100.43

Although it is beyond the scope of this work to pursue the study further, we believe that the Morenci or Hardshell material may provide the basis for resurrecting bisbeeite as a species.

BISMITE

Bismuth oxide, Bi_2O_3. A secondary mineral formed by the oxidation of other bismuth minerals. The validity of the species at some of the localities listed below may be questionable.

Cochise County: Warren district, Campbell orebody, with argentian wittichenite and bismuth, in a compact, silicified hematite matrix (Graeme, 1993).

La Paz County: Reported at a locality north of Vicksburg.

Maricopa and Yavapai Counties: White Picacho district, as massive material in pegmatites (UA 8970).

Yavapai County: Bradshaw Mountains, Castle Creek district, Swallow mine, as an alteration product of bismuthinite (Lindgren, 1926). Eureka district, Bagdad mine. Bumblebee area (UA 6113).

BISMUTH

Bismuth, Bi. An uncommon primary mineral formed in hydrothermal veins, pegmatites, and topaz-bearing quartz veins.

Cochise County: Warren district, Campbell orebody, with wittichenite, bismite, and sphalerite in a matrix of silicified hematite (Graeme, 1993).

Maricopa County: Vulture district, Cleopatra mine. At a locality southeast of Granite Reef Dam.

Mohave County: Aquarius Mountains, 30 miles south of Hackberry, with gadolinite in pegmatite.

Pima County: Sierrita Mountains, Esmeralda mine (UA 7163).

Yavapai County: Bradshaw Mountains, in the Humbug Creek placers and on Minnehaha Flats. Reported in Buckhorn Wash, east of Brooks Hill. White Picacho district, as a rare constituent of pegmatites, as thin flakes and irregular masses, one of which weighed 2.5 lb (Jahns, 1952).

BISMUTHINITE

Bismuth sulfide, Bi_2S_3. A comparatively rare mineral formed under moderately high temperature conditions in hydrothermal veins and in tactites, typically with chalcopyrite.

Cochise County: Unspecified locality, as bladed crystals up to 1 in. long in chalcopyrite, with pyrophyllite (S 269). Warren district, Campbell orebody (Graeme, 1993).

La Paz County: Three Musketeers mine, with bismutite, kettnerite, and wulfenite.

Mohave County: Aquarius Mountains, in small quantities with bismuth and gadolinite in pegmatite.

Yavapai County: Bradshaw Mountains, Castle Creek district, Swallow mine, altering to bismite (Lindgren, 1926). Eureka district, 45 miles west of Prescott, in pegmatite (Dale, 1961); Black Pearl mine, in quartz veins with wolframite (Schmitz, 1987); also with pyrite and beryl (MM 1062). White Picacho district, Midnight Owl mine, in pegmatite (Jahns, 1952).

BISMUTITE

Bismuth carbonate oxide, $Bi_2(CO_3)O_2$. A secondary mineral formed by the alteration of bismuthinite, bismuth, or other bismuth minerals.

Cochise County: Warren district, Campbell mine, as pseudomorphs after aikinite prisms (Graeme, 1993). Dos Cabezas Mountains, Comstock mine, abundant in gossans, as unusually well crystallized material forming pearly-white to pale-tan, paper-thin tetragonal platelets that line voids in the rock left by the leaching of pekoite; the mineral superficially resembles sericite in hand specimen; associated with rare duhamelite.

Graham County: Prospect northwest of Bowie, with kettnerite, malachite, and duhamelite.

La Paz County: Three Musketeers mine, as earthy masses in quartz, with kettnerite.

Maricopa County: White Picacho district, Outpost pegmatite (Jahns, 1952).

Mohave County: Aquarius Mountains, Rare Metals mine, as large masses with rusty-brown chalcedony (Heinrich, 1960). Hualapai Mountains, east of Yucca.

Yavapai County: Eureka district, 7U7 Ranch, in prospects at "the granites," as large (3-in.) pseudomorphs with bismuthinite (Frondel, C., 1943; H 100738). White Picacho district, as an uncommon constituent of pegmatites (Jahns, 1952).

BIXBYITE

Manganese iron oxide, $(Mn,Fe)_2O_3$. Commonly formed in cavities in rhyolite with garnet, topaz, beryl, and hematite; also in metamorphosed manganese ores, as at Långban, Sweden.

Cochise County: Warren district, Shattuck shaft (Graeme, 1981).

Pinal County: Near Saddle Mountain, Winkelman area, encrusting and replacing spessartine (UA 8967, 8968); also as loose crystals in stream beds (White, 1992).

Yuma County: Kofa district, King of Arizona mine, in the North Star vein with psilomelane and in the No. 2 vein with psilomelane, todorokite, groutite, and manganite (Hankins, 1984).

#BLÖDITE

Sodium magnesium sulfate hydrate, $Na_2Mg(SO_4)_2.4H_2O$. Fairly widespread in sedimentary sulfate deposits, both lacustrine and oceanic, as large crystals and saline crusts.

Coconino County: Paria River at Lee's Ferry.

#BOGDANOVITE

Gold tellurium lead iron cupride, $(Au,Te,Pb)_3(Cu,Fe)$. A rare mineral which, at the type locality, formed in the supergene zone of oxidation with gold and various tellurides and tellurites.

Cochise County: Warren district, Campbell mine, as tiny, bronze-colored grains with pyrite, chalcopyrite, and quartz (Graeme, 1993).

#BÖHMITE

Aluminum oxide hydroxide, AlO(OH). A major component of bauxites, together with other aluminum oxide minerals, formed under conditions of severe weathering; also found in certain pegmatites.

Cochise County: Bisbee, Warren district (Graeme, 1981).

Yavapai County: Hillside mine, with montmorillonite and vivianite.

#BOKITE

Aluminum iron vanadium oxide hydrate, $(Al,Fe^{3+})_7(V^{5+},V^{4+},Fe^{3+})_{40}O_{100}\cdot 37H_2O$. A rare mineral formed as veinlets and crusts in carbonaceous shales at its type locality, Balasauskandyk area, Kara-Tau, Kazakhstan.

Apache County: Monument No. 2 mine, where it was identified by H.T. Evans, Jr. in Triassic fossilized wood (Haynes, 1991).

BOLEITE

Lead copper silver chloride hydroxide hydrate, $Pb_9Cu_8Ag_3Cl_{21}(OH)_{16} \cdot H_2O$. A rare secondary mineral formed in small amounts in oxidized lead-copper deposits.

Gila County: Globe-Miami district, Apache mine, with cerussite, brochantite, and matlockite (Bideaux et al., 1960).

Maricopa County: Painted Rock Mountains, Rowley mine near Theba, as minute spheres (0.01 to 0.03 mm in diameter) on cerussite; also associated with linarite, leadhillite, atacamite, diaboleite, and other oxidized-zone minerals (Wilson, W.E., and Miller, 1974).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, Collins vein, as dark-blue cubes typically on diaboleite; in a leadhillite vug in a small block faulted from the Mammoth vein, associated with cerussite, phosgenite, paralaurionite, quartz, hydrocerussite, diaboleite, matlockite, wherryite, and chrysocolla (Palache, 1941b; Fahey et al., 1950; Bideaux, 1980). Vekol mine, as small crystals with chlorargyrite (David Shannon, pers. commun., 1980).

BOLTWOODITE

Potassium uranyl silicate hydroxide hydrate, $K_2(UO_2)_2(SiO_3)_2(OH)_2 \cdot 5H_2O$. A moderately common secondary mineral formed by oxidation of black primary uranium ores.

Coconino County: Cameron area, as one of the more common uranium minerals; Huskon Nos. 17 and 20 mines, as yellow areas in a blackish sandstone (Daphne Ross, cited in Honea, 1961); Ramco Nos. 20 and 22, Jack Daniels No. 1, and Yazzie No. 102 mines (Austin, 1964).

BORNITE

Copper iron sulfide, Cu_5FeS_4. An important ore mineral of copper in many mines in the state. Commonly intimately associated with either chalcocite or chalcopyrite, typically with both. Principally of primary origin, but small amounts of secondary bornite are common in secondarily enriched ores; also in contact-metamorphosed deposits.

Apache and Navajo Counties: Monument Valley, with chalcopyrite, chalcocite, and copper in sandstone, associated with uranium-vanadium ores at several properties (Evensen and Gray, 1958).

Cochise County: Warren district, Campbell mine and other orebodies, as one of the important ore minerals in hydrothermal deposits in limestone (Trischka et al., 1929; Schwartz and Park, 1932; Schwartz, 1939; Yagoda, 1945; Bain, 1952; Bryant, 1968); 1,300- to 1,400-ft levels of the Cole shaft, as 0.25-in. crystals. (For detailed structural information on Bisbee minerals in the bornite-digenite series, see Pierce, L., and Buseck [1978].) Little Dragoon Mountains, Cochise district (Romslo, 1949), Johnson Camp, Black Prince–Peabody mines area (Kellogg, 1906; Cooper and Huff, 1951; Cooper, 1957; Baker, A., 1960; Cooper and Silver, 1964). Turquoise district, Leadville, Great Western, Copper Belle, and Tejon mines. Whetstone Mountains, in small quantities in quartz veins. Huachuca Mountains (UA 1080).

Coconino County: Reported at several localities in orebodies, with chalcocite and cuprite.

Gila County: Globe-Miami district, Old Dominion mine, common as a primary ore mineral; also of secondary origin, forming a distinct blanket beneath the chalcocite zone (Schwartz, 1947, 1958; Peterson, N.P., 1962). Banner district, Christmas mine, as a common ore mineral (Peterson, N.P., and Swanson, 1956; Knoerr and Eigo, 1963; Perry, D.V., 1969).

Graham County: Gila Mountains, Lone Star district, with pyrite and chalcopyrite but much less abundant than the latter; Safford porphyry copper deposit, in veins and disseminations (Robinson, R.F., and Cook, 1966).

La Paz County: Buckskin Mountains, Planet mine. Harquahala Mountains, with chalcopyrite (UA 9344).

Mohave County: Chloride district, Atlanta and Pinkham mines (Schrader, 1909). Grand Wash Cliffs, Bronze L mine.

Pima County: Ajo district, concentrated around pegmatite bodies in the New Cornelia Quartz Monzonite (Joralemon, 1914; Gilluly, 1937, 1942a,b; Schwartz, 1947, 1958). Tucson Mountains, Arizona Tucson property, disseminated in a porphyry. Pima district, as a minor constituent of primary sulfide mineralization at the Twin Buttes mine (Stanley B. Keith, pers. commun., 1973), and as a minor constituent at the Pima mine (Himes, 1972). Silver Bell Mountains, Silver Bell district, in oxidized ores (Engineering Mining Journal, 1904; Kerr, 1951). Santa Catalina Mountains (Dale et al., 1960), Stratton-Daily Camp, in contact ores. Near Helvetia and Rosemont, in drill core with djurleite and chalcopyrite; also associated with later kinoite and apophyllite in skarn formed in Paleozoic limestone and dolomite (Anthony and Laughon, 1970). Comobabi Mountains, Cababi district, with silver and chalcocite (UA 1079).

Pinal County: Pioneer district, as exceedingly rich ore found to the deepest levels of the Magma mine (Ransome, 1914; Harcourt, 1937, 1942; Short et al., 1943; Brett and Yund, 1964; Morimoto and Gyobu, 1971). An analysis by E.T. Allen (1916) of bornite from the Magma mine gave the following results (wt %):

Cu	62.99	S	25.58	Pb	0.10
Fe	11.23	Ag	0.00	TOTAL	99.90

For detailed structural information on Magma-mine minerals in the bornite-digenite series, see Pierce, L., and Buseck 1978.

Galiuro Mountains, Copper Creek district, Childs-Aldwinkle mine (Kuhn, 1941; Denton, 1947a). Dripping Spring Mountains, Saddle Mountain district, Adjust mine. Mammoth district, San Manuel mine, sparingly present in sulfide ores (Chapman, 1947; Schwartz, 1947, 1953; Lovering, 1948; Lowell, J.D., 1968). Globe-Miami district, Silver King mine (Guild, 1917).

Santa Cruz County: Santa Rita and Patagonia Mountains, at several mining properties (Schrader and Hill, 1915; Schrader, 1917; Marshall and Joensuu, 1961).

Yavapai County: Bradshaw Mountains, common in copper-bearing veins, typically carries free gold. Black Hills, Yeager mine, as a shoot of high-grade ore (Lindgren, 1926; Anderson, C.A., and Creasey, 1958). Eureka district, United Verde mine, present in small amounts with chalcopyrite, tennantite, and pyrite as both a primary and a secondary mineral (Lausen, 1928; Schwartz, 1938).

#BOTALLACKITE

Copper chloride hydroxide, $Cu_2Cl(OH)_3$. A rare secondary mineral associated with other copper chlorides; formerly found only at the type locality in Cornwall, England, and in the Michigan copper district.

Cochise County: Bisbee, Warren district, as very sparse (only two specimens are known), pale-blue, tabular crystals, associated with paratacamite and atacamite.

BOTRYOGEN

Magnesium iron sulfate hydroxide hydrate, $MgFe(SO_4)_2(OH)\cdot7H_2O$. Typically formed in arid climates as a result of oxidation of pyritic ores.

Cochise County: Warren district, 2,200-ft level of the Campbell mine, as porous botryoidal crusts of orange crystals associated with copiapite (Fabien Cesbron, pers. commun., 1975).

#BOULANGERITE

Lead antimony sulfide, $Pb_5Sb_4S_{11}$. Formed at low to moderate temperatures in hydrothermal veins.

Yuma County: Kofa Mountains, King of Arizona district, North Star mine, in veinlets with pyrite, rhodochrosite, epidote, and fluorite (Hankins, 1984).

BOURNONITE

Lead copper antimony sulfide, $PbCuSbS_3$. One of the most common sulfosalts, formed in hydrothermal veins at moderate temperatures and commonly associated with galena, tetrahedrite, sphalerite, chalcopyrite, and other sulfides and sulfosalts.

Cochise County: Tombstone district, sparingly, with other copper-antimony minerals (Butler, B.S., et al., 1938b).

Pima County: Santa Rita Mountains, Helvetia-Rosemont district, Busterville mine.

Santa Cruz County: Wrightson district, Hosey and Augusta mines, with tetrahedrite.

Yavapai County: Bradshaw Mountains, Big Bug district, Boggs mine, as masses in quartz and as crystals with pyrite, chalcopyrite, siderite, and actinolite (Blake, W.P., 1890; Guild, 1910; Lindgren, 1926; W.P. Blake's identification of this mineral probably constituted its first recognition in the United States.)

BRACKEBUSCHITE

Lead manganese iron zinc vanadate hydrate, $Pb_2(Mn,Fe,Zn)(VO_4)_2{\cdot}H_2O$. A rare mineral formed as a product of oxidation in hydrothermal lead-zinc veins.

Cochise County: East side of the Swisshelm Mountains, in sec. 29, T. 20 S., R. 28 E., Swisshelm district, at a tiny gold prospect in a quartz vein with coarse, oxidized pyrite crystals and traces of cerussite. Distinctive henna-brown crystals up to 1 mm form spongy aggregates in voids left by oxidation and leaching of galena.

Santa Cruz County: Palmetto mine, as microcrystals with wulfenite (Carl Richardson, UA x3381).

BRANNERITE

Uranium calcium cerium titanium iron oxide, $(U,Ca,Ce)(Ti,Fe)_2O_6$. A rare mineral found in placer gravels, granitic rocks, and quartz veins.

Cochise County: Swisshelm Mountains, with powellite in granite (AEC mineral collection).

BRAUNITE

Manganese silicate, $Mn^{2+}Mn^{3+}_6SiO_{12}$. Formed in veins and lenses as a product of the metamorphism of other manganese minerals, and with pyrolusite, psilomelane, and wad as a secondary mineral formed by weathering.

Cochise County: Warren district, Higgins mine, as radiating masses and compact needles (Palache and Shannon, 1920; Hewett and Rove, 1930; Taber and Schaller, 1930; Hewett and Fleischer, 1960); White Tail Deer mine, as coarse (up to 1 in. long) cleavable crystals in irregular replacement pods in limestone around the mine shaft. Gleeson district, Maid of Sunshine mine, as microcrystals (Peter Megaw, UA x2919).

Gila County: Globe-Miami district, present in supergene oxides, probably derived from alabandite (Hewett and Fleischer, 1960).

Graham County: Grand Reef mine, as microcrystals (Kenneth Bladh, UA x527).

Maricopa County: Southwestern slope of Squaw Peak, Phoenix, as microscopic, euhedral rectangular crystals in manganese-rich andalusite (Thorpe, 1980).

Mohave County: Rawhide Mountains, Artillery Peak deposit, associated with a variety of manganese oxide minerals (Head, 1941).

Pima County: Arivaca district, COD mine, forming a matrix cut by veinlets of hausmannite (Hewett, 1972). Tucson Mountains, north end of the Juan Santa Cruz picnic grounds, in some of the piemontite in sandstone (Guild, 1935). Coyote and Baboquivari Mountains, with psilomelane and pyrolusite in fractures in andesite (Havens et al., 1954). Waterman Mountains, Silver Hill mine, as microcrystals (William Kurtz, UA x410).

Santa Cruz County: Patagonia Mountains, Patagonia district, in supergene oxides that may have been derived from alabandite (Hewett and Fleischer, 1960). Harshaw district (Havens et al., 1954).

#BRAUNITE I I

Calcium manganese iron silicate, $Ca(Mn,Fe)^{3+}_{14}SiO_{24}$. Originally found in manganese ores of the Kalahari manganese province, Republic of South Africa, which principally consist of braunite, bixbyite, cryptomelane, hematite, and pyrolusite (De Villiers, P.R., and Herbstein, 1967; De Villiers, J.P.R., 1980).

Cochise County: Warren district, on the surface near the White Tail Deer mine, abundant as cores of braunite crystals up to 1 in. (Graeme, 1993); a small amount of neltnerite is also present, suggesting that the three minerals are independent and stable phases.

#BRAZILIANITE

Sodium aluminum phosphate hydroxide, $NaAl_3(PO_4)_2(OH)_4$. A hydrothermal mineral formed in cavities in pegmatites, typically with other phosphates.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites (London, 1981).

BREZINAITE

Chromium sulfide, Cr_3S_4. A very rare mineral described from the Tucson Ring iron meteorite.

Pima County: In the Irwin-Ainsa (Tucson) iron meteorite, presumably found near Tucson, as tiny (5-80 microns) anhedral grains in the metal matrix and contiguous to silicate inclusions. A chemical analysis (Bunch, J.E., and Fuchs, 1969) gave the following results (wt %):

Cu	48.3	Ti	0.96	Ni	0.08
Fe	3.9	Mn	0.86	S	45.0
V	1.61			TOTAL	100.71

BROCHANTITE

Copper sulfate hydroxide, $Cu_4SO_4(OH)_6$. A fairly common secondary mineral formed in oxidized copper deposits especially in arid regions. Associated with a variety of common oxidized copper minerals, including malachite, with which it may be confused upon cursory examination.

Cochise County: Warren district, widely distributed as an intergrowth with malachite; Shattuck mine, as magnificent, coarse, crystalline masses; with cuprite at the Copper Queen and the Calumet and Arizona mines (Ransome, 1904; Holden, 1922; Palache, 1939b; Omori and Kerr, 1963). Tombstone district, Toughnut mine, as needlelike crystals lining vugs in cuprite with connellite and malachite (Butler, B.S., et al., 1938b). Gleeson district, Maid of Sunshine mine, as sharp acicular crystals.

Coconino County: Grand Canyon National Park, Horseshoe Mesa, Grandview (Last Chance) mine, associated with cyanotrichite and other sulfate minerals, as radiating groups of acicular crystals and as shorter prismatic crystals (Leicht, 1971).

Gila County: Banner district, 79 mine, where it is intimately associated with oxidizing sulfide minerals (Kiersch, 1949; Keith, 1972). Apache mine near Globe, with cerussite, matlockite, and boleite (Bideaux et al., 1960).

Graham County: Lone Star district, Gila Mountains near Safford, in metasomatized latites and andesites with pseudomalachite, malachite, antlerite, carbonate-apatite, chrysocolla, jarosite, and lepidocrocite (Hutton, 1959b); Safford porphyry copper deposit, as an important constituent of oxide mineralization, although less so than chrysocolla (Robinson, R.F., and Cook, 1966).

Greenlee County: Clifton-Morenci district, abundant as an intergrowth with malachite, less common as crystals (Lindgren and Hillebrand, 1904; Lindgren, 1904, 1905; Guild, 1910; Moolick and Durek, 1966).

La Paz County: Harcuvar Mountains, Bullard district, Bullard mine, with djurleite (Roddy, 1986). Buckskin Mountains, Mineral Hill property. Thule Mountains, Venegas prospect, associated with gypsum (Wilson, E.D., 1933). Apache mine near Salome (UA 7826).

Mohave County: Grand Wash Cliffs, Bentley district, Grand Gulch mine (Hill, 1914b). Bill Williams Fork, as minute crystals associated with cuprite and chrysocolla (Genth, 1868).

Pima County: Pima district, Mission mine, as well-formed crystals (William E. Rhodes, pers. commun.); San Xavier West mine at Twin Buttes (Arnold, 1964); with chrysocolla and cuprite at the Twin Buttes open-pit mine (UA 9608) and the Banner mine (UA 9354). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). New Cornelia orebody at Ajo, uncommon as crusts in the weathered zone (Gilluly, 1937). Waterman Mountains, Silver Hill mine (UA 6799). On the south side of Saginaw Hill, about 7 miles southwest of Tucson, associated with other oxidized-zone minerals, including malachite, pseudomalachite, libethenite, atacamite, and chrysocolla (Khin, 1970). Silver Bell district, El Tiro pit, as microcrystals (Kenneth Bladh, UA x287).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, where it is relatively abundant and typically associated with other sulfate-bearing minerals such as linarite, caledonite, and leadhillite (UA 6114). Galiuro Mountains, Copper Creek district. Sacaton mine (ASARCO), in drill core (Robert O'Haire, pers. commun., 1972); subsequently shown to be common in the oxide zone. Lake shore mine, as the principal copper mineral in the highest grade supergene copper zone (Cook, 1988a). Silver Reef Mountains, Nugget Fraction mine, as large masses with chalcocite.

Yavapai County: Black Hills, United Verde mine, in the lower part of the oxidized zone, in chlorite schist that contains chalcopyrite, with antlerite and cyanotrichite (Phelps Dodge Corp., pers. commun., 1972).

#BROCKITE

Calcium thorium cerium phosphate hydrate, $(Ca,Th,Ce)(PO_4)\cdot H_2O$. Formed in veins and altered granitic rocks as earthy coatings and aggregates, presumably under oxidizing conditions.

Mohave County: Rawhide Mountains, as white, fine-grained, opaque masses in veins with hematite and geothite (Staatz, 1985).

BROMARGYRITE (formerly Bromyrite)

Silver bromide, AgBr. A complete solid-solution series extends from bromargyrite to chlorargyrite (AgCl). Formed in the oxidized zones of silver deposits from primary silver minerals.

Cochise County: Tombstone district, Empire mine, fourth level of the Skip shaft, as individual gray-green crystals and irregular scales throughout limonitic gangue (Butler, B.S., et al., 1938b; UA 7517). The composition (wt %) of sample H 97646, based on an analysis by R. Carrillo, is as follows:

Cl	0.6	I	2.6	Ag	56.7
Br	38.9			TOTAL	98.8

Pearce district, Commonwealth mine, with chlorargyrite, embolite, iodargyrite, and acanthite in quartz veins (Endlich, 1897). Warren district, 200-ft level of the Shattuck mine, as greenish-yellow crusts and ill-formed crystals replacing silver; Shattuck shaft (Graeme, 1993).

Coconino County: Prospect Canyon district, Ridenaur mine, with vesignieite, naumannite, tyuyamunite, metatyuyamunite, and calciovolborthite (Wenrich and Sutphin, 1989).

Gila County: Unspecified locality near Globe, as the iodine-rich variety iodobromite (Blake, W.P., 1905). Hechman mine, in thin seams and crusts in a quartz vein.

Graham County: Grand Reef mine, as bright-yellow, botryoidal masses with cerussite (George Godas, pers. commun., 1987).

Greenlee County: Clifton, Stargo mine, as microcrystals (Gene Wright, UA x1502).

Bronzite (ferroan ENSTATITE)

Meteoriticists retain "bronzite" in meteorite classification schemes.

BROOKITE

Titanium oxide, TiO_2. Trimorphous with rutile and anatase. An accessory mineral in igneous and metamorphic rocks; also in hydrothermal veins and as a detrital mineral.

Gila County: Reported in concentrates derived from the Globe area, with biotite, quartz, and ilmenite.

Santa Cruz County: Patagonia Mountains, near the Santo Niño mine near Duquesne, with anatase, chalcopyrite, wulfenite, and molybdenite, all as microcrystals in interstices between adularia crystals (collected by William Hunt).

BRUCITE

Magnesium hydroxide, $Mg(OH)_2$. Forms as an alteration product of periclase in contact-metamorphosed limestones and dolomites; also a low-temperature hydrothermal vein mineral.

Cochise County: Bisbee, Warren district, Czar shaft (Graeme, 1981).

Mohave County: Oatman district, 3 miles northwest of Oatman, in veins with magnesite and serpentine cutting volcanic rocks (Wilson, E.D., and Roseveare, 1949; Funnell and Wolfe, 1964).

Brunsvigite (See Chlorite group)

#BURSAITE

Lead bismuth sulfide, $Pb_5Bi_4S_{11}$(?). A very rare mineral associated with other sulfides in skarn.

Cochise County: Middle Pass district, Abril mine, in retrograde calcite veins cutting massive garnet-hematite skarns; includes perfectly formed prisms up to 4 mm long; associated sphalerite is notably deficient in iron compared to that in the skarn itself.

BUTLERITE

Iron sulfate hydroxide hydrate, $Fe(SO_4)(OH)\cdot 2H_2O$. Monoclinic, dimorphous with parabutlerite. The United Verde mine is the type locality.

Yavapai County: Black Hills, United Verde mine, as a thin crystalline coating formed as a result of the burning of pyritic ores (Lausen, 1928; Cesbron, 1964; Fanfani et al., 1971; H 90539; S 95953; UA 52, 7867). A chemical analysis by T.F. Buehrer (Lausen, 1928) gave the following results (wt %):

H_2O	22.83	Fe_2O_3	36.31	FeO	0.41
SO_3	38.63	Al_2O_3	0.55	Na_2O	2.73
				TOTAL	101.46

Specific gravity: 2.55

BÜTSCHLIITE

Potassium calcium carbonate hydrate, $K_6Ca_2(CO_3)_5\cdot 6H_2O$. Associated with calcite as a product of the hydration of fairchildite, formed in clinkers of fused wood ash in partly burned trees. Because bütschliite and fairchildite were characterized on material from Arizona as well as Idaho, the occurrence noted here presumably constitutes a co–type locality.

Coconino County: Grand Canyon National Park. Discovered by Ranger William J. Kennedy in an unspecified, partly burned tree "at a fire on the north side of Kanabownits Canyon one-quarter mile from the Point Sublime road and one-half mile from the North Entrance road" (Milton, 1944; Milton and Axelrod, 1947; Mrose et al., 1966).

BUTTGENBACHITE

Copper nitrate chloride hydroxide hydrate, $Cu_{37}(NO_3)_4Cl_8(OH)_{62}\cdot 8H_2O$. McLean and Anthony (1972) specified this formula by analogy to the revised formula of connellite, with which the mineral is isostructural; see also Fanfani et al. (1973) for an alternative chemical formula. A very rare secondary hydroxide mineral first discovered in Likasi, Shaba, Zaire, Africa. The Arizona locality is only the second one reported in the world.

Pima County: South Comobabi Mountains, Cababi district, Mildren and Steppe claims, as a product of the oxidation of sulfide ores, in quartz veins that cut andesite; identification is based on optical properties and qualitative chemical analysis on very limited material (Williams, S.A., 1962, 1963).

C

CACOXENITE

Iron phosphate hydroxide hydrate, $Fe_4(PO_4)_3(OH)_3 \cdot 12H_2O$. An uncommon mineral of secondary origin associated with other phosphates and iron oxides in iron deposits and iron-bearing pegmatites.

Pima County: Silver Bell district, Silver Bell mine, Oxide pit, as golden to brownish-yellow acicular crystals up to 1 mm long clustered in sheaths and forming undulatory mats; associated with turquoise(?) crystals and sharp torbernite crystals in the contact zone of an andesite dike (Kenneth Bladh, pers. commun., 1974).

#CALAVERITE

Gold telluride, $AuTe_2$. Typically in low-temperature hydrothermal deposits, but also in moderate- and high-temperature deposits.

Cochise County: Warren district, among the sulfides of the Campbell orebody (Graeme, 1993).

CALCIOVOLBORTHITE

Calcium copper vanadate hydroxide, $CaCu(VO_4)(OH)$. A rare secondary mineral formed in small quantities in association with other oxidized vanadium minerals.

Apache County: Monument Valley, Garnet Ridge, in vein fillings and in the cement of the Navajo Sandstone, along and near the contact with a breccia dike; associated with malachite, chrysocolla, tyuyamunite, limonite, pyrite, and chalcopyrite (Gavasci and Kerr, 1968).

Cochise County: Reported at the Gallagher Vanadium property near Tombstone.

Coconino County: Prospect Canyon district, Ridenaur mine, with vesignieite, naumannite, bromargyrite, tyuyamunite, and metatyuyamunite (Wenrich and Sutphin, 1989).

La Paz County: New Water Mountains, Copper Queen mine, as small aggregates of platy crystals (William Hunt, pers. commun., 1984).

Navajo County: Monument Valley, Monument No. 1 mine.

Yavapai County: Big Bug district, in NW1/4 sec. 18, T. 8 N., R. 1 W. (Robert O'Haire, pers. commun., 1972).

CALCITE

Calcium carbonate, $CaCO_3$. A very broadly distributed mineral formed under a wide range of conditions: as a widespread sedimentary-rock-forming mineral composing limestone and chalk, as a metamorphic rock-former in marble derived from limestone and dolomite, and as travertine precipitated from thermal springs and other surface waters. Some of the most spectacular calcite specimens are dripstone (stalactites and stalagmites) formed by the evaporation of underground waters carrying calcium and carbonate ions in aqueous solution. Some limestone caverns in Arizona contain excellent examples of dripstone. The rock materials popularly termed *onyx marble* and *Mexican onyx* are distinctly banded and variously colored travertines. These materials are not related to onyx, which is banded, colored silica.

By far the most abundant form of calcite is the sedimentary rock, limestone. Calcite is widely distributed throughout the sedimentary rock sequence in the state, particularly in Paleozoic rocks; e.g., in the Redwall and Kaibab Formations (the most extensive limestones of northern Arizona) and in the Mississippian Escabrosa Limestone and several Pennsylvanian and Permian formations in south-central and southeastern Arizona. Calcite is also commonly formed in veins through hydrothermal processes, which allow the mineral to attain its best morphological development.

The examples cited here are merely representative of the numerous occurrences of this very abundant mineral.

Cochise County: Warren district, as remarkable masses of fine crystals in oxidized ore, as scalenohedra stained bright red by chalcotrichite (H 70306) and green by included malachite (Hovey, 1900); Copper Queen mine (Guild, 1911), as abundant stalactites in the oxidized-zone workings, locally colored by copper salts; Shattuck mine, 300-ft level, as a limestone cavern about 340 ft in diameter and 80 ft high, discovered in 1914; some of the magnificent cavestone material from Bisbee, found during the early days of mining, has fortunately been preserved in collections throughout the United States. Tombstone district, as coarsely crystalline aggregates along the flanks of the "roll" deposits, and as snow-white linings of caverns in manganese-bearing orebodies; Lucky Cuss mine, as blue crystals (UA 9739); Empire mine, as black crystals (UA 9747). Chiricahua Mountains, Crystal Cave, as crystal aggregates; near Fort Bowie in Immigrant Canyon and at the bend of Whitetail Creek, as extensive marble deposits. Little Dragoon Mountains, northwest of Manzora, as marble; marble was quarried a few miles southeast of Dragoon station (Engineering Mining Journal, 1926). Turquoise district, as crystals (UA 1046). Huachuca Mountains, Ramsey Canyon, Hamburg mine, as well-crystallized scalenohedra with quartz crystals.

Coconino County: Near Cameron, replacing aggregates of lenticular gypsum crystals (AEC mineral collection). Grand Canyon, Supai, as scalenohedral crystals twinned on the basal pinacoid (S 94328); Havasupai Falls, as travertine; in Havasu Canyon and at Mooney, Bridal Veil, and other falls. About 20 miles south of Canyon Diablo, as a brown variety of travertine shading into amber (*onyx marble*) (Engineering Mining Journal, 1922).

Gila County: Globe-Miami district, Old Dominion mine, as fine groups of scalenohedral crystals in cavities in limestone; at the foot of Sleeping Beauty Mountain, about 10 miles west of Globe, quarried as marble; about 20 miles north of Globe in T. 4 N., R. 16 E., as large deposits of multicolored and variegated travertine (Funnell and Wolfe, 1964). Banner district, 79 mine, sparingly as "butterfly" habit twins on descloizite, smithsonite, and rosasite; also as 1/8-in., frosty-white plates with well-developed basal pinacoids, perched on aurichalcite (Keith, 1972).

Graham County: Safford area, as "sand crystals," consisting of abundant quartz sand grains incorporated in calcite crystals (UA 4873, 6474).

La Paz County: South of the Harquahala Mountains, about 9 miles east of Wenden, as variegated marble (Strong, 1962). Continental mine near Bouse, as white scalenohedra up to 1 cm long, on hematite and chrysocolla (MM K404-408).

Maricopa County: Cave Creek, as travertine (Engineering Mining Journal, 1892a); Camp Creek, west of Cave Creek, as soft travertine containing boulders variegated in greens and yellows and veined in browns and reds (Bowles, 1940).

Mohave County: Big Sandy Valley (UA 7548) and Kingman area (UA 8921), as "sand crystals." Moss mine area, as excellent, large, clear, tabular crystals (UA 880). Abundant at the mouth of the Grand Canyon.

Pima County: Quijotoa Mountains, as fine groups of large scalenohedra (UA 7559, 9351). Santa Rita Mountains, King mine, Helvetia (UA 9350); Greaterville, as brown travertine unusually free of cracks; quarried as marble 6 miles north of Helvetia. Pima district, Twin Buttes open-pit mine, as creamy-white crusts several inches thick, composed of simply terminated, rhombohedral crystals; many of the crusts are several square feet wide (Stanley B. Keith, pers. commun., 1973; UA 10083). Colossal Cave, near the southwestern slopes of the Rincon Mountains, as abundant stalactites and stalagmites; dust layers are typically intercalated with bands of calcite, indicative of dry periods of nondeposition. Ajo district, as crystals having inclusions of chalcotrichite.

Pinal County: Superior district, Magma mine, as delicate, pink scalenohedral crystal groups (Barnes and Hay, 1983); the best of these crystals rival English calcites. Childs-Aldwinkle mine, with molybdenite (UA 537). Santa Catalina Mountains, Peppersauce Canyon, as dripstone in a cave; near Condon Mountain, at the northern end of the range, as good-quality marble.

Santa Cruz County: Santa Rita Mountains, Onyx Cave, as magnificent groups of scalenohedral crystals (UA 2024-2027) and as dripstone. Tyndall district, Cottonwood Canyon, Glove mine, as yellow-stained clusters of scalenohedral crystals (UA 9346) in exceptionally attractive, coralloidal material formed in naturally cavernous areas. Patagonia Mountains, Holland mine (UA 6707); Washington Camp, as groups of large, pink, equant crystals on quartz crystals.

Yavapai County: Bradshaw Mountains, Hassayampa district, Cash mine, as beautiful examples of crystallized calcite, quartz, adularia, and ore minerals; Big Bug Creek area near Mayer, as deposits of banded travertine that have yielded decorative stone. Near Cordes, as manganiferous banded travertine (UA 882). In the Eureka district, at Ash Fork (DeKalb, 1895), and near Montezuma Castle National Monument (Funnell and Wolfe, 1964), as travertine. Verde Valley, as pseudomorphous replacements of glauberite crystals from the lake beds (Snyder, 1971; UA 9871, 9874). About 3 miles southeast of Castle Hot Springs, as optical-quality crystals in numerous veins.

Yuma County: Reported in the Gila Mountains, south of Dome station, as very pure marble deposits.

CALEDONITE

Lead copper carbonate sulfate hydroxide, $Pb_5Cu_2(CO_3)(SO_4)_3(OH)_6$. An uncommon secondary mineral found in small amounts in some oxidized copper-lead deposits.

Graham County: Grand Reef mine, as microcrystals with brochantite (Jones, R.W., 1980; Kenneth Bladh, UA x529).

Maricopa County: Painted Rock Mountains, Rowley mine near Theba, Jones shaft, as fine, clear blue-green crystals up to several millimeters long, in small veins, associated with cerussite, linarite, and leadhillite (Wilson, W.E., and Miller, 1974; UA 4066). Osborn district, Tonopah-Belmont mine, as pale-blue crystals up to 2 mm long (Allen, G.B., and Hunt, 1988).

Pima County: South Comobabi Mountains, Cababi district, Mildren mine, as single anhedra up to 25 mm in diameter, surrounded by cerussite altering to malachite (Williams, S.A., 1962, 1963). Pima district, Twin Buttes mine (William Hefferon, pers. commun., 1983).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, 400-ft level of the Collins vein, as excellent crystals; forms include {100}, {120}, {010}, {101}, {111}, {131}, and {011}. An exceptionally large specimen, 3.5 × 3.5 × 2 in., consists of a solid mass of interlocking acicular crystals with a fine, deep-blue color (UA 9675).

CALOMEL

Mercury chloride, Hg_2Cl_2. A secondary mineral formed by the alteration of other mercury minerals, principally cinnabar but also eglestonite.

Maricopa County: Mazatzal Mountains, Sunflower district, with eglestonite and metacinnabar (UA 217, specimen collected by Carl Lausen).

CANFIELDITE

Silver tin sulfide, Ag_8SnS_6. Associated with pyrite and other silver sulfosalts in hydrothermal veins.

Cochise County: Warren district, Campbell mine, intimately associated with stannoidite in pyrite ore. Locally, some ores are reported to have been extremely rich in silver and tin.

CANNIZZARITE

Lead bismuth sulfide, $Pb_4Bi_5S_{11}$(?), whose properties and composition are poorly known.

Graham County: Aravaipa district, Landsman Camp, as tinfoillike microcrystals on and embedded in quartz veinlets in hedenbergite tactite.

CARBONATE-CYANOTRICHITE

Copper aluminum carbonate sulfate hydroxide hydrate, $Cu_4Al_2(CO_3,SO_4)(OH)_{13}\cdot 2H_2O$. A very rare secondary mineral associated with other oxidized copper minerals in some deposits.

Cochise County: Warren district, Holbrook shaft, as fibrous radiating needles in tiny spherules on silicified shaly limestones; on azurite and associated with antlerite (Graeme, 1993).

#CARBONATE-FLUORAPATITE (Francolite)

Calcium phosphate carbonate fluoride, $Ca_5(PO_4,CO_3)F$. A species of the apatite group, of which it is a member.

Apache County: Monument Valley, Monument No. 2 mine, thought to be related to bone material (Witkind and Thaden, 1963).

Yavapai County: Bagdad area, rare in the leached sulfide zone of the porphyry copper deposit in a quartz monzonite stock; as tiny, cream-colored hexagonal plates deposited on chalcedony and in open cavities in the indigenous, yellow-brown iron oxides (Anderson, C.A., 1950).

#CARLSBERGITE

Chromium nitride, CrN. The first nitride identified in iron meteorites; subsequently discovered in more than 70 iron meteorites, as tiny plates in kamacite; also formed as rings around daubreelite.

Coconino County: Meteor Crater, in the Canyon Diablo meteorite, as microscopic oriented laths in kamacite (E.R.D. Scott, pers. commun., 1988).

CARNALLITE

Potassium magnesium chloride hydrate, $KMgCl_3\cdot 6H_2O$. Found in sedimentary salt deposits formed from oceanic waters, with halite, sylvite, polyhalite, anhydrite, and gypsum.

Apache and Navajo Counties: In the subsurface of the southern part of east-central Arizona, in a northeast-trending zone of Permian evaporite deposits (Peirce, H.W., 1969); a drill-hole log (sec. 24, T. 18 N., R. 25 E.) listed carnallite, halite, sylvite, polyhalite, anhydrite, and gypsum (H. Wesley Peirce, pers. commun., 1972).

CARNOTITE

Potassium uranyl vanadate hydrate, $K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$. A secondary mineral widely distributed on the Colorado Plateau, where it is an important uranium and vanadium ore. Formed by the action of meteoric waters on preexisting uranium and vanadium minerals, including uraninite and montroseite; disseminated or locally concentrated in sandstone and associated with fossilized tree trunks or other vegetal matter. Commonly associated with tyuyamunite and metatyuyamunite and other oxidized uranium and vanadium minerals.

Apache County: Carrizo Mountains, at numerous places in the Salt Wash Member of the Morrison Formation (Isachsen et al., 1955; UA 534, 7748). Lukachukai Mountains (UA 7141) and Chuska Mountains (Joralemon, 1952; Lowell, J.D., 1955; Masters, 1955; Wright, 1955; Garrels and Larsen, 1959). Monument Valley, Monument No. 2 and Cato Sells mines, mixed with tyuyamunite (Isachsen et al., 1955; Mitcham and Evensen, 1955; Wright, 1955; Finnell, 1957; Evensen and Gray, 1958; Witkind and Thaden, 1963; Young, R.G., 1964).

Coconino County: Cameron district, Huskon No. 10 mine, associated with schröckingerite (Austin, 1964). Vermillion Cliffs, in petrified wood.

Maricopa County: Vulture Mountains, southeast of Aguila, on minor fractures in tuff (Hewett, 1925; H 106863).

Navajo County: Monument Valley, Monument No. 1 and Mitten No. 2 mines and other prospects (Evensen and Gray, 1958; Holland et al., 1958; Witkind, 1961; Witkind and Thaden, 1963).

Pima County: Cienega Wash near Vail, where the road crosses the southern Pacific tracks (Robert O'Haire, pers. commun., 1972).

Yavapai County: Anderson mine, sparse on sandstone (AEC mineral collection) as small, yellow to orange microcrystals (Sherborne et al., 1979). Eureka district, Hillside mine (Axelrod et al., 1951; S 117681).

Yuma County: Muggins Mountains, Red Knob claims, associated with weeksite, opal, vanadinite, gypsum, calcite, and azurite (Outerbridge et al., 1960).

CASSITERITE

Tin oxide, SnO_2. The most important and widely distributed tin mineral. Formed in high-temperature veins and pyrometasomatic deposits associated with felsic granitic igneous rocks; also in pegmatites and rhyolites.

Cochise County: Warren district, Campbell mine.

Graham County: Apache Tin claims, 25 miles east of Safford on U.S. Highway 70, in spherulitic rhyolite and associated placers, as pebbles (UA 7045), and in rhyolite (UA 7028).

Maricopa County: In the Outpost pegmatite, as tabular crystals with well-defined faces, honey-yellow to very dark brown, some zoned, up to 1.5 in. in diameter, associated with copper and bismuth minerals.

Pinal County: East of Tablelands, as a single small piece of stream tin from rhyolite flows.

Yavapai County: White Picacho district, as a rare constituent of pegmatites (Jahns, 1952).

CELADONITE

Potassium magnesium iron aluminum silicate hydroxide, $K(Mg,Fe^{2+})(Fe^{3+},Al)Si_4O_{10}(OH)_2$. A member of the mica group, with composition and properties like those of glauconite but formed in vesicles in basaltic rocks. It is common throughout the state but seldom mentioned in the literature.

Cochise County: Steele Hills, in seams and vesicles in a basalt within the Threelinks Conglomerate (Cooper and Silver, 1964). Reported in the Warren district.

Navajo County: Hopi Buttes volcanic field, Seth-La-Kai diatreme, in volcanic sandstone and tuffs, with limonite, laumontite, gypsum, and montmorillonite, associated with weak uranium mineralization (Lowell, J.D., 1956).

Pinal County: Malpais Hill and Midway Station, as vesicle fillings (Bideaux et al., 1960; Thomssen, 1983).

CELESTITE

Strontium sulfate, $SrSO_4$. In veins, beds, or lenticular masses in sedimentary rocks; also as a gangue mineral with lead-zinc ores.

Cochise County: One mile northwest of Portal, as sharp, well-formed crystals up to 5 mm long, as free crystals in vesicles in basalt; associated with prehnite, pyrite, and pumpellyite.

Gila County: 79 mine, as microcrystals (Lena Marvin, UA x2921).

La Paz County: Plomosa district, with lead and silver ores.

Maricopa County: About 15 miles from Gila Bend and 3 miles east of the Black Rock railroad siding, on the northwest side of a low mountain range, with gypsum, sandstone, and conglomerate as beds in sandy tuff (Phalen, 1914; Moore, B.N., 1935, 1936; UA 907). Northeast slope of the Vulture Mountains, 15 miles southeast of Aguila, in NW1/4 sec. 20, T. 6 N., R. 7 W., as beds in shaly tuff (Butler, B.S., 1929; Moore, B.N., 1935, 1936; Hewett et al., 1936; Harness, 1942; UA 1154).

Mohave County: Artillery Mountains, Graham prospect, as nodules scattered on the surface (Lasky and Webber, 1949). Hack Canyon mine, Pipe No. 1, as massive cleavage pieces up to 4 cm (MM K493, K502).

Yavapai County: Anderson mine, as small crystals with gypsum and weeksite (William Hunt, pers. commun., 1985).

CELSIAN

Barium aluminum silicate, $BaAl_2Si_2O_8$. An uncommon monoclinic member of the feldspar group. Commonly associated with manganese deposits.

Yavapai County: Reported in an unspecified locality near Yarnell.

Cerargyrite (see CHLORARGYRITE)

CERUSSITE

Lead carbonate, $PbCO_3$. A very common secondary mineral of oxidized lead deposits, formed by reaction between carbonated waters and lead minerals or solutions containing lead. Commonly formed as concentric layers around the lead sulfate, anglesite, which, in turn, surrounds a core of unaltered galena. Cerussite is so widespread in Arizona that only a few localities can be noted.

Cochise County: Tombstone district, as the most abundant lead mineral; Toughnut mine (Butler, B.S., et al., 1938b; Rasor, 1938; Frondel, C., and Pough, 1944; UA 9737). Warren district, as sharp, pale-gray, nearly perfect, tabular, sixling twinned crystals up to 2 in. in diameter, on psilomelane (Sinkankas, 1964); Hendricks Gulch, as impure "sand carbonate" near a fissure in limestone (Ransome, 1904; Guild, 1910; Schwartz and Park, 1932). Chiricahua Mountains, Hilltop mine, as large, twinned crystals (Pough, 1941). Huachuca Mountains, Outlook mine (UA 7642). Turquoise district, as the principal lead ore mineral; Silver Bill mine, as microcrystals (Robert Massey, UA x1861). Gunnison Hills, Texas-Arizona mine (Cooper and Silver, 1964).

Coconino County: Grand View mine, as twinned and phantom microcrystals (Wolfgang Mueller, UA x119, x121).

Gila County: Dripping Spring Mountains, London-Arizona mine, as the principal lead ore mineral; C and B mine, as *V*- and several other twin types (Crowley, 1980). Banner district, 79 mine, as the most abundant supergene mineral formed as "sand carbonate," and as beautifully crystallized material, including sixling and *V*-shaped twinned crystals, associated with anglesite, wulfenite, and vanadinite (Kiersch, 1949; Keith, 1972). Globe-Miami district, Defiance mine, as the principal ore mineral (Wilson, E.D., et al., 1950); Apache mine, in large masses associated with anglesite and galena (Wilson, E.D., et al., 1951).

Graham County: Aravaipa district (Denton, 1947b; Simons, 1964). Stanley district (Ross, C.P., 1925a). Grand Reef mine, as a variety of habits, including large, sixling twinned crystals, some reported up to fist size, reticulated masses, and microcrystals (Kenneth Bladh, George Godas, UA x529, x2560).

Greenlee County: Clifton-Morenci district (Reber, 1916), Hormeyer mine, with gold ore.

La Paz County: Trigo Mountains, Silver district, Red Cloud mine, as single and twinned crystals and as large, reticulated masses; many crystals are arrowhead-shaped twins (Pirsson, 1891; Guild, 1910; Foshag, 1919; Edson, 1980).

Maricopa County: Painted Rock Mountains, Rowley mine near Theba, as sharp, clear, tiny crystals, also massive (Wilson, W.E., and Miller, 1974). Wickenburg district, Moon Anchor mine, Potter-Cramer property, and Rat Tail claim, associated with galena, sphalerite, and a variety of lead and chromium oxidized minerals (Williams, S.A., 1968; Williams, S.A., and Anthony, 1970; Williams, S.A., et al., 1970). S and O claims (also called Amethyst Hill) east of Wickenburg, as simple to complex reticulated crystals.

Mohave County: Cerbat Mountains, Chloride, Mineral Park, and Gold Basin districts, at some properties with free gold. Wallapai district, Tennessee-Schuylkill mine (Schrader, 1909; Thomas, B.E., 1949). McCracken Peak, McCracken mine.

Pima County: Santa Rita Mountains, Helvetia district, Golden Gate and Blue Jay mines; Greaterville district. Empire Mountains, Total Wreck, Chief, and Hilton mines (Schrader and Hill, 1915); 49 mine, as trillings up to 0.75 in., free in finer "sand carbonate," associated locally with aurichalcite and turquoise (Gene Schlepp, pers. commun., 1974); C and A lease, southwest of Pantano (UA 7680). Sierrita Mountains, Pima district, as "sand carbonate"; Paymaster mine, Olive Camp, as massive and crystallized material (Ransome, 1922; Nye, 1961); Twin Buttes open-pit mine (Stanley B. Keith, pers. commun., 1973). Silver Bell Mountains, as silky crystals and as earthy mixtures with smithsonite. Quijotoa Mountains, Morgan mine, El Tiro and other properties, with chlorargyrite. Tucson Mountains, Old Yuma mine, with wulfenite and vanadinite (Guild, 1911). Waterman Mountains, Indiana-Arizona mine, as white, needlelike crystals with azurite.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, Collins vein, as single crystals and magnificent twinned and reticulated crystal aggregates (Pogue, 1913; Peterson, N.P., 1938a,b; Palache, 1941b; Fahey et al., 1950; Bideaux, 1980; UA 850). A complex single crystal in the Smithsonian Institution exhibits the following crystallographic forms: {001}, {010}, {100}, {110}, {130}, {012}, {023}, {011}, {032}, {021}, {031}, {041}, {051}, {102}, {302}, {111}, {112}, and {211}(!). Galiuro Mountains, Copper Creek district, Blue Bird and other lead deposits; Saddle Mountain district. Tortilla Mountains, Florence Lead-Silver mine, formed by the alteration of primary ores containing galena, pyrite, sphalerite, and tennantite, and associated with hemihedrite, wulfenite, willemite, vauquelinite, minium, and mimetite (Williams, S.A., and Anthony, 1970).

Santa Cruz County: Santa Rita Mountains, Tyndall district, Victor, Ivanhoe, and Rosario properties; Cottonwood Canyon, Glove mine, as large crystalline masses (Olson, H.J., 1966); Montosa Canyon, Isabella mine, as "sand carbonate," along a mineralized fault in limestone, associated with specular hematite (Anthony, 1951); Wrightson district, American Boy mine. Patagonia Mountains, Flux and Domino mines, as magnificent groupings of needlelike and pencillike crystals and as massive material (Kunz, 1885; Shannon, D.M., 1981; UA 213, 7134, 9727), and at several other properties (Kunz, 1885; Schrader, 1917).

Yavapai County: Black Hills, Verde district, Copper Chief mine. Bradshaw Mountains, Silver Belt mine, with chlorargyrite, in ancient mine workings (Lindgren, 1926). Eureka district, Hillside mine (Axelrod et al., 1951). Bella mine (Kunz, 1885). Big Bug district, Iron King mine (Creasey, 1952; Anderson, C.A., and Creasey, 1958).

Yuma County: Castle Dome Mountains, associated with anglesite and yellow and red lead oxides (Wilson, E.D., 1933; Batty et al., 1947); Castle Dome district, Hull mine, as sixling twins.

CERVANTITE

Antimony oxide, Sb_2O_4. A secondary mineral formed through the oxidation of stibnite and other antimony minerals.

La Paz County: Dome Rock Mountains, in veins, as radiating blades of stibnite partly altered to cervantite and stibiconite.

CESAROLITE

Lead hydrogen manganese oxide; formula uncertain, perhaps $PbH_2Mn_3O_8$. A rare secondary mineral; in some places, associated with the oxidation of galena.

Cochise County: Warren district, in upper Paleozoic limestones, probably of supergene origin (Hewett and Fleischer, 1960; Hewett et al., 1963).

Maricopa County: As dull black crystalline films on vein quartz that contains cerussite and minium in cavities.

#CESBRONITE

Copper tellurite hydroxide hydrate, $Cu_5(TeO_3)_2(OH)_6 \cdot 2H_2O$. Formed in veins with electrum, teineite, and carlfriesite at the type locality (Williams, S.A., 1974).

Cochise County: Tombstone district.

CHABAZITE

Calcium aluminum silicate hydrate, $CaAl_2Si_4O_{12} \cdot 6H_2O$. A member of the zeolite group. Typically formed in amygdules and fissures in mafic volcanic rocks; also formed through the alteration of volcanic glass in tuffs.

Cochise County: San Simon Basin, 7 miles northwest of Bowie, in bedded lake deposits with analcime, herschelite, erionite, clinoptilolite, halite, and thenardite (Regis and Sand, 1967; Edson, 1977).

Coconino County: Black Peak near Cameron, in mafic dikes associated with breccia pipes; localized in the centers of dolomite replacements of olivine, and as small veins (Barrington and Kerr, 1961).

Gila County: Christmas mine, as rhombohedral crystals in vugs in hydrothermally altered andesite porphyry, where it appears to be a late-stage mineral (D. Perry, pers. commun., 1967); also as chalky, pinkish-white material (F.A. Mumpton, pers. commun.). Near Bowie, as chalky, pale-buff-yellow material (F.A. Mumpton, pers. commun.). Roosevelt Lake–Tonto Creek area, in at least five zeolite deposits in altered tuff beds (Eyde, 1978). In a road cut 23 miles south of Globe on State Highway 77 (Eyde, 1978).

Graham County: Southwest of Pima, in several zeolite deposits in altered tuffs (Eyde, 1978).

Maricopa County: Seven Springs area, as microcrystals (Robert Mudra, UA x79).

Mohave County: East of Big Sandy Wash, east half of T. 16 N., R. 13 W., in Pliocene tuff with analcime, clinoptilolite, erionite, and phillipsite (Ross, C.S., 1928, 1941).

Navajo County: Coliseum diatreme, near Indian Wells, filling or lining vesicles.

Pima County: Ajo district, Well No. 1 of Phelps Dodge Corp., as crystals in vugs in altered volcanic rock (William Thomas, pers. commun., 1988).

Pinal County: In a railway cut at Malpais Hill, north of Mammoth, as crystals intergrown with calcite (Bideaux et al., 1960). About 5.5 miles south of Superior, in a wash on the east side of State Highway 177, in basalt with analcime and thomsonite (William Hunt, pers. commun., 1985).

Yavapai County: In basalts west of Perkinsville, with phillipsite(?); (McKee, E.H., and Anderson, 1971).

CHALCANTHITE

Copper sulfate pentahydrate, $CuSO_4 \cdot 5H_2O$. A water-soluble secondary mineral found in the oxidized zone of sulfide copper deposits; commonly forms crusts and stalactites in mine workings. Decomposes in a dry atmosphere.

Cochise County: Warren district, Copper Queen mine, as stalactites and irregular, porous excrescences several inches thick on mine walls (Merwin and Posnjak, 1937); Lavender open-pit mine (UA 1651); Calumet and Arizona mine, as stalactites (Mitchell, 1921).

Coconino County: Grand Canyon National Park, Horseshoe Mesa, Grandview (Last Chance) mine, as cross-fiber veinlets associated with clay, some clearly of postmine origin (Leicht, 1971).

Gila County: Globe-Miami district, Old Dominion mine, as stalactites and as coatings on floors of old openings; Castle Dome mine, largely as a postmine mineral (Peterson, N.P., et al., 1951; Peterson, N.P., 1962); Inspiration orebody (Olmstead and Johnson, 1966). Dripping Spring Mountains, Banner district, 79 mine, with olivenite, sphalerite, galena, siderite, anglesite, and brochantite (Kiersch, 1949; Thomas Trebisky, pers. commun., 1972). Cherry Creek area, Donna Lee mine. Sierra Ancha Mountains, First Chance, Little Joe, and Shipp No. 2 mines, as efflorescences on mine walls (Granger and Raup, 1969).

Greenlee County: Clifton-Morenci district, as small bodies in the oxidized ores of Copper Mountain, and as stalactites in one of the upper drifts of the Jay shaft (Lindgren, 1905; Guild, 1910; Moolick and Durek, 1966).

Maricopa County: Rowley mine, as microcrystals (Carl Richardson, UA x1198).

Mohave County: Cerbat Mountains, Wallapai district, as a common secondary mineral (Thomas, B.E., 1949).

Navajo County: Monument Valley, Mitten No. 2 mine (Witkind and Thaden, 1963).

Pima County: Silver Bell Mountains, Silver Bell district, as thick coatings on the walls of old mine workings. Santa Rita Mountains, Helvetia-Rosemont district, as fibrous veins (Schrader and Hill, 1915; Creasey and Quick, 1955). Pima district, San Xavier West mine (Arnold, 1964).

Pinal County: Galiuro Mountains, Copper Creek district, Old Reliable, Copper Giant, Glory Hole, and Copper Prince mines, as coatings on the walls of drifts and in fractures (Simons, 1964). Mammoth district, Mammoth–St. Anthony mine area (UA 4585). Scott claim, as microcrystals (Marvin Deshler, UA x1236).

Santa Cruz County: Patagonia Mountains, Duquesne and Washington Camp (Schrader, 1917).

Yavapai County: Black Hills, United Verde mine, as stalactites up to 2 ft long (Guild, 1910; UA 5569). Crown King district, Springfield mine, as fine crystals on timbers in the dump. Copper Basin district. Bagdad, abundant in old mine dumps (Therese Murchison, pers. commun., 1972). Great Southern mine, as microcrystals (Marvin Deshler, UA x941). DeSoto mine at Cleator, as microcrystals (Joseph Leising, Jr., UA x3771).

Yuma County: Muggins Mountains, as microcrystals (William Kurtz, UA x4471).

Chalcedony (see QUARTZ)

CHALCOALUMITE

Copper aluminum sulfate hydroxide hydrate, $CuAl_4(SO_4)(OH)_{12}{\cdot}3H_2O$. A very rare secondary mineral discovered in only a few oxidized copper deposits. The Bisbee district is the type locality.

Cochise County: Warren district; Larsen and Vassar (1925) described the mineral, based on material from an unspecified locality in Bisbee. An analysis by H.E. Vassar gave the following results (wt %):

$Na_2O + K_2O$	0.50	CuO	14.78	$H_2O(-)$	28.95
Al_2O_3	38.71	MgO	0.05	$H_2O(+)$	1.90
SO_3	14.80	CaO	0.01	Insol.	0.09
				TOTAL	99.79

Specific gravity: 2.29

Sacramento pit, in vugs in a dense quartz-goethite gossan, associated with cuprite and malachite, as tiny, beautifully formed, single crystals and twins; commonly altered to pale-blue, massive, botryoidal gibbsite. The crystals are shaped like equilateral triangles; the flat sides are bounded by {100}, one edge by {010}, and the other two edges by {012} and {11$\bar{2}$} (Williams, S.A., and Khin, 1971).

Coconino County: Grand Canyon National Park, Horseshoe Mesa, Grandview (Last Chance) mine, sky-blue to greenish in color, as botryoidal crusts on limonite coating earlier zeunerite crystals; also associated with scorodite, olivenite, and brochantite (Leicht, 1971).

CHALCOCITE

Copper sulfide, Cu_2S. A widely distributed, important, copper ore mineral. Uncommon as a primary mineral but important as a secondary mineral in the zone of secondary enrichment, where it may replace other sulfides. Of commercial importance in Arizona, where many large, low-grade, copper orebodies owe much of their value to secondary chalcocite.

Apache and Navajo Counties: Monument Valley district, associated with other sulfide minerals in uranium-vanadium ores in sandstone (Mitcham and Evensen, 1955; Evensen and Gray, 1958).

Cochise County: Warren district, Campbell and Shattuck mines, locally abundant as a secondary mineral in limestone replacements; Sacramento open-pit mine, as disseminated ores (Ransome, 1904; Guild, 1910; Trischka et al., 1929; Schwartz and Park, 1932; Schwartz, 1934, 1939; Grout, 1946; Hutton, 1957; Bain, 1952); Lavender open-pit mine, as the principal ore mineral (Bryant and Metz, 1966). Cochise district, Johnson Camp area, in small amounts in quartz veins cutting granite, schist, and limestone (Kellogg, 1906). Tombstone district, with acanthite and stromeyerite (Butler, B.S., et al., 1938b); Empire mine (UA 9731). Turquoise district, an important constituent of enriched ores.

Coconino County: Grand Canyon National Park, Horseshoe Mesa, Grandview (Last Chance) mine (Rogers, A.F., 1922; Leicht, 1971); Orphan mine (UA 2368).

Gila County: Globe-Miami district, as an important constituent of disseminated sulfide deposits (Ransome, 1903a; Schwartz, 1921, 1928, 1934, 1939, 1947, 1958; Peterson, N.P., 1962); Old Dominion mine, as compact massive bodies (Ransome, 1903a); Castle Dome mine, replacing chalcopyrite in the upper part of the deposit (Peterson, N.P., 1947); Copper Cities deposit (Peterson, N.P., 1954; Simmons and Fowells, 1966). Banner district, Christmas mine, locally associated with bornite in the chalcopyrite-bornite, inner ore zone of the orebodies, replacing dolomite (Perry, D.V., 1969); Dripping Spring Mountains, 79 mine (Kiersch, 1949; Keith, 1972).

Graham County: Aravaipa district (Denton, 1947b; Simons, 1964), Ten Strike group of claims. Gila Mountains, Lone Star district, as both steely and sooty varieties, replacing pyrite, chalcopyrite, and bornite in the Safford porphyry copper deposit, where it formed a blanketlike deposit on the primary ore zone (Robinson, R.F., and Cook, 1966).

Greenlee County: Clifton-Morenci district, Morenci open-pit mine, in a thick blanket (Moolick and Durek, 1966); as the principal ore mineral of disseminated and vein deposits, in places as solid veins 2 to 3 ft thick (Lindgren, 1903, 1904, 1905; Guild, 1910); Ryerson mine (S 86029; sample collected by W. Lindgren); Montezuma mine (S 86042).

La Paz County: In prospects at Cinnabar, 8 miles southwest of Quartzsite.

Maricopa County: Cave Creek district, Red Rover mine, with argentiferous tetrahedrite.

Mohave County: Near Bill Williams Fork (Genth, 1868). Grand Wash Cliffs, Grand Gulch, Bronze L, and Copper King mines (Hill, 1914b). Cerbat Mountains, Wallapai district, Mineral Park mine (Thomas, B.E., 1949; Field, 1966); also in other districts.

Pima County: Ajo district, disseminated in a narrow band bordering the southern part of the New Cornelia orebody (Joralemon, 1914). Santa Rita Mountains, Helvetia and other districts (Schrader, 1917). Sierrita Mountains, Pima district, Esperanza mine, in an extensive enriched blanket (Schmidt, H.A., et al., 1959; Lynch, D.W., 1967); Pima mine, as a product of secondary enrichment (Journeay, 1959); Copper Glance and Queen mines, as large, nearly pure masses (Ransome, 1922); Twin Buttes mine, in secondarily enriched ores (Stanley B. Keith, pers. commun., 1973). Silver Bell Mountains, Silver Bell district, El Tiro and Oxide open-pit mines, as an important secondarily enriched ore mineral (Richard and Courtright, 1966). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Cerro Colorado Mountains, Heintzelman mine (S 534).

Pinal County: Pioneer district, Magma mine, as large, nearly pure, secondary bodies and an important constituent of the primary ores of the deeper levels, associated with digenite, bornite, and djurleite; as slender prismatic crystals up to 2 cm long and as *V*- twins on the 3,260-ft level (Barnes and Hay, 1983); Belmont mine, as fine-grained, sooty material (Ransome, 1914; Guild, 1917; Bateman, 1929; Harcourt, 1942; Short et al., 1943; Morimoto and Gyobu, 1971). Ray mine, as the essential mineral of disseminated ores (Ransome, 1919; Schwartz, 1947; Clarke, O.M., 1953; Lewis, D.V., 1955; Metz and Rose, 1966). Galiuro Mountains, at several properties, including the Childs-Aldwinkle mine, where primary chalcocite has formed in the deeper levels (Kuhn, 1941; Denton, 1947a). Mammoth district, Mammoth–St. Anthony mine, as thin films and as replacements of chalcopyrite (Peterson, N.P., 1938a,b; Fahey et al., 1950); San Manuel mine, in hydrothermally altered monzonite and quartz monzonite porphyry, replacing chalcopyrite in the secondary sulfide zone; associated with bornite, chalcopyrite, cuprite, chrysocolla, and copper (Chapman, 1947; Schwartz, 1947, 1949; Lovering, 1948; Thomas, L.A., 1966; Lowell, J.D., 1968).

Santa Cruz County: Santa Rita Mountains, at several properties, including the Ivanhoe mine, Tyndall district, where it formed large bodies (Schrader and Hill, 1915; Schrader, 1917). Palmetto district, 3R mine, as an orebody of secondary origin (Handverger, 1963).

Yavapai County: Black Hills, in the oxidized zone of the United Verde mine, and in exceptionally large, pure, massive bodies in the United Verde Extension mine (Fearing, 1926; Schwartz, 1938; Anderson, C.A., and Creasey, 1958). Eureka district, Bagdad mine (Anderson, C.A., 1950; Moxham et al., 1965). Copper Basin district, in the oxidation zone of sulfide deposits in breccia pipes (Johnston, W.P., and Lowell, 1961).

Yuma County: Castle Dome Mountains, with malachite (S 65493).

CHALCOMENITE

Copper selenite hydrate, $CuSeO_3{\cdot}2H_2O$. A secondary mineral formed through the oxidation of copper and lead selenides.

Cochise County: Middlemarch mine, Missionary shaft, as isolated pods in a skarn predominantly composed of epidote, quartz, chlorite, calcite, pyrite, sphalerite, and chalcopyrite, plus minor amounts of covellite, azurite, and malachite; orthorhombic crystals are sky blue, arranged in parallel aggregates, bow ties, and radiating clusters on quartz and garnet (Sousa, 1980).

CHALCOPHANITE

Zinc iron manganese oxide hydrate, $(Zn,Fe^{2+}, Mn^{2+})Mn_3^{4+}O_7{\cdot}3H_2O$. A secondary mineral associated with other manganese and iron oxides.

Cochise County: Warren district, Cole shaft, as crystalline material perched on geothite-rich gossan (AM 34586).

Gila County: Banner district, southwest workings of the Kullman-McCool mine (also called D.H. claims), as octahedral microcrystals.

La Paz County: Sheep Tanks mine, vein B, as tabular crystals with hollandite and aragonite in veins of banded black calcite (Cousins, 1972).

Maricopa County: Osborn district, Tonopah-Belmont mine, as striated rhombohedra up to 1.5 mm (Allen, G.B., and Hunt, 1988).

Pinal County: In a railway cut between San Manuel and Mammoth (UA 9726). Mineral Hill district, Reymert mine, with psilomelane, hollandite, coronadite, and todorokite (Wilson, K.S., 1984).

Yuma County: Kofa district, King of Arizona mine, with todorokite, groutite, aurorite, and pyrolusite (Hankins, 1984).

CHALCOPHYLLITE

Copper aluminum arsenate sulfate hydroxide hydrate, $Cu_{18}Al_2(AsO_4)_3(SO_4)_3(OH)_{27}\cdot 33H_2O$. A rare secondary mineral formed in the oxidized zone of copper deposits with other oxidized copper minerals.

Cochise County: Warren district, Calumet and Arizona mine, associated with cuprite and connellite (Palache and Merwin, 1909).

Graham County: Turtle Mountain area, east of Bonito Creek, as crystals in vesicles in basalt (Bideaux et al., 1960).

CHALCOPYRITE

Copper iron sulfide, $CuFeS_2$. The most important ore mineral of copper and a major constituent of nearly all copper sulfide deposits. Predominantly of primary origin in veins and replacement bodies, as disseminated particles in a variety of rock types, and in contact metamorphic zones.

Apache County: Monument Valley, Garnet Ridge, in vein fillings and in the cement of the Navajo Sandstone, both along its contact with a breccia dike and in nearby areas (Gavasci and Kerr, 1968).

Apache and Navajo Counties: Monument Valley, associated with chalcocite, bornite, and copper in uranium-vanadium ores in Shinarump Conglomerate, Moenkopi Formation, and DeChelly Member of the Cutler Formation (Mitcham and Evensen, 1955; Evensen and Gray, 1958).

Cochise County: Warren district, as massive orebodies; mined at the Copper Queen, Calumet and Arizona, Junction (Mitchell, 1920), and other properties. Tombstone district, as the most abundant copper mineral. Turquoise district, as the principal ore mineral in pyritic bodies. Little Dragoon Mountains, Cochise district, as an important ore mineral at several properties (Cooper, 1957); Keystone and St. George properties (Romslo, 1949). Dragoon Mountains, Primos mine near Dragoon (Palache, 1941a). Huachuca Mountains, Reef mine (Palache, 1941a). Chiricahua Mountains, Humboldt mine (Hewett and Rove, 1930).

Gila County: Globe-Miami district, Old Dominion mine, as large masses in the Mescal Limestone (Woodbridge, 1906); Summit mine, forming the bulk of the ore; Miami and Inspiration mines, in the protore; Castle Dome mine, as the principal ore mineral; Copper Cities deposit (Peterson, N.P., 1954). The presence of a chalcopyrite-enriched zone beneath the supergene chalcocite blanket in the Inspiration mine has led some researchers to believe that the chalcopyrite is of supergene origin; thin chalcopyrite films have formed on the surfaces of pyrite crystals in the mine (Olmstead and Johnson, 1966). Payson district, as the chief ore mineral of copper deposits. Dripping Spring Mountains, Banner district, Christmas mine, as the most abundant ore mineral (Tainter, 1948; Knoerr and Eigo, 1963; Perry, D.V., 1969); 79 mine, rarely as disphenoidal crystals up to 0.5 in., showing {112}, coated by smithsonite (Keith, 1972).

Graham County: In ores of the Stanley (Ross, C.P., 1925a) and Aravaipa (Denton, 1947b; Simons, 1964) districts. Lone Star district, San Juan mine, in a low-grade sulfide deposit (Rose, 1970) and in the Safford porphyry copper deposit (Robinson, R.F., and Cook, 1966).

Greenlee County: Clifton-Morenci district, in the lower levels of veins and disseminated in limestone near porphyry contacts (Lindgren, 1903, 1904; Guild, 1910); it is the only important primary copper mineral in the Morenci open-pit mine, where it is associated with pyrite, molybdenite, and sphalerite as disseminations and small veinlets (Moolick and Durek, 1966).

La Paz County: Buckskin Mountains, Planet mine (Bancroft, H., 1911). Harquahala Mountains, Golden Eagle mine.

Mohave County: Cerbat Mountains, common in nearly all the copper mines and prospects; Johnny Bull–Silver King property (Tainter, 1947c). Grand Wash Cliffs, Bronze L and Copper King mines, as the main ore mineral. Ithaca Peak, in veins with pyrite, sphalerite, and galena in a quartz monzonite stock (Eidel, 1966). Bill Williams Fork, associated with copper, cuprite, chrysocolla, malachite, brochantite, chalcocite, covellite, and pyrite (Genth, 1868). Copper World mine near Yucca, associated with sphalerite, pyrrhotite, and very minor löllingite (Rasor, 1946).

Pima County: Santa Rita Mountains, as the most important copper mineral in the mines and prospects (Schrader and Hill, 1915); Helvetia district, as the principal ore mineral at several properties, including the Rosemont lease, Copper World mine, and Leader mine (Creasey and Quick, 1955). Pima district, at several properties (Webber, 1929; Eckel, 1930a; Guild, 1934), including the Esperanza mine (Tainter, 1947b; Lynch, D.W., 1967); Pima mine, as a primary ore mineral closely associated with grossular hornfels (Journeay, 1959; Himes, 1972); Mission mine, as the principal ore mineral (Richard and Courtright, 1959); and Twin Buttes open-pit mine (Stanley B. Keith, pers. commun., 1973). Catalina district, Pontotoc mine, with epidote and hematite in gneiss associated with limestone (Guild, 1934); near Marble Peak, in contact deposits with garnet and epidote (Dale et al., 1960). Ajo district, as scattered grains in the New Cornelia Quartz Monzonite (Joralemon, 1914; Gilluly, 1937). South Comobabi Mountains, Cababi district, Little Mary mine (Williams, S.A., 1963). Silver Bell Mountains, El Tiro and Oxide open-pit mines (Kerr, 1951; Richard and Courtright, 1966).

Pinal County: Pioneer district, Magma mine, as massive replacements of limestone (Short et al., 1943; Sell, 1961) and as very fine crystals up to 2.5 cm long

(Barnes and Hay, 1983); Belmont mine. Galiuro Mountains, Copper Creek district, Copper Prince mine, where several thousand tons of nearly pure chalcopyrite were mined (Joralemon, 1952); Childs-Aldwinkle mine (Kuhn, 1941); Old Reliable mine (Denton, 1947a). Ray district, in protore. Pioneer district, Silver King mine (Guild, 1917). Mammoth district, San Manuel mine, of hypogene origin; the most important ore mineral (Chapman, 1947; Thomas, L.A., 1966).

Santa Cruz County: Santa Rita Mountains, as the most abundant copper ore mineral in most of the districts; Tyndall district, American Boy mine. Patagonia Mountains, Santo Niño mine, with large bodies of massive molybdenite (Blanchard and Boswell, 1930); Indiana mine, with pyrite, sphalerite, and chalcopyrite (Stanley B. Keith, pers. commun., 1973). Oro Blanco district, Idaho and Montana mines, Annie Laurie prospect (Warren, H.V., and Loofburrow, 1932; Anderson, R.Y., and Kurtz, 1955).

Yavapai County: Black Hills, United Verde mine, as the principal ore mineral in the pyritic orebody (Anderson, C.A., and Creasey, 1958); also abundant at the Copper Chief and Shea properties. Bradshaw Mountains, Agua Fria, Black Canyon, and Pine Grove districts; Big Bug district, Iron King mine (Creasey, 1952). Wickenburg Mountains, Monte Cristo mine, with silver and nickel arsenides (Bastin, 1922).

CHALCOSIDERITE

Copper iron aluminum phosphate hydroxide hydrate, $Cu(Fe,Al)_6(PO_4)_4(OH)_8\cdot 4H_2O$. The iron-bearing analog of turquoise (see also this mineral description) but much less common than that mineral.

Cochise County: Reported in the Warren district, in small quantities at the Shattuck mine (UA 1468).

#CHAMOSITE (including the varieties thuringite and delessite)

Iron magnesium aluminum silicate hydroxide oxide, $(Fe^{2+},Mg,Fe^{3+})_5Al(Si_3Al)O_{10}(OH,O)_8$. A member of the chlorite sheet-silicate group. Formed with clays and iron oxides in lateritic deposits and in sedimentary ironstones.

Cochise County: Reported in the Warren district.

Mohave County: Southwest flank of the Hualapai Mountains, secs. 3, 4, and 9, T. 17 N., R. 16 W., Antler mine, in schist (Romslo, 1948).

Pima County: Chicago mine near Sells, with epidote and pumpellyite as amygdules in altered andesite.

Santa Cruz County: Santo Niño mine, in an oligoclase-rutile rock rich in molybdenite; chamosite replaces former dark silicates in the mafic igneous rock that hosts the ore.

Yavapai County: As a fine-grained component of schists in the metamorphosed alteration zone associated with the Precambrian, volcanogenic, Bruce massive-sulfide deposit (Larson, 1976). United Verde mine area, where the variety thuringite is present as a constituent of *black schist,* a chlorite-rich aggregate that has replaced rocks in the region (Anderson, C.A., and Creasey, 1958).

CHENEVIXITE

Copper iron arsenate hydroxide hydrate, $Cu_2Fe_2(AsO_4)_2(OH)_4 \cdot H_2O$(?). A widespread but uncommon mineral; of secondary origin in the oxidized portion of copper deposits. A relatively common mineral in leached cappings over enargite-pyrite mineralization.

Santa Cruz County: Santa Rita Mountains, Cottonwood Canyon, Glove mine (Terry Wallace, pers. commun., 1989; K. Cole, UA x4692). Patagonia Mountains, Alum Gulch, as minute green spherules in porous quartzose rock with contact silicates and specular hematite (Loghry, 1972; UA 8218). Humboldt mine, Patagonia, as microcrystals (Jessie Hardman, UA x3008); Harshaw district, Volcano-Sunnyside mine, as 1.5-cm masses in goethite and pseudomorphs after cuprite.

Chert (see QUARTZ)

CHEVKINITE

Calcium cerium iron magnesium titanium silicate, $(Ca,Ce)_4(Fe,Mg)_2(Ti,Fe)_3$-$Si_4O_{22}$. A rare mineral found in granite pegmatites, certain granites, and volcanic ash deposits.

Mohave County: Aquarius Mountains, in a vein that traverses a granitic dike; intimately associated with sphene, monazite, cronstedtite, and quartz (Kauffman and Jaffe, 1946). An analysis reported by these authors gave these results (wt %):

SiO_2	12.04	Y_2O_3	1.50	CaO	3.35
TiO_2	17.08	Al_2O_3	0.93	MgO	0.74
ThO_2	0.82	Fe_2O_3	9.56	P_2O_5	0.38
Ce_2O_3	25.29	FeO	7.76	H_2O	1.50
$(La,Dy)_2O_3$	18.35	MnO	0.50	TOTAL	99.80

Chloanthite (see SKUTTERUDITE)

#CHLORAPATITE

Calcium phosphate chloride, $Ca_5(PO_4)_3Cl$. Associated with certain marbles; formed in pegmatites and in veins that cut gabbroic rocks.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites (London, 1981).

CHLORARGYRITE (Cerargyrite)

Silver chloride, AgCl. A complete solid-solution series extends from chlorargyrite to bromargyrite (AgBr). Formed in the oxidized zones of silver deposits from the alteration of primary silver minerals.

Cochise County: Tombstone district, in oxidized ores (Butler, B.S., et al., 1938b; Rasor, 1938; Romslo and Ravitz, 1947); Santa Ana mine (UA 9162); Bradshaw mine near Charleston, in granular aggregates; Contention mine, as microcrystals, with chrysocolla (Richard Thomssen, UA x590). Pearce district, Pearce Hills, Commonwealth mine, with bromargyrite, embolite, iodargyrite, and acanthite in quartz veins (Endlich, 1897); with conichalcite (Howell, 1977). Dragoon Mountains, Turquoise district, in oxidized lead-silver ores. Warren district, Cole mine, in pockets in massive sulfides (Hutton, 1957) and on malachite; Campbell mine (Schwartz and Park, 1932); Shattuck mine, cementing silica breccia (UA 5566).

Gila County: Globe-Miami district, in many surficial ores (Peterson, N.P., 1962); Old Dominion mine, with manganese oxides. Richmond Basin, where massive chlorargyrite formed plates 0.5 in. thick and several inches in diameter. Stonewall Jackson mine, with acanthite, embedded in siderite gangue; formed by alteration of silver with which it is associated (Guild, 1917). Payson district, Silver Butte mine, with silver (Lausen and Wilson, 1925). In the 1950's a local cowboy in the Globe area discovered a mass of pure chlorargyrite that was loose in the soil and weighed more than 50 lb.

Graham County: Aravaipa district, Orejana adit, with bromargyrite; Windsor shaft (Ross, C.P., 1925a). Copper Creek district, Blue Bird mine (Kuhn, 1951).

Greenlee County: Clifton area, Hargo mine (UA 5523).

La Paz County: Trigo Mountains, Silver district, Silver Clip and Red Cloud mines, as the principal silver mineral in oxidized lead ores (Wilson, E.D., 1933). Padre Kino mine, as massive and crudely crystalline material with cerussite and as microcrystals (Kenneth Bladh, UA x3293).

Mohave County: Hualapai Mountains, Maynard district, at several properties (Schrader, 1907). Cerbat Mountains, at several properties, principally in the Mineral Park, Stockton Hills, White Hills (Engineering Mining Journal, 1892c), and Wallapai districts; Chloride district, Distaff mine, where, with silver, it was the principal silver mineral (Bastin, 1925).

Pima County: Santa Rita Mountains, Helvetia-Rosemont district, Blue Jay mine; Greaterville district. Empire Mountains, Total Wreck mine (Schrader and Hill, 1915; Schrader, 1917). Quijotoa Mountains, Morgan mine. Cerro Colorado Mountains, Cerro Colorado and other mines (Guild, 1910). Papago district, Sunshine-Sunrise group, with galena, chalcocite, cerussite, and anglesite (Ransome, 1922). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Prince Rupert mine, Crittenden, with wire silver (Engineering Mining Journal, 1892b).

Pinal County: Pioneer district, Belmont area, as the chief near-surface silver ore mineral (Romslo and Ravitz, 1947). Mammoth district, Mammoth–St. Anthony mine, Collins vein, as tiny, yellowish, cubo-octahedral crystals implanted on caledonite (Bideaux, 1980). Vekol Mountains, Vekol mine, as 1-mm crystals on jarosite (AM 24967). Tortolita Mountains, Owl Head district, Apache prospect. As microcrystal pseudomorphs at Ray (George Stevens, UA x4440).

Santa Cruz County: Tyndall district, Ivanhoe mine (Guild, 1910). Wrightson district, Anaconda group. Patagonia Mountains, Redrock district, La Plata and Meadow Valley mines; Harshaw district, Hermosa and American mines; Palmetto district, Palmetto mine (Schrader and Hill, 1915; Schrader, 1917).

Yavapai County: Bradshaw Mountains, Hassayampa district, Dos Oris mine, with acanthite and silver; Black Canyon district, Thunderbolt mine, with proustite and silver; Bradshaw district, Tuscumbria mine, with stephanite; Tip Top district, Tip Top mine, with ruby silver; Big Bug district, Silver Belt mine, where the presence of stone hammers and grads in old workings indicates that the deposit was mined in ancient times; Peck district, Swastika mine, as fine crystals. Eureka district, Hillside mine, associated with anglesite, cerussite, smithsonite, silver, and hemimorphite (Axelrod et al., 1951). Tiger district, Lida mine (Engineering Mining Journal, 1892d).

Chlorite

A mineral group name, members of which have compositions that can be expressed by the general formula $(Mg,Fe^{2+},Fe^{3+},Mn)(AlSi_3)O_{10}(OH)_8$. The chlorite minerals are very abundant in Arizona and are formed primarily in thermally metamorphosed rocks and as a product of the hydrothermal alteration of ferromagnesian silicates such as biotite, pyroxene, and amphibole. In many localities, the chlorite species is unknown. A few localities, mainly of the less common chlorite minerals, are listed under the specific or varietal name.

Colorado Plateau Region: With illite and montmorillonite in several members of the Morrison Formation (Keller, 1962). Abundant locally in the Moenkopi Formation (Schultz, 1963).

Pima County: Santa Catalina Mountains, as clinochlore in limestone at the contact with the Leatherwood Quartz Diorite (Wood, 1963).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as green felted masses in the lower levels of the Collins vein (Peterson, N.P., 1938a,b).

Yavapai County: Verde district, United Verde mine, as an abundant alteration mineral. The term *black schist* refers to chlorite-rich aggregates that have replaced rocks in the region. The classifications by C.A. Anderson and Creasey (1958) of chlorites from the United Verde mine involved species names that are no longer valid.

CHLORITOID

Iron magnesium manganese aluminum silicate hydroxide, $(Fe, Mg,Mn)_2Al_4Si_2O_{10}(OH)_4$. A fairly common product of intermediate grade thermal metamorphism of aluminum- and iron-rich pelitic sedimentary rocks. Nothing appears to be known about chloritoid polytypes in Arizona occurrences.

Cochise County: Chiricahua Mountains, as crystals in phyllite (Bideaux et al., 1960).

Maricopa County: Southwest slope of Squaw Peak Park, Phoenix, as manganese-rich porphyroblasts up to 5 mm in schist, with muscovite and quartz (Thorpe, 1980). On a nearby hill in Squaw Peak Park, in schist with staurolite, biotite, and garnet (Thorpe and Burt, 1980).

CHOLOALITE

Copper lead tellurite hydrate, $CuPb(TeO_3)_2 \cdot H_2O$. A very rare mineral associated with other tellurites and tellurates in oxidized ores on mine dumps.

Cochise County: Tombstone district, on a dump about halfway between the Joe and Grand Central shafts; associated with granular jarosite and opal in brecciated shale cemented by vuggy quartz; subhedra of choloalite are corroded by crusts of emmonsite (Williams, S.A., 1981a).

CHONDRODITE

Magnesium iron silicate hydroxide fluoride, $(Mg,Fe)_3SiO_4(OH,F)_2$. A member of the humite group; an uncommon mineral formed in contact-metamorphosed limestones and dolomites and in skarns related to ore deposits.

Cochise County: Cochise district, Johnson Camp area, in tactite formed in the Martin Formation, in bright pink lenses with an unidentified silicate mineral (Cooper and Silver, 1964).

Pinal County: Lakeshore mine, locally abundant in forsterite marble.

CHROMITE

Iron chromium oxide, $FeCr_2O_4$. A member of the spinel group. Commonly associated with peridotites or serpentines in which it may form in veins or as segregations. Commonly associated with magnetite, olivine, garnet, vesuvianite, ilmenite, and pyroxene.

Apache County: Monument Valley, Garnet Ridge, as fragments in a breccia dike that pierces sedimentary rocks (Gavasci and Kerr, 1968).

Coconino County: Canyon Diablo area, associated with krinovite, roedderite, high albite, richterite, and kosmochlor in the Canyon Diablo meteorite (Olsen and Fuchs, 1968).

La Paz County: Trigo Mountains, Silver district, as disseminated grains and small masses with mariposite (a variety of muscovite) in mica schist.

CHRYSOBERYL

Beryllium aluminum oxide, $BeAl_2O_4$. An uncommon mineral formed in granite pegmatites, in certain metamorphic rocks, and as detrital grains.

Mohave County: Virgin Mountains, Hummingbird claims, with beryl crystals up to 15 in. long in pegmatite dikes (Olson, J.C., and Heinrichs, 1960; Meeves, 1966).

CHRYSOCOLLA

Copper aluminum hydrogen silicate hydroxide hydrate, $(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$. A widespread and locally abundant secondary mineral found in practically all oxidized copper deposits of the state. Commonly associated with tenorite and malachite.

Apache County: Garnet Ridge, in veins cutting Navajo Sandstone and as cement along the contacts with a nearby breccia dike; associated with malachite, calciovolborthite, tyuyamunite, limonite, chalcopyrite, and pyrite (Gavasci and Kerr, 1968).

Apache and Navajo Counties: Monument Valley, associated with oxidized uranium-vanadium ores in sandstone (Mitcham and Evensen, 1955).

Cochise County: Warren district, with cuprite, disseminated flakes of copper, azurite, malachite, and small crystals of brochantite, and locally, with tufts of connellite (Ransome, 1904; Holden, 1922; Schwartz, 1934). Tombstone district, widely distributed but not abundant in mine properties (Butler, B.S., et al., 1938b). Cochise district, Johnson Camp area, in copper sulfide orebodies, commonly associated with other oxidized copper minerals (Kellogg, 1906; Cooper and Huff, 1951). Sulfur Springs Valley, in small amounts in numerous veinlets cutting porphyritic andesite flows (Lausen, 1927b).

Coconino County: Jacobs Canyon district, near Jacobs Lake, as a principal constituent of low-grade copper deposits in the Redwall and Kaibab Limestones, associated with malachite and azurite (Fischer, 1937). White Mesa district, with malachite cementing sandstone (Hill, 1914a; Mayo, 1955a).

Gila County: Globe-Miami district (Woodbridge, 1906), abundant in the Live Oak, Keystone, Black Warrior, and Geneva mines (Wells, R.C., 1937); Old Dominion mine, as an important ore mineral (Schwartz, 1921, 1934); Keystone copper mine, 5 miles west of Globe (Wells, R.C., 1937); Bulldog tunnel of the Inspiration mine, with malachite, chalcedony, and quartz, as aggregates of great beauty (Ransome, 1919; Peterson, N.P., 1962; Sun, 1963); Black Copper portion of the Inspiration orebody, as thin coatings on fractures in Pinal Schist, locally as veins up to 5 cm wide, and as matrix cementing subangular schist pebbles in an old stream channel composed of White Tail Conglomerate, interlayered with heulandite in some outcrops; analysis showed that the black variety contains 6.7% MnO_2, whereas the blue-green variety contains 0.06% MnO_2 (Throop, 1970; Throop and Buseck, 1971; see also Kemp, 1905). Banner district, 79 mine, as pseudomorphs after hemimorphite (Keith, 1972; UA 7587) and as massive and botryoidal material, some coating and replacing wulfenite; Christmas mine, as a moderately common supergene mineral associated with andradite-bearing skarns in the Naco Formation (David Perry, pers. commun., 1967).

Graham County: Gila Mountains, Lone Star district near Safford, in metamorphosed latites and andesites, with a variety of other copper minerals (Hutton, 1959b); Safford porphyry copper deposit, as the most abundant copper mineral, making up 50 to 85% of all the oxide mineralization; as veins, blebs, and coatings and commonly intimately associated with kaolinite and halloysite (Robinson, R.F., and Cook, 1966).

Greenlee County: Clifton-Morenci district, as common, fine, glassy-green specimens (Kunz, 1885; Lindgren and Hillebrand, 1904; Lindgren, 1905, Reber, 1916); typically pseudomorphic after malachite and brochantite (Moolick and Durek, 1966).

La Paz County: Bill Williams Fork (Genth, 1868), Buckskin Mountains, Planet mine (Bancroft, H., 1911; Cummings, 1946b) as beautifully banded material associated with cuprite in limestone replacement orebodies (McCarn, 1904); Harquahala Mountains near Salome (NHM 1966, 113). New Water Mountains, Eagle Eye mine, as long (2-mm) fibers in vugs.

Maricopa County: Painted Rock Mountains, Rowley mine near Theba, where small masses and stringers, locally associated with malachite, have yielded quartz-rich, gem-quality material; most of the deposit, however, is friable to powdery (Wilson, W.E., and Miller, 1974).

Mohave County: Cerbat Mountains, Wallapai district, as excellent specimens at the Emerald Isle mine, where it has formed in vein and blanket deposits in a granite porphyry, as well as in alluvium; associated with dioptase and "copper pitch," which cements alluvial detritus (Thomas, B.E., 1949; Searls, 1950; Newberg, 1967). The composition (wt %) of material from the Emerald Isle mine, based on a chemical analysis by L.T. Richardson (Wells, R.C., 1937), is as follows:

SiO_2	40.30	CaO	1.05	$H_2O(+)$	8.38
CuO	28.90	FeO	—	$H_2O(-)$	16.92
MgO	0.40			TOTAL	95.95

Pima County: Sierrita Mountains, Pima district (Eckel, 1930a); Twin Buttes mine, in large masses with brochantite and cuprite (Henry Worsley, pers. commun., 1972; UA 9608). Silver Bell Mountains, El Tiro mine, as clear, emerald-green material (UA 8869). Santa Rita Mountains, Helvetia area (UA 3571). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Ajo district, widespread in the orebody of the New Cornelia mine (Joralemon, 1914; Gilluly, 1937). Santa Catalina Mountains, Pusch Ridge (UA 9328).

Pinal County: Mammoth district, San Manuel mine, as the most abundant copper mineral in the oxidized zone of the orebody (Chapman, 1947; Schwartz, 1947, 1949, 1953; Thomas, L.A., 1966; Lowell, J.D., 1968; Throop and Buseck, 1971); Mammoth–St. Anthony mine, in places as gem-quality material (Peterson, N.P., 1938a,b; Galbraith and Kuhn, 1940; Fahey et al., 1950). Near Florence (UA 6049). Galiuro Mountains, Virgus Canyon, Table Mountain mine, as the only abundant copper mineral (Simons, 1964). Mineral Creek district, Ray mine, as spherulitic aggregations of highly birefringent material, as green and black varieties, with tenorite, malachite, halloysite, and heulandite (Schwartz, 1934; Clarke, O.M., 1953; Stephens and Metz, 1967; Throop and Buseck, 1971); Ray open-pit mine, 2,200-ft level of the Silica orebody, as showy, thumbnail- to cabinet-sized clusters of pseudomorphs, possibly after azurite or gypsum crystals (Wilson, W.E., 1977; Thompson, W., 1980); Copper Butte mine (Phelps, 1946).

Santa Cruz County: Santa Rita Mountains, Tyndall district, Cottonwood Canyon, Glove mine (Olson, H.J., 1966). Patagonia Mountains, Duquesne and Washington Camp (Schrader, 1917); Helvetia, with limonite, forming warty masses and incrustation pseudomorphs after gypsum crystals.

Yavapai County: Black Hills, Arizona-Dundee property, as mammillary fillings in Tertiary conglomerate (Anderson, C.A., and Creasey, 1958). Bradshaw Mountains, Castle Creek district, Whipsaw and Copperopolis properties, as bright-blue material (Lindgren, 1926).

Yuma County: Copper Mountain, Betty Lee group and other properties (Wilson, E.D., 1933).

Chrysoprase (see QUARTZ)

CHRYSOTILE (see Serpentine)

CINNABAR

Mercury sulfide, HgS. Of near-surface origin as veins, replacement deposits, or impregnations. Commonly associated with rocks and hot-spring deposits of recent volcanic origin.

Gila and Maricopa Counties: Mazatzal Mountains, in several properties, typically as veinlets or thin films on fracture surfaces and as discontinuous, somewhat definite, ore shoots in a belt of "schist," which consists of various rock types. Cinnabar is the only important ore mineral in the deposits, but calomel, mercury, and metacinnabar are present in small amounts, as are pyrite, chalcopyrite, azurite, and malachite (Lausen, 1926); several producers are situated on Alder and Sycamore Creeks (Ransome, 1916; von Bernewitz, 1937; Dreyer, 1939; Faick, 1958; Beckman and Kerns, 1965). Phoenix Mountains, Rico, Mercury, and Eureka groups of claims. Sam Hughes claims, north of Phoenix (UA 1391).

La Paz County: Plomosa district, French, American, and Colonial properties, 8 miles southwest of Quartzsite (Bancroft, H., 1909; von Bernewitz, 1937; Beckman and Kerns, 1965). Near Ehrenberg, where it is sparsely distributed in veins and mined on a small scale.

Mohave County: Northern Black Mountains (River Range), Gold Basin district, Fry mine.

Pima County: Roskruge Mountains, Roadside mine (Beckman and Kerns, 1965). Cerro Colorado Mountains, with malachite (UA 3095). Cerro Colorado district, Mary G mine, as tiny crystals and scales lining cavities in quartz (Davis, R.E., 1955).

Pinal County: Mickey Welch claims, south of Casa Grande. Martinez mine near Florence, as microcrystals (William Kurtz, UA x4230).

Yavapai County: Copper Basin district (Beckman and Kerns, 1965), Mercury, Cinnabar, Queen, Zero Hour, and Shylock properties (Johnston, W.P., and Lowell, 1961). White Picacho district, Westerdahl claims.

CLARINGBULLITE

Copper chloride hydroxide hydrate, $Cu_4Cl(OH)_7{\cdot}0.5H_2O$. A very rare, oxide-zone mineral that was first completely described from Zambia in 1977.

Cochise County: Bisbee, Warren district, in a specimen of cuprite collected by Joseph E. Urban in the late 1960's from the Cole shaft, as minute, blue platelets in vugs in the cuprite, with brochantite, malachite, and connellite; Southwest mine, as crystals up to 6 mm, with atacamite, paratacamite, spangolite, and connellite (Graeme, 1993).

CLAUDETITE

Arsenic oxide, As_2O_3. A secondary mineral formed from the oxidation of other arsenic minerals; also formed as a sublimation product of mine fires.

Yavapai County: Black Hills, Jerome, United Verde mine, as silky crystals filling a small cavity above the burned pyritic orebody (Palache, 1934; Buerger, M.S., 1942) and as a foil, 1 × 5 cm (H 92682).

CLAUSTHALITE

Lead selenide, PbSe. A rare lead mineral formed in some complex ores with other sulfides and selenides.

Greenlee County: Blue Range Wilderness Area, in a deep drill hole. A sample from a depth of 2,807 ft showed silvery films of clausthalite lining fractures in a calcite-epidote marble; traces of pyrite and sphalerite were also present.

Cliftonite (a variety of GRAPHITE)

Carbon, C. A rare variety of carbon formed as tiny, cube-shaped, polycrystalline pseudocrystals in metallic meteorites. Controversy surrounds the origins of this material. Some believe that it is pseudomorphic after diamond; others believe that it formed by the diffusion of carbon–a product of the decomposition of cohenite, $(Fe,Ni)_3C$–to nucleation sites, where subsequent growth produced the cubic morphology.

Coconino County: Meteor Crater area, in kamacite (α-Fe,Ni), which surrounds troilite (FeS)-graphite-silicate nodules in the Canyon Diablo meteorite; as tiny, cube-shaped masses composed of many crystallites (El Goresy, 1965; Brett and Higgins, 1967).

#CLINOBISVANITE

Bismuth vanadate, $BiVO_4$. A rare secondary mineral formed under oxidizing conditions.

Cochise County: Dos Cabezas Mountains, at a small prospect near the Comstock mine, as small, dull-red tablets resembling wulfenite, up to 1 mm on an edge; the tablets are perched on greasy brown nontronite, which partially fills voids in massive white vein quartz; associated with bismutite and rare duhamelite.

CLINOCHLORE

Magnesium iron aluminum silicate hydroxide, $(Mg,Fe^{2+},Al)_6(Si,Al)_4O_{10}(OH)_8$. A member of the chlorite group formed during thermal metamorphism and by hydrothermal processes. The variety penninite is common in the state.

Cochise County: Warren district, as coarse crystals formed during retrograde metamorphism of garnet-epidote tactites, commonly found in the deeper levels of the Cole and Dallas mines; the variety penninite, as small scaly crystals interlayered with sericite in altered Bolsa Quartzite north of the Dividend Fault, and as a matrix of breccia dikes exposed in the upper reaches of Brewery Gulch.

Pima County: East side of the Tortolita Mountains, as the variety penninite, formed as large crystals pseudomorphous after hornblende in abundant syenodiorite dikes. Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

Yavapai County: Verde district, United Verde mine area, where the ferroan variety, ripidolite, is a constituent of "black schist"; associated with other members of the chlorite group (Anderson, C.A., and Creasey, 1958).

CLINOCHRYSOTILE

Magnesium silicate hydroxide, $Mg_3Si_2O_5(OH)_4$. A member of the kaolinite-serpentine group (see also these mineral descriptions); the dimorph of chrysotile.

Cochise County: Warren district, Holbrook pit, as scaly micaceous intergrowths with stevensite ("deweylite") and chrysocolla.

CLINOCLASE

Copper arsenate hydroxide, $Cu_3(AsO_4)(OH)_3$. An uncommon mineral of supergene origin, formed in the oxidized portion of copper deposits.

Gila County: Banner district, sixth level of the 79 mine (Keith, 1972).

Pinal County: Hull claims, south of Ray, in thin purple crusts and veinlets (AM 35561).

Santa Cruz County: Temporal Gulch, St. Louis mine, as druses on barite, derived from the alteration of tennantite (Bideaux et al., 1960).

Yavapai County: Copper Mountain, Old Robertson claim, 4 miles east-northeast of Mayer, with olivenite (Robert O'Haire, pers. commun., 1972); with cornwallite (UA 2211, 5758).

CLINOHEDRITE

Calcium zinc silicate hydroxide, $CaZnSiO_3(OH)_2$. An extremely rare mineral; this locality is one of only two known in the world.

Gila County: Banner district, Christmas mine, as sprays of delicate, pale-lavender prisms on fracture surfaces, with stringhamite, kinoite, and apophyllite; only a few specimens were found.

CLINOHUMITE

Magnesium silicate fluoride hydroxide, $Mg_9Si_4O_{16}(F,OH)_2$. A common member of the humite group, it typically forms in contact-metamorphosed limestones and dolomites and in skarns related to mineral deposits.

Apache County: Buell Park diatreme, about 15 miles north of Fort Defiance, as the variety titanclinohumite, a prominent constituent of a kimberlite tuff plug (Balk, 1954; Sun, 1954; Bideaux et al., 1960; McGetchin et al., 1970). A chemical analysis by H.B. Wiik (Balk, 1954) gave these results (wt %):

SiO_2	35.34	Fe_2O_3	1.23	$H_2O(+)$	1.14
TiO_2	5.11	MgO	46.45	$H_2O(-)$	0.02
Al_2O_3	0.00	MnO	0.23	P_2O_5	0.12
Cr_2O_3	0.10	CaO	0.07	F	0.06
FeO	10.20			$(-)O = F_2$	0.02
				TOTAL	100.05*

*Original total was listed as 99.95 wt %
Specific gravity: 3.364 (Sun, 1954)

CLINOPTILOLITE

Sodium potassium calcium aluminum silicate hydrate, $(Na,K,Ca)_{2\text{-}3}Al_3(Al,Si)_2Si_{13}O_{36}\cdot 12H_2O$. A member of the zeolite group. A very abundant mineral in Arizona, formed by the devitrification and alteration of volcanic glass in tuffs. Remarkably enough, until recent years the mineral was practically unknown in the state because its presence in the tuffaceous volcanic rocks is not readily discernible without careful study by optical or X-ray diffraction techniques.

Apache County: Near Nutrioso, with analcime in a Tertiary tuff and sandstone formation (Wrucke, 1961; Sheppard, 1971).

Cochise County: San Simon Basin, 7 miles northwest of Bowie, in bedded lake deposits with analcime, chabazite, herschelite, erionite, thenardite, and halite (Regis and Sand, 1967; Edson, 1977).

Greenlee County: About 6 miles north of Morenci, with mordenite in Tertiary tuff (Sheppard, 1969, 1971).

Maricopa County: Near Horseshoe Reservoir, sec. 3, T. 7 N., R. 6 E., in tuff of the Verde Formation (Sheppard, 1971; F.A. Mumpton, pers. commun.).

Mohave County: Near Wikieup, in a Pliocene lacustrine formation (Sheppard, 1971); east of Big Sandy Wash, east half of T. 16 N., R. 13 W., in Pliocene tuff with analcime, chabazite, erionite, and phillipsite (Ross, C.S., 1928, 1941).

Pima County: Ajo district, Well No. 1, Phelps Dodge Corp. (William Thomas, pers. commun., 1988).

Pinal County: Northern Tortilla Mountains, where it has formed by the alteration of feldspar fragments in abundant, large pumice masses contained in the middle tuff and tuffaceous sandstone member of the Ripsey Wash beds (Schmidt, E.A., 1971).

Yuma County: Near Dome, with bentonite and tuff in a late Tertiary lacustrine formation (Bramlette and Posnjak, 1933; Sheppard, 1971). The composition (wt %), based on an analysis by J.G. Fairchild (Wells, R.C., 1937) is as follows:

SiO_2	64.30	CaO	2.42	MgO	0.62
Al_2O_3	12.78	Na_2O	3.96	$H_2O(-)$	4.78
Fe_2O_3	0.82	K_2O	1.36	$H_2O(+)$	9.50
				TOTAL	100.54

CLINOZOISITE

Calcium aluminum silicate hydroxide, $Ca_2Al_3Si_3O_{12}(OH)$. A member of the epidote group. Typically a product of both regional and contact metamorphism; much like epidote in mode of occurrence. Much of what has been called zoisite is probably clinozoisite.

Cochise County: Tombstone district, Lucky Cuss mine, as small, vitreous green grains with vesuvianite, monticellite, and thaumasite (Butler, B.S., et al., 1938b). Warren district, as pseudomorphs after biotite, with chlorite, sericite, sphene, quartz, and muscovite (Schwartz, 1958). Dragoon Mountains, Stronghold Canyon, with diopside, vesuvianite, and garnet in metamorphosed Paleozoic rocks (Rushing, 1978).

Gila County: Globe-Miami district, Castle Dome mine, as stringers and scattered grains in sericitized plagioclase of the quartz monzonite (Peterson, N.P., et al., 1946, 1951; Creasey, 1959); common along the north side of the Miami-Inspiration orebody (Peterson, N.P., 1962); Copper Cities deposit, formed during hydrothermal alteration, associated with chlorite, epidote, pyrite, sericite, and calcite (Peterson, N.P., 1954).

Pima County: North end of the South Comobabi Mountains and north of the Ko Vaya Hills, as the variety withamite, with manganaxinite and piemontite, as vesicle fillings in andesite flow boulders (Bideaux et al., 1960). Santa Catalina Mountains, with diopside, epidote, actinolite, tremolite, microcline, and plagioclase in arkose at the contact with the Leatherwood Quartz Diorite (Wood, 1963).

Pinal County: Mammoth district, San Manuel mine, as coarse grains with epidote, as a hydrothermal alteration product (Schwartz, 1953).

Yavapai County: Big Bug district, Iron King mine, in diorite, along the northwestern contact with the breccia facies, associated with epidote, chlorite, and hornblende (Creasey, 1952).

CLINTONITE

Calcium magnesium aluminum silicate hydroxide, $Ca(Mg,Al)_3(Al_3Si)O_{10}(OH)_2$. A member of the mica group that may be regarded as a calcium analog of phlogopite (Deer et al., 1962). Formed in chlorite schist with talc and in metamorphosed limestones.

Gila County: Banner district, Christmas mine, north side of 800-ft level, as the variety xanthophyllite, associated with forsterite, garnet, idocrase, and calcite, in contact-metamorphosed diorite (David Perry, pers. commun., 1967, 1969).

COBALTITE

Cobalt arsenic sulfide, CoAsS. A rare mineral most commonly formed as disseminations in contact metamorphic rocks, but also in high-temperature veins. Associated with other cobalt and nickel arsenides and sulfides.

Apache County: Reported in the White Mountains, exact locality unknown.

Graham County: Blue Bird mine, near Mount Turnbull, as massive and microcrystalline material (MM K106).

Maricopa County: Mazatzal Mountains, along the Apache Trail between Fish Creek and Roosevelt Dam.

Pima County: Comobabi Mountains, Cababi district, exact locality unknown.

Yavapai County: Black Hills, near the Old Prudential claim, along the contact between the Bradshaw Granite and greenstone of the Yavapai Schist; altered to erythrite at the surface (Guild, 1910).

COCONINOITE

Iron aluminum uranyl phosphate sulfate hydroxide hydrate, $Fe_2Al_2(UO_2)_2(PO_4)_4(SO_4)(OH)_2 \cdot 20H_2O$. An uncommon secondary mineral formed in the oxidized zones of Colorado Plateau–type uranium deposits. The Sun Valley mine near Cameron is the co-type locality.

Apache County: Black Water No. 4 mine, in the oxidized zone of a uranium deposit in Triassic sandstone, associated with gypsum, jarosite, limonite, and clay; as aggregates of light-creamy-yellow, microcrystalline grains (Young, E.J., et al., 1966). The composition (wt %) of this material, based on a chemical analysis (by Robert Meyrowitz) of 20 mg, is as follows:

Fe_2O_3	9.7	SO_3	5.4	CaO	0.1
Al_2O_3	6.6	H_2O	24.0	Na_2O	<0.1
UO_3	34.9	Acid Insol.	0.5	CO_2	<0.1
P_2O_5	18.3			TOTAL	99.5
				$H_2O(-)$	18.2

Approximate specific gravity (Sun Valley mine material): 2.70

Coconino County: Near Cameron, Sun Valley and Huskon No. 7 mines, "in seams 1 mm or less thick, predominantly along bedding planes of a light-colored arkosic sandstone that is fine-grained, poorly sorted, and thinly bedded" (Young, E.J., et al., 1966).

COESITE

Silicon oxide, SiO_2. First known as a synthetic product created in the laboratory under conditions of extreme pressure. The natural occurrences are associated with meteoric impacts in high-silica rocks, and in high-pressure rocks such as kimberlites and eclogites. The natural occurrence of coesite was predicted by geological inference before its actual discovery. Meteor Crater is the type locality.

Coconino County: Meteor Crater, as an abundant constituent of sheared Coconino Sandstone in debris directly below the crater floor and beyond the crater rim and in breccia deep below the crater floor; also present in lechatelierite in water-lain beds within the crater; as irregular grains, 5 to more than 50 microns in size (Chao, E.C.T., et al., 1960).

COFFINITE

Uranium silicate hydroxide, $U(SiO_4)_{1-x}(OH)_{4x}$. An important primary ore mineral of uranium, presumably of hydrothermal origin, which is associated with uraninite in the deeper unoxidized portions of sandstone uranium deposits.

Apache County: Monument Valley, Monument No. 2 mine, with uraninite, corvusite, montroseite, and doloresite, as constituents of dark, unoxidized uranium-vanadium ores; also in tabular bodies in sandstone-filled, paleo-stream channels or scours (Young, R.G., 1964). Stinking Spring Mountain.

Coconino County: Cameron area, Yazzie No. 102 mine (Austin, 1964).

Gila County: Workman mine, in Dripping Spring Quartzite (Granger and Raup, 1962, 1969).

Mohave County: Hack Canyon district, Hack Canyon copper mine (Wenrich and Sutphin, 1989).

Navajo County: North of Holbrook, at the Ruth group of claims. Monument Valley, Monument No. 1 mine, with uraninite, corvusite, and montroseite (Evensen and Gray, 1958).

COHENITE

Iron nickel cobalt carbide, $(Fe,Ni,Co)_3C$. Found in some metallic meteorites of the state.

COLEMANITE

Calcium borate hydrate, $Ca_2B_6O_{11}{\cdot}5H_2O$. Most commonly formed by the evaporation of inland bodies of salt water.

Maricopa County: In gravels on the Gila River, as the well-crystallized, colorless mineral with bitumen in a fossil egg 62 × 40 mm, enclosed in limestone matrix. An analysis (Morgan and Tallmon, 1904) gave the following results (wt %):

CaO	27.07	B_2O_3	51.00	H_2O	22.01
				TOTAL	100.08

COLUMBITE-TANTALITE (see also FERROCOLUMBITE)

Iron manganese niobium tantalum oxides, $(Fe,Mn)(Nb,Ta)_2O_6$. A complete solid-solution series probably exists between columbite (niobium-bearing) and tantalite (tantalum-bearing). The species has not been determined for every locality. The minerals typically form in lithium-bearing granite pegmatites.

Maricopa County: White Picacho district, as crystals up to 5 in. in diameter in the quartz-rich zone of the Midnight Owl pegmatite (Jahns, 1952). Cave Creek district, where ferberite deposits carry 2.19% combined niobium-tantalum, probably present as columbite-tantalite.

Yavapai County: White Picacho district, in small quantities in several pegmatites (Jahns, 1952). Near Crown King, as a 3-in. twinned crystal in pegmatite.

COLUSITE

Copper arsenic sulfide with tin, vanadium, and iron, $Cu_3(As,Sn,V,Fe)S_4$. An uncommon mineral associated with bornite, chalcocite, tetrahedrite, tennantite, and enargite in some copper deposits.

Cochise County: Warren district, among the ores of the Campbell mine.

Pinal County: Pioneer district, Magma mine (Hammer and Peterson, 1968).

CONICHALCITE

Calcium copper arsenate hydroxide, $CaCu(AsO_4)(OH)$. A member of the adelite group. Formed in the oxidized portions of copper deposits; associated with other secondary minerals, including austinite, olivenite, limonite, brochantite, malachite, azurite, and jarosite.

Cochise County: Warren district, Higgins mine, from which a mineral named *higginsite* (Palache and Shannon, 1920) was later shown to be identical with conichalcite; as excellent crystals and small masses in manganese oxides and limonite (Taber and Schaller, 1930; Richmond, 1940; Radcliffe and Simmons, 1971). An analysis by E.V. Shannon gave the following results (wt %):

CuO	28.67	As_2O_5	41.23	MnO	2.84
CaO	20.83	H_2O	3.49	Insol.	0.86
V_2O_5	1.97	Fe_2O_3	0.48	TOTAL	100.37

Tombstone district, Little Joe mine (UA 43). Pearce Hills, Commonwealth mine, with chlorargyrite (Howell, 1977).

Gila County: Globe district, Thornton Pit of the Inspiration Consolidated Copper Co., as "spheroidal" alteration areas in masses of chrysocolla 2 to 3 in. thick, associated with faults (Kenneth Bladh, pers. commun., 1974); Globe Hills, Copper Hill mine (UA 6425).

Greenlee County: Reported in the Morenci district, in the Candelaria breccia pipe with "bisbeeite."

La Paz County: New Water Mountains, Eagle Eye mine, with chrysocolla.

Pima County: Ajo district, New Cornelia mine, as small green crystals in vugs associated with shattuckite (Schaller and Vlisidis, 1958; UA 8987). Santa Rita Mountains near Rosemont (S 112807).

Pinal County: Galiuro Mountains, Table Mountain mine, as good-quality crystals in vugs with willemite, plancheite, and malachite, and as massive material, with gold (Bideaux et al., 1960). Sawtooth Mountains (Robert O'Haire, pers. commun., 1972). Tortolita Mountains, Azurite mine, with malachite, plancheite, "bisbeeite," and shattuckite (Bideaux et al., 1960).

Santa Cruz County: North end of the Tumacacori Mountains (UA 9265).

Yavapai County: In a shallow pit 13 miles west of Congress, just off U.S. Highway 93. Bagdad open-pit mine, lining vugs (S 114678). Date Creek (Brian Sage, UA x1135) and the Old Robinson claim at Copper Mountain (Brian Sage, UA x1452), as microcrystals.

CONNELLITE

Copper sulfate chloride hydroxide hydrate, $Cu_{27}(SO_4)_2Cl_8(OH)_{62}\cdot 8H_2O$. A very rare secondary mineral from oxidized copper deposits; commonly formed in small cavities in cuprite, with brochantite and malachite. One fist-sized specimen from Bisbee probably contains half of the connellite known in the world.

Cochise County: Warren district, Copper Queen (UA 163; NHM 55921), Calumet and Arizona, and Czar mines, as small, radiating aggregates of slender crystals (Ransome, 1904; Palache and Merwin, 1909; Holden, 1922, 1924; Frondel, C., 1941); crystals of *footeite* (connellite) on type specimens of paramelaconite from the Copper Queen mine are as large as matchsticks. The composition (wt %) of material from the Czar mine, based on an analysis by W.E. Ford (Ford and Beadley, 1915), is as follows:

CuO	73.38	Cl	6.82	SO_3	3.15
N_2O_5	0.72			H_2O	17.13
				TOTAL	101.20
				(−)O = Cl	99.67

Southwest mine, acicular crystals in cuprite with paratacamite (Graeme, 1993). Tombstone district, Toughnut mine, as slender, needlelike crystals and aggregates in cavities in cuprite (McLean and Anthony, 1972; UA 26).

Pima County: Ajo district, New Cornelia mine, in vugs with cuprite (NHM 1965,257). Pima district, Mineral Hill mine, Daisy shaft, with pseudoboleite, gerhardtite, and atacamite in cuprite (Williams, S.A., 1961).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as rare microcrystals associated with caledonite.

COOKEITE

Lithium aluminum silicate hydroxide, $LiAl_4(AlSi_3)O_{10}(OH)_8$. A rare member of the chlorite group. Formed in granite pegmatite; associated with beryl, lepidolite, and spodumene.

Maricopa County: White Picacho district, as rare coatings of pale-pink flakes and foils commonly grouped in feltlike aggregates on lepidolite and spodumene, filling fractures in the interior parts of several lithium-bearing pegmatites (Jahns, 1952).

COPIAPITE

Iron magnesium sulfate hydroxide hydrate, $(Fe^{2+},Mg)Fe_4^{3+}(SO_4)_6(OH)_2\cdot 20H_2O$. A fairly common secondary mineral formed, with other sulfates such as melanterite, alunogen, and halotrichite, from the alteration of sulfide minerals, principally pyrite.

Cochise County: Warren district, Copper Queen mine, in crusts several inches thick, with coquimbite and voltaite (Merwin and Posnjak, 1937); Campbell mine, 2,100-ft level, as bright-yellow crystals.

Coconino County: Cameron area, a fairly common mineral associated with jarosite and other sulfates in uranium deposits (Austin, 1964); Yazzie No. 102 mine, in large, pure masses of yellow scales.

Gila County: Sierra Ancha Mountains, First Chance mine (Granger and Raup, 1969).

Pima County: Sierrita Mountains, Pima district, as silky fibers and foliated masses.

Yavapai County: Black Hills, United Verde mine, as incrustations nearly 1 cm thick, crystals, and crystalline masses, formed by burning of sulfide ore (Anderson, C.A., 1927; Lausen, 1928; H 90538). An analysis by T.F. Buehrer (Lausen, 1928) gave the following results (wt %):

H_2O	31.03	CuO	2.26	K_2O	0.24
SO_3	38.45	FeO	0.38	Na_2O	1.74
Fe_2O_3	27.12			TOTAL	101.22

Specific gravity: 2.09

COPPER

Copper, Cu. Most importantly and abundantly of secondary origin, widely distributed in the oxidized zones of many sulfide copper deposits, where it may be accompanied by cuprite, malachite, azurite, tenorite, and limonite. Also in sedimentary rocks and in cavities in volcanic rocks. May pseudomorphically replace other minerals such as malachite, cuprite, azurite, and chalcopyrite. Very abundant in Arizona.

Apache and Navajo Counties: Monument Valley, as a primary mineral associated with copper sulfides in uranium-vanadium deposits (Evensen and Gray, 1958).

Cochise County: Warren district, abundant at several mines, locally as pseudomorphs after cuprite crystals; Copper Queen mine above the third level, in oxidized ore as masses weighing several hundred pounds (Petereit, 1907; Guild, 1910). Campbell mine, as fine specimens of crystallized material, some coated with silver, recovered from a single pocket (Schwartz and Park, 1932; Schwartz, 1934). Calumet and Arizona mine, as small crystals and irregular networks throughout cuprite and in earthy mixtures of cuprite, limonite, and kaolinite (Ransome, 1904; Holden, 1922; Papish, 1928; Schwartz, 1934; Frondel, C., 1941). Junction mine (Mitchell, 1920). Tombstone district, as microscopic particles in cuprite (Butler, B.S., et al., 1938b). Turquoise district, as large, arborescent masses. Cochise district, Johnson Camp area, Mammoth, Republic, and Copper Chief mines, in trace amounts in oxidized ores (Kellogg, 1906; Cooper and Silver, 1964). Huachuca Mountains, in dark basaltic rock on claims of the Jack Wakefield Mining Co. (R. Davis, pers. commun.).

Gila County: Globe-Miami district, Old Dominion mine, in quartzite as small, hackly particles (Ransome, 1903a; Peterson, N.P., 1962); Castle Dome mine, as an uncommon secondary mineral (Peterson, N.P., et al., 1946, 1951). Banner district, 79 mine, associated with tenorite, chrysocolla, and cerussite (Stanley B. Keith, pers. commun., 1973).

Graham County: Gila Mountains, Lone Star district, rare along thin veinlets or fractures, typically associated with cuprite or chalcotrichite in the oxidized zone of the Safford porphyry copper deposit (Robinson, R.F., and Cook, 1966).

Greenlee County: Clifton-Morenci district, common in the upper parts of veins, partly as branching coralloid forms and groups of indistinct crystals (Kunz, 1885), mostly with cuprite, at the upper limits of the chalcocite zone; Williams vein, as solid copper up to 8 in. thick, with fibrous structure and probably pseudomorphous after chalcocite (Lindgren, 1904, 1905; Reber, 1916).

Maricopa County: Cave Creek district, Red Rover mine, as tiny scales impregnating schist (Lewis, A.S., 1920).

Mohave County: Cerbat Mountains, Wallapai district, in small amounts as a secondary mineral (Thomas, B.E., 1949). Bill Williams Fork (Genth, 1868). Mineral Park district, King claim, in small amounts in thin, platelike masses, associated with chalcocite (Bastin, 1925; see also Eidel et al., 1968).

Pima County: Santa Rita Mountains, at several properties in the Helvetia-Rosemont district (Schrader and Hill, 1915); in exploratory drill core between Helvetia and Rosemont, associated with kinoite, apophyllite, djurleite, bornite, and chalcopyrite (Anthony and Laughon, 1970). Ajo district, New Cornelia mine, abundant as an oxidation product (Schwartz, 1934; Gilluly, 1937; Thomas, W.J., and Gibbs, 1983). Pima district, Pima mine, as a secondary mineral (Journeay, 1959); New Year's mine, with malachite and cuprite (Stanley B. Keith, pers. commun., 1973); Mission mine, in gypsum (UA 5560) and with cuprite (Stanley B. Keith, pers. commun., 1973). W.P. Blake (1855) saw "the pure metal" at a locality he described as "near Altar," in a vein containing "the red oxyd of copper . . . and green crusts of carbonate." South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Silver Bell Mountains, El Tiro pit (Kerr, 1951).

Pinal County: Ray district, Ray Central mine, as large masses (Ransome, 1919) and as unusually large, sawtooth-shaped, single crystals and aggregates up to 5.5 × 1 in., loose in clay (White, 1974; Jones, R.W., and Wilson, 1983); Pearl Handle pit, associated with cuprite and malachite (Stanley B. Keith, pers. commun., 1973). Galiuro Mountains, Copper Prince mine, as twisted and wirelike masses in the oxidized ore (UA 536). Mammoth district, San Manuel mine, generally in the lower part of the supergene sulfide zone (Schwartz, 1949, 1953; UA 6769, a tetrahexahedral crystal). Pioneer district, Magma mine, in small amounts (Short et al., 1943), and as crystal groups (Barnes and Hay, 1983).

Santa Cruz County: Patagonia Mountains, Three R mine, as thin sheets and films apparently derived from chalcocite (Schrader and Hill, 1915; Schrader, 1917).

Yavapai County: Verde district, United Verde Extension mine, locally abundant with cuprite; near Walker, as fine specimens (Lindgren, 1926; Schwartz, 1938; Anderson, C.A., and Creasey, 1958). Copper Basin district (Johnston, W.P., and Lowell, 1961). Eureka district, Bagdad mine (Anderson, C.A., 1950).

COQUIMBITE

Iron aluminum sulfate hydrate, $(Fe_{2-x},Al_x)(SO_4)_3 \cdot 9H_2O$. A common mineral formed in the oxidized portions of base-metal deposits with other secondary sulfates.

Cochise County: Warren district, Copper Queen mine, as porous crusts several inches thick (Merwin and Posnjak, 1937).

Pima County: Pima district (UA 5905), San Xavier West mine (Arnold, 1964).

Pinal County: Superior district, Magma mine, with other sulfates from the 1,000-ft level.

Yavapai County: Black Hills, Jerome, United Verde mine, as an aluminous variety, with copiapite and other sulfate minerals, formed by the burning of pyritic ore (Anderson, C.A., 1927; Lausen, 1928; UA 54; H 91845; H 90623). An analysis by T.F. Buehrer (Lausen, 1928) gave the following results (wt %):

H_2O	31.72	Fe_2O_3	14.69	Na_2O	2.13
SO_3	44.05	Al_2O_3	6.93	TOTAL	99.52

Specific gravity: 2.07

CORDIERITE

Magnesium iron aluminum silicate, $(Mg,Fe^{2+})_2Al_3(Si_5Al)O_{18}$. An early formed product of the metamorphism of argillaceous sedimentary rocks, which persists into conditions of higher-grade metamorphism.

Coconino County: Grand Canyon, as a common constituent of anthophyllite-bearing rocks, e.g., at mile 229, Travertine Canyon (Clark, M.D., 1979).

Graham County: Graham Mountains, as dark-gray, slightly greenish, large (up to 0.5 in. in diameter) crystals, which have been completely replaced by muscovite in graphic granite (John S. White, Jr., pers. commun.; locality noted by John W. Donowick).

Mohave County: Unspecified locality, as sharp, 1-in. crystals (H 91900).

Pinal County: Sacaton Mountains, Gila River Indian Reservation, 10 miles north of Casa Grande, as cyclic twins, with sillimanite, corundum, and titanian andalusite (Bideaux et al., 1960).

CORKITE

Lead iron phosphate sulfate hydroxide, $PbFe_3(PO_4)(SO_4)(OH)_6$. An uncommon secondary mineral formed in the oxidized cappings of certain base-metal deposits.

Yavapai County: Prospect near the Bruce mine, as drusy crusts of brilliant yellow-green crystals on vein quartz.

CORNETITE

Copper phosphate hydroxide, $Cu_3(PO_4)(OH)_3$. A rare mineral formed in the oxidized portions of base-metal deposits at only a few localities in the world.

Pima County: Southern side of Saginaw Hill, about 7 miles southwest of Tucson, in association with other oxide-zone minerals, including brochantite, pseudomalachite, malachite, libethenite, atacamite, and chrysocolla; in well-crystallized, fine-grained, soft clusters plastering the fracture surfaces in chert or chert gangue; as clear, light-peacock-blue crystal aggregates and as darker, deep-blue or deep-greenish-blue crystalline clots, which may alter to pseudomalachite. Crystals are typically between 0.05 and 0.20 mm in size (Khin, 1970).

CORNUBITE

Copper arsenate hydroxide, $Cu_5(AsO_4)_2(OH)_4$. An exceedingly rare mineral formed in the oxide zone of some base-metal deposits.

Santa Cruz County: Prospect near the Humboldt mine, as lovely pistachio-green crystals associated with luetheite and chenevixite. The crystals are measurable and clearly triclinic, verifying the symmetry proposed in the original description. Marshall mine, as microcrystals (Jessie Hardman, UA x2010).

Cornuite(?)

Amorphous silicate of copper. An ill-defined material whose validity as a species is questioned by some authorities. Commonly associated with chrysocolla.

Pima County: South Comobabi Mountains, Cababi district, Mildren and Steppe claims, as a product of the oxidation of sulfide ores in quartz veins that cut andesite (Williams, S.A., 1962, 1963).

CORNWALLITE

Copper arsenate hydroxide hydrate, $Cu_5(AsO_4)_2(OH)_4{\cdot}H_2O$. A rare secondary mineral first recognized from Cornwall and recently from several localities in the western United States. Associated with other copper arsenates such as clinoclase, chenevixite, and duftite.

Yavapai County: Near Mayer, with clinoclase (UA 5758); Old Robertson claim, 4 miles east-northeast of Mayer, as films and coatings (S 117492).

CORONADITE

Lead manganese oxide, $Pb(Mn^{2+}, Mn^{4+})_8O_{16}$. Related to cryptomelane. A rare mineral formed in the oxidized portion of mineralized veins. First described from the Coronado vein in the Clifton-Morenci district (Lindgren and Hillebrand, 1904).

Cochise County: Near the White Tail Deer mine, associated with neltnerite, hübnerite, tilasite, and braunite II. Gleeson, Silver Bill mine (Knudsen, 1983).

Greenlee County: West end of the Coronado vein, in fairly large amounts (Lindgren and Hillebrand, 1904; Lindgren, 1905; Guild, 1910; Fairbanks, 1923; Frondel, C., and Heinrich, 1942; Fleischer and Richmond, 1943; Hewett and Fleischer, 1960; H 83825). An analysis by W.F. Hillebrand gave the following results (wt %):

MnO_2	56.13	MoO_3	0.34	CaO, MgO, + Loss	0.45
MnO	6.56	Al_2O_3	0.63		
PbO	26.48	Fe_2O_3	1.01		
ZnO	0.10	H_2O	1.03	Insol.	7.22
CuO	0.05			TOTAL	100.00

Maricopa County: Osborn district, Tonopah-Belmont mine, as botryoidal incrustations (Allen, G.B., and Hunt, 1988).

Mohave County: Artillery Mountains, in numerous veinlets of manganese oxides along fractures, joints, bedding planes, and breccia zones in Tertiary rocks; associated with cryptomelane, hollandite, psilomelane, pyrolusite, ramsdellite, and lithiophorite (Mouat, 1962).

Pima County: Mineral Hill district, Reymert mine, with psilomelane, hollandite, chalcophanite, and todorokite (Wilson, K.S., 1984).

Pinal County: Pioneer district, Magma mine, in small amounts near the lower limits of the oxidized zone, with sauconite (Fleischer and Richmond, 1943; Short et al., 1943; Hewett and Fleischer, 1960; Hewett et al., 1963).

Santa Cruz County: Santa Rita Mountains, Cottonwood Canyon, Glove mine, coating wulfenite (David Shannon, UA x4343).

#CORRENSITE

A silicate clay mineral that consists of repeating layers of chlorite- and vermiculite-smectite-like components; common in some sedimentary rocks; may be characterized only with the assistance of X-ray diffraction techniques.

Coconino County: Grand Canyon region, abundant in various units of the widespread Supai Formation (McKee, E.D., 1982).

CORUNDUM

Aluminum oxide, Al_2O_3. A relatively common mineral formed in pegmatites and in contact metamorphic zones related to intrusions of silica-undersaturated rocks such as nepheline syenites.

Mohave County: Grand Wash Cliffs, Red Lake district, as blue, red, and white material with andalusite in an aluminous pegmatite dike. Ruby No. 1 claim, about 5 miles south of Kingman, as single crystals up to 7.5 cm long in mica schist.

Pinal County: Sacaton Mountains, Gila River Indian Reservation, with sillimanite, cordierite, and titanian andalusite (Bideaux et al., 1960); sec. 12, T. 5 S., R. 5 E., with rutile and quartz in felsite (Wilson, E.D., 1969).

Yavapai County: Mingus Mountain quadrangle, as an accessory mineral in trachyandesite (McKee, E.H., and Anderson, 1971).

CORVUSITE

Sodium calcium vanadium iron oxide hydrate, $(Na,Ca)(V^{5+},V^{4+},Fe^{2+})_8O_{20}{\cdot}4H_2O$. A widespread mineral in the sandstone uranium-vanadium deposits of the Colorado Plateau; locally an abundant ore mineral of vanadium. Probably of primary origin.

Apache County: Monument Valley, abundant at the Monument No. 2 and Cato Sells mines, where it is associated with coffinite, montroseite, uraninite, and doloresite (Weeks et al., 1955; Finnell, 1957; Witkind and Thaden, 1963; Young, R.G., 1964). Lukachukai Mountains, in the Salt Wash Member of the Morrison Formation (Chenoweth, 1967).

Navajo County: Monument Valley, Monument No. 1 and Mitten No. 2 mines, in the dark uranium-vanadium ores, associated with a variety of uranium and vanadium minerals (Evensen and Gray, 1958; Holland et al., 1958; Witkind, 1961; Witkind and Thaden, 1963).

COSALITE

Lead bismuth sulfide, $Pb_2Bi_2S_5$. A rare sulfosalt formed in moderate-temperature veins in contact metamorphic deposits, and in pegmatites.

Cochise County: Warren district, Campbell shaft (Graeme, 1981).

Graham County: Aravaipa district, Landsman claim, with calcite and diopside.

COTUNNITE

Lead chloride, $PbCl_2$. A rare mineral associated with cerussite and anglesite in oxidized mineral deposits as an alteration product of galena.

Mohave County: Grand Wash Cliffs, Bentley district, Grand Gulch mine, reported as small veinlets replacing chalcocite (Hill, 1914b).

COVELLITE

Copper sulfide, CuS. Commonly formed as a secondary mineral in the zone of oxidation and secondary enrichment of copper deposits, with chalcocite and other copper sulfides. Also formed as a primary mineral. Widespread in small amounts in most copper deposits, typically as coatings and iridescent tarnish on other sulfides.

Cochise County: Tombstone district, lining boxwork structures formed by the removal of primary sulfide minerals (Butler, B.S., et al., 1938b). Warren district, Campbell mine, in massive sulfide orebodies in limestone, believed to be of supergene origin; Cole mine, in veins in limestone with chalcocite (Schwartz and Park, 1932; Bain, 1952; Hutton, 1957); Junction mine (Mitchell, 1920). Little Dragoon Mountains, Cochise district, Johnson Camp area, as a common mineral in the upper portions of cupriferous veins and pyrometasomatic deposits (Cooper and Silver, 1964). Primos mine near Dragoon (Palache, 1941a).

Gila County: Globe-Miami district, as a widespread but minor constituent of the disseminated copper deposits (Peterson, N.P., 1962); Roseboom (1966) suggested that its association with djurleite in the district indicates an unstable assemblage; Castle Dome mine (Peterson, N.P., 1947; Peterson, N.P., et al., 1951); Copper Cities mine (Peterson, N.P., 1954). Payson area, in small amounts replacing chalcopyrite and bornite. Dripping Spring Mountains, Banner district, Christmas mine, as a replacement of bornite, with secondary chalcocite (Peterson, N.P., and Swanson, 1956; Perry, D.V., 1969). 79 mine, in minor amounts, associated with oxidation products of galena (Kiersch, 1949).

Graham County: Aravaipa district, as films and blebs in enriched ores (Ross, C.P., 1925a; Denton, 1947b).

Greenlee County: Clifton-Morenci district, Ryerson and Montezuma mines (Lindgren, 1905; Guild, 1910).

Mohave County: Cerbat Mountains, Wallapai district, common as an accessory mineral in sulfide deposits (Thomas, B.E., 1949).

Pima County: Ajo district, New Cornelia open-pit mine, as minute blebs and coatings on other copper minerals (Gilluly, 1937). Helmet Peak area (UA 7159). Sierrita Mountains, Pima district, La Coronado mine.

Pinal County: Mammoth district, widespread but sparse at the San Manuel mine (Chapman, 1947; Schwartz, 1949, 1953); Mammoth–St. Anthony mine, replacing chalcopyrite. Pioneer district, sparingly distributed in the Magma mine (Bateman, 1929; Short et al., 1943).

Santa Cruz County: Patagonia Mountains, Three R mine and other properties, as films on other sulfides (Schrader and Hill, 1915). Oro Blanco district, Idaho and Montana mines near Ruby (Warren, H.V., and Loofburrow, 1932).

Yavapai County: United Verde Extension mine, as fine specimens (Lindgren, 1926; Schwartz, 1938). Eureka district, Bagdad mine, as films on chalcopyrite in the chalcocite zone (Anderson, C.A., 1950).

COWLESITE

Calcium sodium aluminum silicate hydrate, $(Ca,Na)Al_2Si_3O_{10}\cdot 6H_2O$. An uncommon member of the zeolite group. The Superior occurrence is a co-type locality.

Pinal County: About 5.5 miles south of Superior, as tiny, white, bladed crystals up to 1 mm long in vesicles in olivine bombs and scoria from middle Tertiary cinder cones (H 116448); associated with calcite and the zeolites thomsonite, chabazite, analcime, and mordenite (Wise and Tschernich, 1975). Based on chemical analysis by electron microprobe, the anhydrous constituents (wt %) of Superior material are as follows:

SiO_2	46.37	Fe_2O_3	0.08	Na_2O	0.80
Al_2O_3	25.87	CaO	15.12	K_2O	0.10
				TOTAL	88.34

Specific gravity: 2.12

#CRANDALLITE

Calcium aluminum phosphate hydroxide hydrate, $CaAl_3(PO_4)_2(OH)_5\cdot H_2O$. As fibrous aggregates in certain phosphate deposits, associated with other phosphate minerals such as wavellite; also formed during the alteration and replacement of variscite nodules.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites (London, 1981).

CREASEYITE

Copper lead iron aluminum silicate hydrate, $Cu_2Pb_2(Fe,Al)_2Si_5O_{17}\cdot 6H_2O$. A rare mineral known from only a few localities, including three in Arizona and one in

Sonora, Mexico. Formed in partially oxidized, lead-copper ores. The Mammoth–St. Anthony mine is the type locality.

Maricopa County: Potter-Cramer mine, in vuggy, leached fluorite gangue with willemite, mimetite, wickenburgite, and ajoite (Williams, S.A., and Bideaux, 1975). Osborn district, Tonopah-Belmont mine, as pale-green acicular crystals up to 0.8 mm long (Allen, G.B., and Hunt, 1988).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as pale-green fibrous tufts in or on cerussite, wulfenite, and fluorite (Williams, S.A., and Bideaux, 1975). The composition (wt %), based on the average of several analyses by Marjorie Duggan, is as follows:

CuO	13.5	Fe_2O_3	12.3	Al_2O_3	2.1
PbO	37.0	SiO_2	25.5	H_2O	8.8
ZnO	1.2			TOTAL	100.4

#CREDNERITE

Copper manganese oxide, $CuMnO_2$. A secondary mineral formed by the oxidation of copper and manganese mineral deposits.

Cochise County: Bisbee, Warren district, identified on an old specimen in the collections of the University of Arizona (UA 6993); Dallas shaft (Graeme, 1993).

CREEDITE

Calcium aluminum sulfate fluoride hydroxide hydrate, $Ca_3Al_2(SO_4)(F,OH)_{10}\cdot 2H_2O$. A rare mineral formed in hydrothermal veins.

Graham County: Aravaipa district, Grand Reef mine, with linarite and anglesite in quartz-lined veins (Richard L. Jones, pers. commun., 1969).

CRISTOBALITE

Silicon oxide, SiO_2. A high-temperature polymorph of SiO_2. Typically associated with volcanic rocks as a metastable mineral. Also the major constituent of opal.

Pima County: Roskruge Mountains, in cavities in andesite, associated with tridymite and clay (anauxite).

#Opal

Silicon oxide hydrate, $SiO_2\cdot nH_2O$. Amorphous. Regarded as an amorphous aggregate of crystallites of cristobalite that contain much water (Frondel, C., 1962). Most opal in nature is produced by the accumulation of the tests of silica-secreting marine animals. It is also deposited from hot-spring, underground, and surface waters; hydrothermally produced in mineral deposits; and formed by the weathering of silicate minerals. Distinct from chalcedonic silica (see also this mineral description under QUARTZ).

Cochise County: Tombstone district, Lucky Cuss mine, as small seams in ore, presumed to be of late-stage hydrothermal origin (Butler, B.S., et al., 1938b).

Gila County: Globe-Miami district, Inspiration mine, in the oxidized zone as thin layers and in vugs, with chrysocolla and malachite (Sun, 1963). Northwestern region, as fluorescent hyalite, at several uranium deposits in the Dripping Spring Quartzite (Granger and Raup, 1969).

Greenlee County: Clifton-Morenci district, in monzonite porphyry, where it forms in cavities left after the leaching of pyrite (Reber, 1916), especially on the periphery of the Morenci orebody (Moolick and Durek, 1966).

Maricopa County: North slope of Saddle Mountain, west of Hassayampa. Near Castle Hot Springs, in pink rhyolite.

Mohave County: Union Pass, west of Kingman, as tiny specks of fire opal. Eastern slopes of the Black Mountains, northwest of Kingman.

Pima County: Ajo district, associated with shattuckite, ajoite, and quartz (Sun, 1961). Silver Bell Mountains, Silver Bell mine, as veinlets in the oxidized zone, with jarosite (Kerr, 1951). Pima district, Copper Glance mine, as common opal formed in the old dump (Therese Murchison, pers. commun., 1972).

Pinal County: Picket Post Mountain near Superior, in cavities in dacite (UA 6879).

Santa Cruz County: Grosvenor Hills near Santa Cruz. Jay R claim and Arizona Blue Fire Opal claim, sec. 25, T. 22 S., R. 11 E., as commercially mined blue and precious opal.

Yavapai County: Bradshaw Mountains, 14 miles from Mayer on the Agua Fria River, with chalcedony (Hewett et al., 1963). Eureka district, Bagdad mine, in quartz veins. East of the Black Canyon Road, near Moore Wash.

Yuma County: Muggins Mountains, Red Knob claims, associated with secondary uranium minerals (Outerbridge et al., 1960).

Crocidolite (a variety of RIEBECKITE)

CROCOITE

Lead chromate, $PbCrO_4$. An unusual secondary mineral formed in oxidized, chromium-bearing lead deposits. Commonly associated with galena, sphalerite, cerussite, and exotic secondary lead chromate minerals.

Gila County: Sierra Ancha Mountains, Workmans Creek, as smears in the upper Dripping Spring Quartzite, with metatorbernite (Robert O'Haire, pers. commun., 1972).

Maricopa County: Reported in the "Vulture region" at the Collateral, Chromate, Blue Jay, and Phoenix properties (Silliman, 1881). South of Wickenburg, Moon

Anchor mine, Potter-Cramer property, and Rat Tail claim, as a minor oxide-zone mineral derived from lead-zinc ores; associated with a variety of secondary lead, zinc, and chromium minerals (Williams, S.A., 1968; Williams, S.A., et al., 1970). Black Butte claim, as small massive chunks with vanadinite (Flagg, 1942).

Pima County: South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963).

CRONSTEDTITE

Iron silicate hydroxide, $Fe_2^{2+}Fe^{3+}(SiFe^{3+})O_5(OH)_4$. An uncommon member of the kaolinite-serpentine group. Formed under conditions similar to those of the chlorites.

Mohave County: Aquarius Mountains, in pegmatite at the Rare Metals mine, with sphene, monazite, apatite, and chevkinite (Kauffman and Jaffe, 1946; Heinrich, 1960).

CRYPTOMELANE

Potassium manganese oxide, $K(Mn^{2+},Mn^{4+})_8O_{16}$. Typically associated with the psilomelane manganese ores; probably most commonly of secondary origin. The Tombstone deposit is a co–type locality.

Cochise County: Tombstone; material collected by A.E. Granger exhibited fine-grained, cleavable, and fibrous varieties in the same specimen (Richmond and Fleischer, 1942). The composition (wt %) of massive, cleavable material, based on an analysis by Michael Fleischer, is as follows:

MnO_2	83.13	BaO	0.13	$H_2O(+)$	2.58
MnO	2.08	SrO	0.00	Al_2O_3	0.37
CuO	0.12	CaO	0.27	Fe_2O_3	0.46
NiO	0.00	Na_2O	0.44	SiO_2	0.58
CoO	0.00	K_2O	3.50	TiO_2	0.01
ZnO	5.23	$H_2O(-)$	0.81	P_2O_5	0.07
MgO	0.05			TOTAL	99.83

Specific gravity: 4.33

Coconino County: Peach Springs district, as fine-grained massive material intimately associated with hollandite; contains 0.23% thallium and 5.5% BaO (Crittenden et al., 1962). Adams-Woodie prospect, along the Aubrey Cliffs, about 22 miles northeast of Peach Springs, cementing rock fragments in veins cutting Kaibab Limestone; associated with psilomelane (Hewett et al., 1963).

Gila County: Sierra Ancha district, Apache mine, as botryoidal material, intimately associated with hollandite; contains 0.34% thallium, about 9% BaO, and about 2% K_2O (Crittenden et al., 1962; Hewett et al., 1963).

Mohave County: Artillery Mountains, Black Jack, Price, and Priceless veins, and the Plancha and Maggie Canyon bedded deposits (Mouat, 1962).

Pima County: Santa Rita Mountains, Cottonwood Canyon, Glove mine, after wulfenite, with calcite.

Pinal County: Galiuro Mountains, Blake Place (UA 7037). Pioneer district, Magma mine (Hewett and Fleischer, 1960).

Santa Cruz County: Patagonia Mountains, Patagonia district, Mowry mine (Fleischer and Richmond, 1943). Harshaw district, where argentian cryptomelane is present in large quantities (Davis, S.R., 1975).

Yavapai County: Burmeister mine near Mayer, sec. 17, T. 11 N., R. 3 W., with other manganese oxides interlayered with volcanic ash, clastic sediments, and a basalt flow; also found in and near mounds of opalized dolomite deposited after travertine and silica by an extinct spring (Hewett and Fleischer, 1960; Hewett et al., 1963).

CUBANITE

Copper iron sulfide, $CuFe_2S_3$. Typically a high-temperature sulfide, commonly associated with chalcopyrite (with which it may be intimately intergrown), pyrrhotite, and pentlandite.

Cochise County: Chiricahua Mountains, California district, El Tigre mine, as microscopic blebs with acanthite in black-banded quartz (Tsuji, 1984).

Gila County: Banner district, Christmas mine, as lamellae of probable exsolution origin in chalcopyrite, in the pyrrhotite-chalcopyrite zone of the lower Martin orebody (Perry, D.V., 1969; McCurry, 1971). Workman Creek area, Workman Adit No. 1, in chalcopyrite (Granger and Raup, 1969).

Pinal County: Superior district, Magma mine (Barnes and Hay, 1983).

Yavapai County: In the Precambrian, volcanogenic, Bruce massive-sulfide deposit, with mackinawite and chalcopyrite (Larson, 1976).

CUMMINGTONITE

Magnesium iron manganese silicate hydroxide, $(Mg,Fe,Mn)_7Si_8O_{22}(OH)_2$. A monoclinic amphibole, which is typically a product of regional metamorphism, although it is known to form as a primary igneous mineral in certain mafic rocks.

La Paz County: BBC claims, as yellow-green fibers in hematite matrix (David Shannon, pers. commun., 1988).

Mohave County: Reported in the Hualapai district, Antler mine.

CUPRITE

Copper oxide, Cu_2O. A widespread secondary copper mineral; formed in many of the oxidized copper mines and prospects of Arizona, where it may be associated with malachite, azurite, tenorite, limonite, or locally, copper.

Cochise County: Warren district, as an important ore constituent; magnificent specimens from Bisbee grace mineral collections throughout the world; Copper Queen mine, mainly as earthy material mixed with limonite, but also as crystals and the variety chalcotrichite (H 97648); Calumet and Arizona mine, as large crystalline masses associated with copper and in beautiful druses of ruby-red crystals, which are mostly simple cubes (Douglas, 1899; Ransome, 1903b, 1904; Mitchell, 1920; Holden, 1922; Schwartz and Park, 1932; Schwartz, 1934; Frondel, C., 1941); the remarkable crystal habit of the variety chalcotrichite is nicely illustrated by scanning-electron-microscope photography (Dunn, 1978); Southwest mine, as transparent, modified cubic crystals up to 5 cm (Graeme, 1993). Tombstone district, as bright-red cubic crystals associated with malachite, brochantite, and locally, connellite, which lines small cavities in cuprite at the Toughnut mine (Butler, B.S., et al., 1938b). Dragoon Mountains, Turquoise district, as aggregates of octahedral crystals. Cochise district, as deep-red splendent crystals lining pockets in quartz veins in the Texas Canyon Quartz Monzonite (Cooper and Silver, 1964).

Gila County: Globe-Miami district, Castle Dome and Iron Cap mines, sparse throughout the leached and chalcocite zones of porphyry copper deposits; associated with malachite, azurite, copper, and turquoise (Schwartz, 1921, 1934; Peterson, N.P., 1947); Buffalo and Continental mines, as massive material and as chalcotrichite; Old Dominion mine, as large, dull octahedra (Ransome, 1903a; Peterson, N.P., 1962). Dripping Spring Mountains, Banner district, 79 mine (Keith, 1972).

Greenlee County: Clifton-Morenci district, in several mines at the upper limit of the chalcocite zone, as cubic crystals and as chalcotrichite (Kunz, 1885; Lindgren, 1903, 1904, 1905; Reber, 1916).

Maricopa County: White Picacho district, as a supergene mineral in some pegmatites.

Mohave County: Bill Williams Fork (Genth, 1868); Planet mine, with chrysocolla (McCarn, 1904). Cerbat Mountains, Wallapai district (Thomas, B.E., 1949), Altata mine, as "rich and beautifully crystalline" material.

Pima County: Santa Rita Mountains at Rosemont, as crystal aggregates lining cavities (Schrader and Hill, 1915). Silver Bell Mountains, as cubic crystals and as chalcotrichite in small fractures (Engineering Mining Journal, 1904; Kerr, 1951). Waterman Mountains, Silver Hill mine, with azurite and malachite (UA 6719). Pima district, Copper Glance mine, associated with copper that has replaced an iron pipe in the sump (UA 6386); Twin Buttes open-pit mine, in oxidized ores (Stanley B. Keith, pers. commun., 1972). Tucson Mountains, Amole district, Saginaw and Arizona Tucson properties, in porphyry that is disseminated over a wide area. Ajo district, New Cornelia open-pit mine, so abundant that miners made baseballs from the variety chalcotrichite (Schwartz, 1934; Gilluly, 1937; Thomas, W.J., and Gibbs, 1983). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963).

Pinal County: Copper Creek district, Childs-Aldwinkle mine (Kuhn, 1941).

Mammoth district, San Manuel mine, near the base of the oxide zone (Schwartz, 1949, 1953; Thomas, L.A., 1966); Mammoth–St. Anthony mine, as rare crystalline masses associated with chalcotrichite. Mineral Creek district, Mineral Creek property, as slender ruby-red crystals up to 1 cm long, in a Holocene gravel deposit, with jarosite and goethite (Phillips et al., 1971). Ray district, as sparkling ruby-red aggregates in a stope worked from the old Ray shaft (Ransome, 1919), and as crystalline material and chalcotrichite in the oxidized zone of the Ray deposit (Metz and Rose, 1966).

Santa Cruz County: Patagonia Mountains, Patagonia district, Westinghouse property. Oro Blanco Mountains, Montana mine, as fine bright crystals in vugs (Schrader, 1917).

Yavapai County: Black Hills, United Verde Extension mine, where it is locally abundant and commonly accompanied by copper; as beautiful druses of crystallized material and as chalcotrichite (Lindgren, 1926; Schwartz, 1938; Anderson, C.A., and Creasey, 1958). White Picacho district, as a supergene mineral in some pegmatites (Jahns, 1952). Copper Basin district, secs. 20 and 21, T. 13 N., R. 3 W., as massive crystalline material (David Shannon, pers. commun., 1971). Walnut Grove district, Zonia copper mine, with malachite and chrysocolla (Kumke, 1947).

Yuma County: Muggins Mountains, Red Knob mine, associated with wulfenite, vanadinite, chalcedony, and limonite (Honea, 1959).

Cuprogoslarite (a variety of GOSLARITE)

#CUPROPAVONITE

Silver lead copper bismuth sulfide, $AgPbCu_2Bi_5S_{10}$. Found in zoned, mesothermal, base- and precious-metal deposits.

Cochise County: Warren district, Campbell sulfide orebody, with chalcopyrite, bornite, sphalerite, chalcocite, galena, minor hessite, silver, and wittichenite (Graeme, 1993).

CUPROTUNGSTITE

Copper tungstate hydroxide, $Cu_2(WO_4)(OH)_2$. A rare secondary mineral formed by the alteration of scheelite; generally in concentric layers about a scheelite core. The Cave Creek occurrence is the type locality.

Cochise County: Little Dragoon Mountains, Burrell claim, 1.5 miles west of Dragoon, altering from scheelite (Dale et al., 1960).

La Paz County: Reported in the Eagle Tail district, Livingston claims, south of Quartzsite.

Maricopa County: Cave Creek district, associated with ferberite (UA 1192). Recalculated analyses (Schaller, 1932) gave the following results (wt %):

(1)

WO_3	55.36	CaO	4.12	H_2O	7.19
CuO	32.66	MgO	0.67	TOTAL	100.00

(2)

WO_3	59.04	CaO	2.89	H_2O	4.94
CuO	32.68	MgO	0.45	TOTAL	100.00

Mohave County: Boriana mine (Chatman, 1988).

Pima County: Santa Rita Mountains, 200-ft level of the Helvetia mine.

CYANOTRICHITE

Copper aluminum sulfate hydroxide hydrate, $Cu_4Al_2(SO_4)(OH)_{12}\cdot 2H_2O$. A rare secondary mineral associated with other oxidized copper minerals in some deposits.

Cochise County: Warren district, with azurite and malachite (UA 3107). Turquoise district, Maid of Sunshine mine, as abundant acicular crystal groups, with azurite, malachite, and spangolite (MM 9791).

Coconino County: Grand Canyon National Park, Horseshoe Mesa, Grandview (Last Chance) mine, as radiating crystals of exceptional beauty and massive nodules and veins, closely associated with brochantite (Rogers, A.F., 1922; Gordon, 1923; Leicht, 1971).

Greenlee County: Clifton-Morenci district, Morenci mine; Copper Mountain mine near Morenci, as narrow seams in siliceous gangue, coated with earthy hematite, as incrustations up to 2 mm thick, and as thin fibers and small tufts in cavities (Genth, 1890). The mean of three analyses (by Genth) gave the following results (wt %):

CuO	46.71	SO_3	12.49	H_2O	21.89
Al_2O_3	16.47	Fe_2O_3	1.34	Insol.	0.44
				TOTAL	99.34

Yavapai County: Jerome, in the lower part of the oxidized zone, in a chlorite schist that contains chalcopyrite, with antlerite and brochantite.

D

Danaite (cobaltian ARSENOPYRITE)

DANALITE

Iron zinc manganese beryllium silicate sulfide, $(Fe,Zn,Mn)_4Be_3(SiO_4)_3S$. A rare accessory mineral in granite and greisens.

Yavapai County: Black Hills, south of Jerome (UA 7970).

#DANBURITE

Calcium borosilicate, $CaB_2Si_2O_8$. Formed in contact-metamorphosed limestones and dolomites (skarns and tactites); may be associated with feldspar, axinite, scapolite, sphene, and tourmaline.

Cochise County: Courtland-Gleeson district, Maude Hill, as granular patches in drill core taken from the garnet-epidote tactite.

#DARAPSKITE

Sodium sulfate nitrate hydrate, $Na_3(SO_4)(NO_3)\cdot H_2O$. An uncommon water-soluble mineral typically formed in very arid desert regions, associated with other soluble sulfates and with nitrates in some places, as in northern Chile.

Greenlee County: Peloncillo Mountains, northeast of Bowie, where it forms in caves during wet, cold weather, together with niter; these minerals disappear during hot, dry weather.

DATOLITE

Calcium borosilicate hydroxide, $CaBSiO_4(OH)$. An uncommon mineral found in metamorphosed limestones or basaltic rocks; it may form in amygdules in basalts. Associated with prehnite, diopside, and grossularite.

Pima County: Pima district, Pima mine, in thin veins in diopside-garnet tactites, as microscopic material. Southern half of the Rosemont district, with prehnite in skarn or tactite (McNew, 1981).

#DAUBREELITE

Iron chromium sulfide, $Fe^{2+}Cr_2S_4$. A fairly common constituent of meteorites, in small amounts, commonly associated with troilite.

Coconino County: Meteor Crater near Winslow, in the Canyon Diablo meteorite, with troilite (Frondel, C., and Marvin, 1967a).

DAVIDITE-(La)

Lanthanum cerium yttrium uranium iron titanium oxide hydroxide, (La,Ce)-$(Y,U,Fe^{2+})(Ti,Fe^{3+})_{20}(O,OH)_{38}$. A rare mineral which, in Arizona, formed in a transitional contact zone between a metaspessartine dike and quartz monzonite intrusive.

Pima County: Quijotoa Mountains, Pandora prospect, about 5 miles west of Covered Wells, as dark-brown, pitchy-lustered masses in a matrix of sphene, epidote, and feldspar, in a transition zone between a metaspessartine dike and a quartz monzonite intrusive; nearly entirely metamict (noncrystalline due to α-particle bombardment; Pabst and Thomssen, 1959; Pabst, 1961). Gatehouse et al. (1979)

established the atomic structure of davidite from material from the Quijotoa Mountains; they also provided a detailed, electron-microprobe chemical analysis.

DELAFOSSITE

Copper iron oxide, $CuFeO_2$. A rare secondary mineral formed in the oxidized portions of copper deposits with hematite, cuprite, tenorite, and copper.

Cochise County: Warren district, Cole shaft, with cuprite (UA 7124); Calumet and Arizona mine, in a stope above the 14th level of the Hoatson shaft, in "kaolin and ferruginous clay at about the lowest zone of oxidation" (Rogers, A.F., 1913; Pabst, 1938; see also Frondel, C., 1935). The average of two analyses with oxygen by difference (by G.S. Bohart) gave the following results (wt %):

Cu	41.32	O	21.21	Insol.	0.21
Fe	37.26			TOTAL	100.00

Pinal County: Ray mine, with chalcotrichite (UA 3925).

Yavapai County: Verde district, United Verde mine, as crusts of black tabular crystals, up to 8 mm on an edge, perched on milky quartz.

DESCLOIZITE

Lead zinc copper vanadate hydroxide, $Pb(Zn,Cu)(VO_4)(OH)$. A secondary mineral formed in small amounts in some oxidized lead-zinc or copper deposits; associated with cerussite, vanadinite, and other secondary minerals. See also the related species mottramite.

Cochise County: Warren district, Shattuck mine (Harcourt, 1942), as the cuprian variety, reportedly the first vanadium mineral found in the district; as small stalactites several centimeters long and up to about 8 mm across at the base. The mean of three analyses (Wells, R.C., 1913) gave the following results (wt %):

ZnO	0.31	P_2O_5	0.24	CrO_3	0.50
PbO	55.64	V_2O_5	21.21	H_2O	3.57
CuO	17.05	As_2O_5	1.33	Insol.	0.17
				TOTAL	100.02

Tombstone district, Lucky Cuss, Toughnut, and Tombstone Extension mines (Butler, B.S., et al., 1938b). The composition (wt %) of material from the Lucky Cuss mine (S 48406), based on an analysis by W.F. Hillebrand (1889b), is as follows:

PbO	57.00	As_2O_5	1.10	CaO	1.01
CuO	1 1.21	P_2O_5	0.19	MgO	0.04
FeO	tr.	H_2O	2.50	K_2O	0.10
ZnO	4.19	Cl	0.07	Na_2O	0.17
V_2O_5	19.79	SiO_2	0.80	CO_2	0.82
				TOTAL	98.99

Coconino County: Havasu Canyon, as fine stalactitic crystal groups.

Gila County: Payson district, in small amounts at the Oxbow and Zulu mines (Lausen and Wilson, 1925). Globe district; a locality 2 miles north of the Old Dominion mine; the 400-ft level of the Comstock Extension mine; disseminated in the Defiance mine (Peterson, N.P., 1962); Apache mine, brown to reddish in poorly crystallized masses and coatings, commonly associated with vanadinite (Wilson, W.E., 1971). Banner district, 79 mine, as tiny wedge-shaped crystals on hemimorphite; locally, crystals up to 0.25 in. incrust wulfenite and line cavities (Keith, 1972); northeast workings of the Kullman-McCool (Finch, Barking Spider) mine, as common crystalline masses; Gray Horse mine, as single crystals and crystal aggregates. Dripping Spring Mountains, C and B Vanadium mine, 10 miles northwest of Christmas, as crystal aggregates and sharp, brown to brown-black crystals up to 5 mm, associated with vanadinite and mimetite (Trebisky and Keith, 1975).

Maricopa County: South of Wickenburg, at several localities, including the Moon Anchor mine, Potter-Cramer property, and Rat Tail claim; associated with a suite of exotic secondary minerals (Williams, S.A., 1968). Vulture Mountains, Black Hawk property, 1 mile south of the Vulture mine, as a velvety coating of fine crystals. White Picacho district, in pegmatites. Painted Rock Mountains, Rowley mine near Theba, as sparse black coatings of minute crystals associated with vanadinite (Wilson, W.E., and Miller, 1974).

Mohave County: Grand Wash Cliffs, Bentley district, Grand Gulch mine (Hill, 1914b).

Pima County: Tucson Mountains, Amole district, Old Yuma mine, as rare brownish-orange crystals up to 5 mm long. Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, with mottramite, forming crusts of small pointed crystals (Galbraith and Kuhn, 1940; Bideaux, 1980); Genth (1887a) first noted the mineral at the mine. Dripping Spring Mountains, Bywater mine (S 16420). Copper Creek district, Blue Bird mine (Kuhn, 1951). Mineral Creek district, Ray mine (S 93866). Slate Mountains, Turning Point mine, as tiny red crystals coating vanadinite (Hammer, 1961).

Yuma County: Near Radium Hot Springs (UA 7894). Reported in the Castle Dome district (Guild, 1910).

DEVILLINE

Calcium copper sulfate hydroxide hydrate, $CaCu_4(SO_4)_2(OH)_6 \cdot 3H_2O$. A rare species formed in the oxidized portion of copper ore deposits.

Cochise County: Warren district, San Juan mine, as microscopic crystals with gypsum (Bruce Maier, pers. commun.).

Coconino County: Grand Canyon National Park, Horseshoe Mesa, Grandview

(Last Chance) mine, as bluish-green crusts of lathlike crystals with gypsum (Leicht, 1971).

Graham County: Grand Reef mine (George Godas, pers. commun., 1987).

Pima County: South Comobabi Mountains, Cababi district, Little Mary mine, as a zincian variety associated with brochantite, anglesite, zincian dolomite, and gypsum; in quartz veins cutting andesite (Williams, S.A., 1962, 1963; UA 6737). New Cornelia mine at Ajo (William Thomas, pers. commun., 1988).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as a rare, scaly alteration of powdery djurleite (Bideaux, 1980).

DIABOLEITE

Lead copper chloride hydroxide, $Pb_2CuCl_2(OH)_4$. A rare secondary mineral previously known only from Somerset, England. Formed in oxidized lead ores with boleite, cerussite, hemimorphite, and other secondary minerals. From a study of diaboleite and its associated minerals, H.E. Wenden (Winchell and Wenden, 1968) concluded that diaboleite formed at low temperatures consistent with data from their experiments on synthesizing the species under hydrothermal conditions (between 100° and 170°C).

Maricopa County: Painted Rock Mountains, Rowley mine near Theba, in sparse amounts in association with linarite and anglesite, as sandy aggregates, not as distinct crystals (Wilson, W.E., and Miller, 1974).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, 400-ft level of the Collins vein, as crystals of superb quality, associated with cerussite, wulfenite, phosgenite, and boleite (Palache, 1941b; Fahey et al., 1950; UA 5168, 6202, 6473; NHM 1947,91). Crystallographic forms recognized by Palache include {001}, {010}, {0.1.10}, {110}, {101}, {012}, {011}, {021}, {201}, {112}, {111}. An analysis by F. Gonyer gave the following results (wt %):

PbO	72.01	Cl_2	11.42	Insol.	0.19
CuO	12.68	H_2O	6.03	$(-)O = Cl_2$	2.57
				TOTAL	99.76

Specific gravity: 5.42

DIADOCHITE

Iron phosphate sulfate hydroxide hydrate, $Fe_2(PO_4)(SO_4)(OH)\cdot 5H_2O$. A secondary mineral found in gossans and formed in mine openings.

Santa Cruz County: Santa Rita Mountains, Gringo Gulch, about 3 miles north-northwest of Patagonia, in fist-sized masses of fine-grained crystalline material (sample collected by James A. Yanez).

DIAMOND

Carbon, C. In Arizona, diamond has only been found in meteorites. Evidence has been put forward to support the concept that meteoric diamonds were formed by shock on impact with the Earth (Carter, N.L., and Kennedy, 1964); arguments refuting this idea were advanced by Anders and Lipschutz (1966).

Coconino County: In 1891 a 40-lb mass of the Canyon Diablo meteorite was dissolved and found to contain tiny black diamonds. Subsequently, small diamonds embedded in graphite, and in places associated with lonsdaleite, have been found in other fragments from the same fall (Foote, A.E., 1891a; Kunz and Huntington, 1893; Ksanda and Henderson, 1939; Frondel, C., and Marvin, 1967a).

DIASPORE

Aluminum oxide hydroxide, AlO(OH). The dimorph of böhmite. A constituent of bauxite ores formed by extensive weathering and leaching of aluminous rocks and common in solfatarically altered volcanic rocks with alunite.

Cochise County: Warren district, as a microscopic constituent of sericitized quartz monzonite.

Greenlee County: Steeple Rock area, northwest of Duncan, associated with widespread nacrite, which formed by solfataric alteration of dacites and quartz latites.

Maricopa County: Unspecified locality near Tempe (UA 7451).

Santa Cruz County: Red Mountain, Patagonia, abundant in hydrothermally altered andesites; associated with quartz, pyrite, and alunite.

#DICKINSONITE

Potassium barium sodium calcium manganese iron magnesium aluminum phosphate hydroxide fluoride, $(K,Ba)(Na,Ca)_5(Mn^{2+},Fe^{2+},Mg)_{14}Al(PO_4)_{14}(OH,F)_2$. Found in granite pegmatites.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites (London, 1981).

DICKITE

Aluminum silicate hydroxide, $Al_2Si_2O_5(OH)_4$. A member of the kaolinite group. Of hydrothermal origin, commonly found in mineral deposits with sulfides.

Cochise County: Warren district, Lavender pit, as dense, white, and earthy material cementing massive pyrite.

Pinal County: Mammoth district, San Manuel mine, associated with alunite in the most intensely altered rocks (Schwartz, 1953).

DIGENITE

Copper sulfide, Cu_9S_5. Common in copper deposits, where it is typically associated with chalcocite; forms in both hypogene and supergene environments. A detailed discussion of crystallographic aspects of the bornite-digenite series, based partly on some Arizona minerals, is provided in Pierce, L., and Buseck (1978).

Cochise County: Warren district, associated with djurleite (Roseboom, 1966; Pierce, L., and Buseck, 1978). Cochise district, Johnson Camp, Black Prince adit, intergrown with chalcopyrite (Cooper and Silver, 1964; Roseboom, 1966).

Mohave County: Wallapai district, Alum prospect, about one mile northwest of Mineral Park, where it is the dominant supergene mineral replacing pyrite (Vega, 1984).

Pima County: Pima district, Twin Buttes mine, in copper ores (William Hefferon, pers. commun.).

Pinal County: Pioneer district, forming a part of all chalcocite-bornite intergrowths on and below the 3,400-ft level of the Magma mine (Short et al., 1943; Morimoto and Gyobu, 1971; Pierce, L., and Buseck, 1978).

Santa Cruz County: Washington Camp–Duquesne districts, Simplot mine, replacing chalcopyrite (Lehman, 1978).

Yavapai County: Black Mountains, United Verde mine, in the fire zone as distinct crystals (Harcourt, 1942).

DIOPSIDE

Calcium magnesium silicate, $CaMgSi_2O_6$. A member of the pyroxene group. Generally of metamorphic origin; most abundant in crystalline limestones with other contact metamorphic calcium silicate minerals.

Apache County: Buell Park, a chromian variety found as detrital grains (Bideaux et al., 1960). Monument Valley, Garnet Ridge, as an emerald-green mineral formed in a breccia dike, associated with garnet (Gavasci and Kerr, 1968).

Cochise County: Warren district, as grains in unoxidized pyritic ores. Tombstone district, Comstock Hill, as small, pale-green crystals in the contact zone (Butler, B.S., et al., 1938b). Little Dragoon Mountains, Johnson area, Republic and Moore mines, as one of the abundant contact metamorphic silicate minerals in limestone (Cooper and Huff, 1951; Baker, A., 1960); April mine, abundant in contact-metamorphosed limestones (Perry, D.V., 1964).

Gila County: Banner district, Christmas mine, as a common constituent of hornfels and an important skarn mineral, with tremolite, a prominent gangue mineral (Peterson, N.P., and Swanson, 1956; Perry, D.V., 1969); 79 mine, in contact-metamorphosed limestones with andradite, tremolite, and epidote (Keith, 1972).

Graham County: Stanley district, Grey Throne prospect, as single crystals and massive with andradite garnet.

Greenlee County: Clifton-Morenci district, abundant in contact-metamorphosed limestones of the Longfellow Formation (Lindgren, 1905; Moolick and Durek, 1966).

La Paz County: Harquahala Mountains, sec. 14, T. 5 N., R. 10 W., in coarse masses with sparse crystals of very light-colored material, along contact zones (Funnell and Wolfe, 1964; David Shannon, pers. commun., 1972).

Pima County: Santa Rita Mountains, Helvetia-Rosemont district, in the wall rocks of orebodies in metamorphic limestones (Schrader and Hill, 1915; Schrader, 1917); Peach-Elgin copper deposit, with almandine, and grossular, as bedded replacements (Heyman, 1958). Sierrita Mountains, Pima district, in contact-metamorphosed limestones; Twin Buttes mine, in skarns (Stanley B. Keith, pers. commun., 1973); Pima mine, abundant in limestone hornfels with grossular and tremolite (Journeay, 1959); Mission mine, as the most abundant mineral in the hornfels host rock (Richard and Courtright, 1959; Kinnison, 1966).

Santa Cruz County: Patagonia Mountains, Westinghouse property, Duquesne area (Schrader and Hill, 1915).

Yavapai County: Bradshaw Mountains, Big Bug district, with magnetite at the Henrietta mine.

DIOPTASE

Copper silicate hydroxide, $CuSiO_2(OH)_2$. A rare mineral of secondary or mesogene origin found with other oxidized copper minerals.

Gila County: Globe-Miami district, Inspiration mine, as clusters of radiating crystals and sheaves partly coated by later chalcotrichite, with cubic pseudomorphs after fluorite(?). Payson district, Oxbow and Summit mines, as small prismatic crystals (Lausen and Wilson, 1925). Banner district, Christmas mine (UA 2549).

Greenlee County: Bon Ton group, near the head of Chase Creek, about 9 miles from Clifton, "as brilliant crystals lining cavities in what is called locally 'mahogany ore' . . ." (Hills, 1882; see also Kunz, 1885; Lindgren and Hillebrand, 1904; Lindgren, 1905; Guild, 1910).

La Paz County: Harquahala district, Harquahala mine, as microcrystals (Marvin Deshler, UA x2547), and with crystalline hematite and malachite on cherty-appearing brownish rock (John S. White, Jr., pers. commun., 1972); also as microcrystals from the Pride mine (Francis Sousa, UA x3090). Buckskin Mountains, in small quantities at the Chicago prospect. As microcrystals from a locality near Parker (Michael Rauschkolb, UA x2688).

Mohave County: Cerbat Mountains, Wallapai district, in minor amounts with chrysocolla in both blanket and vein deposits (Thomas, B.E., 1949).

Pima County: Santa Rita Mountains, Helvetia-Rosemont district (UA 8075). Tohono O'odham (Papago) Indian Reservation.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as aggregates of small, deep-emerald-green crystals and as druses of stout crystals in chrysocolla (Galbraith and Kuhn, 1940; Palache, 1941b; Bideaux, 1980; UA 7921; NHM 1966,112; H 104226, 104227). Pioneer district, Magma mine, as deep-green crystal incrustations, partly coated with small olivenite crystals, from the upper levels, particularly from the outcrop of the No. 1 Glory Hole (Short et al., 1943). At an unspecified locality near Riverside on the Gila River (Smith, W.B., 1887b). Galiuro Mountains, Virgus Canyon, Table Mountain mine, where it is fairly common in vugs in jasperoid of the Escabrosa Limestone (Bideaux et al., 1960; Simons, 1964; UA 548, 673). Ray area (UA 1276, 2876). Silver Reef Mountains, Nugget Fraction mine (David Shannon, pers. commun., 1993). Lakeshore copper deposit, associated with chrysocolla (Romslo, 1950).

Yavapai County: Amazon Wash, Black Rock district, near the Gold Bar mine, 15 miles northwest of Wickenburg.

DJURLEITE

Copper sulfide, $Cu_{1.96}S$. Djurleite was described by E.H. Roseboom in 1966, and his prediction that it would prove to be a relatively common supergene mineral has been borne out. It forms in intimate association with the more common chalcocite, and the distinction between the two usually rests on X-ray diffraction analysis. It is highly probable that as details of the sulfide mineralogy of the copper mines of Arizona are worked out, many more djurleite occurrences will be discovered.

Cochise County: Warren district, in association with digenite (Roseboom, 1966).

Gila County: Globe-Miami district, in association with covellite (Roseboom, 1966; AM 34772, a pure, massive lump, which constitutes part of the type material).

La Paz County: Dome Rock Mountains, as large, pure masses in vein quartz; partial oxidation has produced graemite, teineite, and brochantite (Williams, S.A., and Matter, 1975).

Pima County: Near Helvetia and Rosemont, in drill core that penetrated contact-metamorphosed Paleozoic limestones and dolomites, with chalcopyrite, bornite, apophyllite, copper, and kinoite (Anthony and Laughon, 1970).

Pinal County: Pioneer district, Magma mine, with digenite and bornite (Morimoto and Gyobu, 1971). At a small prospect in the Copper Creek area, with vesignieite (UA 9607). Mammoth district, Mammoth–St. Anthony mine, replacing galena.

DOLOMITE

Calcium magnesium carbonate, $CaMg(CO_3)_2$. Most common as a sedimentary rock-forming mineral in a rock of the same name, and abundant in dolomitic limestones; also as a gangue mineral in hydrothermal mineral deposits.

Cochise County: Tombstone district, as massive beds interbedded with limestones and shales of the Naco Formation (Butler, B.S., et al., 1938b). Cochise district, Johnson Camp area (Cooper and Huff, 1951). Warren district, in several beds of the Martin Formation (Hewett and Rove, 1930).

Coconino County: Portions of the Kaibab Limestone in the Flagstaff and Grand Canyon areas are highly dolomitic, especially beds west of El Tovar (Weitz, 1942).

Gila County: Christmas mine area, in many units in the Martin and Escabrosa Formations (Perry, D.V., 1969).

Greenlee County: Clifton-Morenci district, in beds in the lowest part of the Modoc Formation and in the upper part of the Morenci Shale; sparingly in the Longfellow Limestone (Lindgren, 1905).

La Paz County: Harquahala Mountains, as a bed several feet thick near the Bonanza mine.

Maricopa County: Agua Fria-Humbug area, 38 miles north of Marinette; also east of Agua Fria, near Castle Hot Springs (Weitz, 1942).

Mohave County: As thick beds on Tassai Ridge, below Pearce Ferry, Lake Mead area; Peach Springs area, in flat-lying beds (Weitz, 1942).

Pima County: Sierrita Mountains, Pima district, as coarsely crystallized material in fissures; Mission open-pit mine, as microcrystals with fluorite (UA x3550); Twin Buttes mine (William Hefferon, pers. commun.). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963).

Pinal County: Vekol mine, Casa Grande area, as lustrous, chocolate-brown, rhombohedral crystals; the color is present as a very thin coating (Shannon, D.M., 1983a; UA 7661).

Santa Cruz and Pima Counties: Santa Rita and Patagonia Mountains, widely distributed in metamorphosed areas in limestones near contacts with intrusive rocks (Schrader, 1917).

Yavapai County: Black Hills, United Verde mine, as a fairly abundant gangue mineral. Bradshaw Mountains, Tillie Starbuck mine. Hassayampa district, as small rhombohedral crystals coating walls of cavities. Burmeister mine near Mayer, in mounds that are partly replaced by opal and chalcedony, deposited by an extinct spring (Hewett and Fleischer, 1960; Hewett et al., 1963) in beds up to 80 ft thick south and southwest of Seligman (Weitz, 1942).

DOLORESITE

Hydrogen vanadium oxide, $H_8V_6O_{16}$. Formed intimately mixed with oxide minerals, especially paramontroseite, which it replaces, in slightly oxidized uranium-vanadium ores in sandstone.

Apache County: Monument Valley, Monument No. 2 mine, as crystals and chocolate-brown bladed masses with satinlike cleavage surfaces; associated with a variety of other vanadium minerals (Stern et al., 1957; Jensen, 1958; Witkind and Thaden, 1963; Young, R.G., 1964).

DOMEYKITE

Copper arsenide, Cu_3As. A rare mineral, probably of primary origin; locally associated with nickeline.

Cochise County: Many years ago, the University of Arizona received specimens of this species, but the exact location and other data regarding them are unknown (Guild, 1910).

DRAVITE (see Tourmaline)

DUFRENOYSITE

Lead silver sulfide, $Pb_2Ag_2S_5$. A rare mineral known from only a few localities; associated with sphalerite and other sulfides and sulfosalts.

Mohave County: Reported in the Mineral Park district, but the exact locality is unknown.

DUFTITE

Lead calcium copper zinc arsenate hydroxide, $(Pb,Ca)(Cu,Zn)(AsO_4)(OH)$. A rare mineral formed in the oxidized zones of base-metal deposits. The mineral in the localities noted below is believed to be the equivalent of the β-duftite of Guillemin (1956).

Gila County: Banner district, Christmas mine, as brilliant pea-green crusts of microcrystals hidden beneath drusy quartz on which diopside spherules are perched.

Maricopa County: At several localities south of Wickenburg, including the Moon Anchor mine and Potter-Cramer property, as a secondary mineral in the oxidized portion of galena-sphalerite veins, associated with a variety of exotic secondary minerals of lead and chromium (see wickenburgite description, Williams, S.A., 1968).

Mohave County: Grand Deposit mine, abundant as massive material cementing sandstone.

Pima County: Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

Pinal County: Table Mountain mine, as microcrystals (H. Peter Knudsen, UA x266).

Yavapai County: As microcrystals from an unspecified locality at Jerome (Thomas Trebisky, UA x1084).

DUGGANITE

Lead zinc copper tellurate arsenate hydroxide, $Pb_3(Zn,Cu)_3(TeO_6)(AsO_4)(OH)_3$. An extremely rare secondary mineral formed by oxidation of other tellurium minerals in acid waters. Known only from mine dumps at Tombstone, which is the type locality, and from Moctezuma, Sonora, Mexico.

Cochise County: Tombstone district, in the dumps at three properties: the Emerald and Old Guard mines and the Joe shaft. It is found in either quartz or manganese oxide gangue associated with khinite and parakhinite, from which it may form by alteration, and with xocomecatlite, bromargyrite, and a host of other tellurites and tellurates. Crystals are curved, stubby prisms, varying in color from yellow green to water green, and are, exceptionally, up to 0.3 mm long. The composition (wt %), based on an analysis by Marjorie Duggan (Williams, S.A., 1978), is as follows:

PbO	55.3	CuO	1.2	As_2O_5	10.4
ZnO	17.6	TeO_3	14.0	H_2O	1.5
				TOTAL	100.0

Specific gravity: 6.33

DUHAMELITE

Copper lead bismuth vanadate hydroxide hydrate, $Cu_4Pb_2Bi(VO_4)_4(OH)_3 \cdot 8H_2O$. A very rare mineral found in quartz veins in metamorphic terrane. The Gila County deposit is the type locality.

Cochise County: Prospect northwest of Bowie, with kettnerite and malachite. Dos Cabezas Mountains, Comstock mine, with bismutite.

Gila County: Green Valley district, at an old mine 5 km southwest of Payson, on the banks of Lousy Gulch; formed in small gold-bearing veins that cut Precambrian greenstones; associated with chrysocolla and hematite as bundles of fibers on corroded chrysocolla or directly on gangue. The average of three chemical analyses by Marjorie Duggan (Williams, S.A., 1981b) gave the following results (wt %):

CuO	20.4	Bi_2O_3	15.9	H_2O	11.8
PbO	28.4	V_2O_5	23.1	TOTAL	99.6

DUMONTITE

Lead uranyl phosphate hydroxide hydrate, $Pb_2(UO_2)_3(PO_4)_2(OH)_4 \cdot 3H_2O$. A rare secondary mineral associated with kasolite and other secondary uranium minerals.

Santa Cruz County: Nogales district, White Oak mine, with kasolite, uranophane, and autunite (Granger and Raup, 1962).

DUMORTIERITE

Aluminum borate silicate oxide, $Al_7(BO_3)(SiO_4)_3O_3$. An uncommon mineral typically found in the same environments as kyanite, andalusite, staurolite, and sillimanite, with which it may be associated in schists and gneisses.

Cochise County: About 4 miles north-northeast of Willcox, just east of U.S. Highway 666, as a purple vein (Duke, 1960; Funnell and Wolfe, 1964).

La Paz County: Near Quartzsite, as microcrystals (Marvin Deshler, UA x584); about 3 miles south of Quartzsite, as rich masses in quartzite, some used as lapidary material, with kyanite, sillimanite, lazulite, pyrophyllite, and andalusite (Wilson, E.D., 1929; Bideaux et al., 1960; Reynolds et al., 1988). In boulders along the Colorado River, between Yuma and Ehrenberg, as fine, fibrous dumortierite altering to pyrophyllite and associated with kyanite (Wilson, E.D., 1929). Near Clip (Diller and Whitfield, 1889; Ford, 1902; Schaller, 1905; Bowen and Wyckoff, 1926; Wilson, E.D., 1933). The composition (wt %) of material from Clip, based on an analysis by W.E. Ford, is as follows:

Al_2O_3	63.56	SiO_2	29.86	H_2O	1.41
B_2O_3	5.26	Fe_2O_3	0.23	TOTAL	100.32

Santa Cruz County: Patagonia district, 12 miles northeast of Nogales (UA 6268).

#Dunhamite(?)

A rare supergene lead tellurite that forms monoclinic gray crystals or granular masses. Produced from altaite or other tellurides as a very early oxidation product.

Cochise County: Tombstone district, Joe and Grand Central mines, as a moderately abundant mineral that matches the original but scanty description, which was based on material that rimmed altaite in polished sections from the Hillside mine, Organ Mountains, Doña Ana Mountains, New Mexico. The Tombstone mineral also rims altaite and is associated with rodalquilarite. No original material from the Doña Ana locality had been preserved, but old specimens from the Bob Root collection, obtained at the type locality, include a mineral that closely matches the Tombstone mineral.

DYSCRASITE

Silver antimonide, Ag_3Sb. A rare mineral found in silver vein deposits with galena, silver, and silver sulfosalts.

Pima and Santa Cruz Counties: Santa Rita and Patagonia Mountains, mainly the Tyndall and Old Baldy districts, as a secondary mineral in quartz diorite (Schrader, 1917).

≡ E

#ECLARITE

Lead copper iron bismuth sulfide, $Pb_9(Cu,Fe)Bi_{12}S_{28}$. A rare hydrothermal mineral.

Cochise County: Gordon Camp, as fascicular prisms up to 5 mm long embedded in dense, massive skarn composed of andradite, hedenbergite, magnetite, and hematite. Middle Pass district, Abril mine, as 0.1-mm prisms embedded in sphalerite in veins cutting massive garnet-hematite skarn. (See also bursaite.)

#EDENITE

Sodium calcium magnesium iron aluminum silicate hydroxide, $NaCa_2(Mg,Fe^{2+})_5$-$Si_7AlO_{22}(OH)_2$. An uncommon hornblendelike member of the amphibole group of silicates.

Cochise County: Bisbee, Warren district, Lowell shaft, a white to gray fibrous mineral, associated with tremolite and kaolinite (Graeme, 1981).

EGLESTONITE

Mercury oxychloride, Hg_4OCl_2. Commonly associated with other mercury minerals in ore deposits of that metal; closely associated with calomel, from which it may be derived by oxidation.

Maricopa County: Mazatzal Mountains, Sunflower district, with calomel and metacinnabar (UA 217; specimen collected by Carl Lausen).

#Eichbergite(?)

Copper iron bismuth antimony sulfide, $(Cu,Fe)(Bi,Sb)_3S_5$(?). A mineral of questioned validity, formerly reported (Palache et al., 1944) from a magnesite deposit in Styria, Germany [*sic*; Styria is a province of Austria], but which has not been reported or verified in the literature since its original description.

Maricopa County: Cortez prospect, in vein quartz with bismuthinite and neyite.

ELBAITE (see Tourmaline)

#Electrum (gold-silver alloy; "argentian gold")

Cochise County: Bisbee, Warren district, in ores of the Campbell mine.

Embolite

Silver chloride bromide, Ag(Cl,Br). An intermediate member of the chlorargyrite-bromargyrite solid-solution series that formed, as they did, from primary silver minerals in the oxidized portions of silver deposits.

Cochise County: Tombstone district, Toughnut mine; State of Maine mine, with chlorargyrite, as the primary silver ore mineral (Rasor, 1938). Commonwealth mine at Pearce, especially abundant and associated with chlorargyrite, bromargyrite, iodargyrite, and acanthite in quartz veins (Endlich, 1897; Guild, 1910; UA 3567, 7527). Warren district, with malachite (H 94744).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as octahedral crystals on caledonite.

Santa Cruz County: Noon Camp, Nogales area (S 48704).

EMMONSITE

Iron tellurium oxide hydrate, $Fe_2Te_3O_9 \cdot 2H_2O$. A rare secondary mineral formed by the alteration of tellurides and tellurium. The occurrence near Tombstone is the type locality. It seems likely, however, that the type description was based on rodalquilarite.

Cochise County: Unknown locality near Tombstone, as "yellowish green, translucent, crystalline scales and patches throughout a rather hard brownish gangue composed of lead carbonate, quartz, and a brown substance containing oxidized iron and tellurium plus water" (Hillebrand, W.F., 1885). One of several partial analyses (by Hillebrand) of impure type material gave the following results (wt %):

Te(Se)	59.14	ZnO	1.94
Fe	14.20	CaO	0.56

The specific gravity was determined as being "not less than 5." Toughnut-Empire mine, with mackayite and tellurium (Bideaux et al., 1960); Frondel, C., and Pough (1944) noted that the mineral from Tombstone formed in a hard brownish gangue composed of an intimate mixture of cerussite, quartz, and a brownish oxygenated compound of iron and tellurium. The mineral is associated with cerussite and rodalquilarite on a specimen found at the surface between the dumps of the Joe and Grand Central shafts (Williams, S.A., 1981b).

#EMPLECTITE

Copper bismuth sulfide, $CuBiS_2$. In hydrothermal veins with other sulfides and sulfosalts formed at moderate temperatures.

Cochise County: Warren district, from the sulfide ores of the Campbell mine (Graeme, 1993).

EMPRESSITE

Silver telluride, $Ag_{2-x}Te_{1+x}$. This silver telluride is considerably rarer than hessite.

Cochise County: Tombstone district, Joe mine, as large (1-in.) masses of tin-white crystalline material in flinty quartz-opal gangue; partly altered to rickardite, then to anglesite and rodalquilarite.

ENARGITE

Copper arsenic sulfide, Cu_3AsS_4. Found in veins and replacement deposits formed under moderate-temperature conditions; associated with other sulfides.

Cochise County: Warren district, Campbell mine, as rounded grains and blades, primarily in chalcocite but in bornite as well; also associated with tetrahedrite, tennantite, and famatinite (Schwartz and Park, 1932).

Gila County: Globe-Miami district, Miami mine, with tennantite and aikinite in veins cutting chalcopyrite (Legge, 1939).

Pinal County: Superior district, where it is the most important ore mineral of copper in the lowest levels of the Magma mine (Short et al., 1943). Galiuro Mountains, Childs-Aldwinkle mine, sparingly with tennantite (Kuhn, 1941).

Santa Cruz County: Patagonia district, Volcano mine (UA 5858), as a rare vein mineral with pyrite, beneath a chalcocite enrichment blanket (Kistner, 1984).

Yavapai County: Wickenburg Mountains, Monte Cristo mine, associated with tennantite, nickeline, and silver (Bastin, 1922).

ENDELLITE

Aluminum silicate hydroxide hydrate, $Al_2Si_2O_5(OH)_4{\cdot}2H_2O$. A hydrated member of the kaolinite group; in places formed by the action of sulfate-containing waters on kaolinite, but also formed independently of it. A hydrothermal alteration mineral associated with porphyry copper deposits. In Arizona, the distinction has generally not been made between halloysite and the hydrated mineral, endellite.

Cochise County: Warren district, Southwest mine, as a product of hydrothermal alteration (Schwartz, 1956).

Gila County: Globe-Miami district, as a product of hydrothermal alteration in granite porphyry, near orebodies in schist (Schwartz, 1947); Castle Dome mine, in small amounts in the capping and in the chalcocite zone in quartz monzonite (Peterson, N.P., et al., 1946).

Graham County: Gila Mountains, Lone Star district.

Greenlee County: Morenci district, with allophane, as a product of intense hydrothermal activity (Schwartz, 1947, 1958).

Pima County: Silver Bell Mountains, Silver Bell mine.

Pinal County: Mammoth district, San Manuel mine, in small veinlets in alunite-kaolinite rock (Lovering et al., 1950; Schwartz, 1953). Mineral Creek district, Ray orebody, in the hydrothermally altered porphyry stock, associated with sericite, kaolinite, and hydromuscovite; as veinlets and coating fracture surfaces; commonly exhibits colloform texture and may be intergrown with chrysocolla (Schwartz, 1934, 1947; Stephens and Metz, 1967).

ENSTATITE

Magnesium silicate, $MgSiO_3$. A member of the pyroxene group of rock-forming minerals. Common in mafic igneous rocks such as gabbro, norite, and peridotite and in their extrusive equivalents. Associated with calcic plagioclase feldspars.

Gila County: Dripping Spring Mountains, Banner district, on the Reagan claims near the 79 mine.

Pima County: Ajo district, in the basal facies of the Batamonte andesite series (Gilluly, 1937).

Santa Cruz County: Santa Rita and Patagonia Mountains, sparingly in some andesites.

#EOSPHORITE

Manganese aluminum phosphate hydroxide hydrate, $MnAl(PO_4)(OH)_2.H_2O$. Found in granite pegmatite with other phosphate minerals.

Maricopa and Yavapai Counties: White Picacho district, in granite pegmatites (London, 1981).

EPIDOTE

Calcium aluminum iron silicate hydroxide, $Ca_2(Al,Fe)_3Si_3O_{12}(OH)$. Forms in a wide variety of rock types; characteristically a product of low- to medium-grade thermal metamorphism of igneous and sedimentary rocks. In the southwestern United States, it is a product of propylitic alteration of country rock, associated with base-metal mineralization. Also common in contact-metamorphosed limestones with other calcium silicates. Widespread in the southern part of the state.

Apache County: Monument Valley, Garnet Ridge, in the matrix of ejection boulders of garnet gneiss (Gavasci and Kerr, 1968).

Cochise County: Tombstone district, in shale and quartzite (Butler, B.S., et al., 1938b). Chiricahua Mountains, common in the California district where a copper-bearing epidote vein up to 5 ft wide extends for over 1 mile (Dale et al., 1960). Turquoise district, in the wall rocks of pyritic deposits in Abrigo Limestone. Warren district, Sacramento Hill, in hydrothermally altered porphyry dikes in limestone (Schwartz, 1947, 1958, 1959). Cochise district, abundant in metamorphosed limestones and shales near the Texas Canyon stock (Kellogg, 1906; Cooper and Silver, 1964).

Gila County: Globe-Miami district, Castle Dome mine, in the marginal parts of the mineralized area (Peterson, N.P., et al., 1946; Creasey, 1959); Copper Cities deposit (Peterson, N.P., 1954). Payson district, Harrington claims, with chalcopyrite. Dripping Spring Mountains, Banner district, Christmas mine (Ross, C.P., 1925a; Perry, D.V., 1969); 79 mine, in contact-metamorphosed limestones with diopside, andradite, and tremolite (Keith, 1972).

Graham County: Aravaipa (Simons, 1964) and Stanley (Ross, C.P., 1925a) districts, widely distributed in contact metamorphic copper deposits. Lone Star district, San Juan property, in the strong propylitic alteration zone, which is locally peripheral to a chlorite-pyrite zone, in andesite, associated with chlorite and carbonates (Rose, 1970).

Greenlee County: Clifton-Morenci district, in contact-metamorphosed rocks, rarely as well-defined crystals (Lindgren, 1905; Reber, 1916).

La Paz County: Abundant in metamorphosed limestones at several localities. Dome Rock Mountains, in wall rocks of cinnabar veins.

Mohave County: Cerbat Mountains, Wallapai district, common as an alteration product of wall rocks in sulfide vein deposits in gneisses (Thomas, B.E., 1949).

Pima County: Santa Rita Mountains, widespread in metamorphosed limestones in the wall rocks of copper deposits (Schrader and Hill, 1915; Schrader, 1917). Sierrita Mountains, common as a metamorphic mineral and as an alteration product in igneous dikes; Sierrita mine, a product of the hydrothermal alteration of dioritic rocks (Roger Lainé, pers. commun., 1973); the results of many chemical analyses of epidotes in the Sierrita Mountains are given in Fellows (1976). Pima district, in contact metamorphic deposits in limestones, in considerable amounts with magnetite, garnet, wollastonite, and hedenbergite (Webber, 1929; Eckel, 1930a); in the tactites and skarns of the Twin Buttes mine (Stanley B. Keith, pers. commun., 1973). Santa Catalina Mountains, in contact metamorphic copper deposits near Marble Peak, in places as splendid crystals (Dale et al., 1960); Pontotoc mine (Guild, 1934). Ajo district, as a widespread but sparse mineral formed as an alteration product of dark silicate minerals (Gilluly, 1937; Schwartz, 1947, 1958; Hutton and Vlisidis, 1960). Tucson Mountains (UA 7139). Silver Bell Mountains, as an alteration product in dacite porphyry (Kerr, 1951).

Pinal County: Mammoth district, San Manuel and Kalamazoo orebodies, in hydrothermally altered quartz monzonite and monzonite porphyries, associated with the less intensely altered areas; associated with zoisite, chlorite, hydrobiotite, and secondary biotite (Schwartz, 1947; Creasey, 1959; Lowell, J.D., 1968).

Santa Cruz County: Santa Rita and Patagonia Mountains, abundant in metamorphosed limestones (Schrader and Hill, 1915); Tyndall district, Glove mine (Olson, H.J., 1966).

Yavapai County: Bradshaw Mountains, in lenses in schist; Weaver district, in dikes at Rich Hill. Reported in Pylan Creek, 12 miles southeast of Wagoner, as crystals with a prism diameter of 5 in. White Picacho district, as small, widely dispersed crystals (Jahns, 1952). Big Bug district, Iron King mine, in gabbro and diorite, associated with clinozoisite (Creasey, 1952).

EPSOMITE

Magnesium sulfate hydrate, $MgSO_4 \cdot 7H_2O$. A secondary mineral commonly formed as efflorescences in old mine workings or caves.

Cochise County: Warren district, as a late secondary mineral in some of the mines (Richard Graeme, pers. commun., 1974).

Greenlee County: Clifton-Morenci district, as delicate efflorescences on the wall of mine openings (Lindgren, 1905; Guild, 1910).

Pima County: Silver Bell Mountains, El Tiro mine, as capillary, hairlike crystals; reported in the Pima district. Ajo district, in the oxidized portion of the New Cornelia orebody, possibly of postmine origin (Gilluly, 1937).

Pinal County: Mammoth district, San Manuel mine, with other secondary sulfate minerals coating mine openings.

Santa Cruz County: Unspecified locality south of Patagonia (UA 6732).

ERIONITE

Calcium sodium potassium aluminum silicate hydrate, $(Ca,Na_2,K_2)Al_9Si_{27}O_{72} \cdot 27H_2O$. A member of the zeolite group. Researchers disagree whether this species is actually offretite. Hey and Fejer (1962) maintain that the species are identical and that offretite has priority; however, Fleischer (1966) states that a vote on the matter by the Commission on New Minerals and Mineral Names of the International Mineralogical Association was indecisive.

Cochise County: San Simon Basin, 7 miles northeast of Bowie, in bedded lake deposits associated with analcime, herschelite, chabazite, clinoptilolite, thenardite, and halite (Regis and Sand, 1967; Edson, 1977).

Mohave County: East of Big Sandy Wash, east half of T. 16 N., R. 13 W., in Pliocene tuff with analcime, chabazite, clinoptilolite, and phillipsite (Ross, C.S., 1928, 1941).

Pima County: Ajo, Well No. 1 of the Phelps Dodge Corp. (William Thomas, pers. commun., 1988).

Pinal County: In a railway cut 1 mile north of Malpais Hill on the west side of the San Pedro River, with chabazite, phillipsite, heulandite, and calcite, on celadonite (Richard Thomssen, 1983; UA 9221).

Santa Cruz County: Red Mountain porphyry copper prospect, as a rare mineral, with pyrite (Kistner, 1984).

Yavapai County: 4.2 miles south of Kirkland Junction on U.S. Highway 89, in altered tuff with clinoptilolite (Eyde, 1978).

ERYTHRITE

Cobalt arsenate hydrate, $Co_3(AsO_4)_2 \cdot 8H_2O$. Commonly contains nickel; a complete solid-solution series extends to annabergite, $Ni_3(AsO_4)_2 \cdot 8H_2O$. A secondary mineral typically formed by the oxidation of cobalt and nickel arsenides.

Apache County: Reported in the White Mountains, exact locality unknown, with cobaltite.

Gila County: Locality 0.5 mile northeast of the Mule Shoe Bend of the Salt River.

Navajo County: Near the Salt River at Show Low (UA 1996).

Yavapai County: Black Hills, near claims of the Old Prudential Copper Co., as powdery incrustations from the alteration of cobaltite (Guild, 1910).

ETTRINGITE

Calcium aluminum sulfate hydroxide hydrate, $Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O$. Typically formed by the alteration of contact-metamorphosed limestones.

Cochise County: Tombstone district, Lucky Cuss mine, as an alteration product of calcium and aluminum silicates (Butler, B.S., et al., 1938b; H 68800). An analysis (Moses, 1893) of material discovered by W.F. Stanton gave the results (wt %) shown below. This analysis permitted a formula to be assigned to the species for the first time.

CaO	25.615	H_2O(115°)	33.109
Al_2O_3	10.157	Loss (red heat)	10.872
SO_3	17.675	SiO_2	1.901
		TOTAL	99.329

EUCRYPTITE

Lithium aluminum silicate, $LiAlSiO_4$. Formed from the alteration of spodumene. Commonly intergrown with albite in pegmatites.

Yavapai County: White Picacho district, Midnight Owl and Independence pegmatites (London and Burt, 1978, 1982b; London, 1981).

#EUGENITE

A silver mercury intermetallic compound, $Ag_{11}Hg_2$.

Cochise County: Warren district, Southwest mine, as grains measuring 1 micron or less, in massive cuprite.

EUXENITE

Yttrium calcium cerium uranium thorium niobium tantalum titanium oxide, $(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)_2O_6$. A member of the euxenite-polycrase series. A rare mineral formed in granite pegmatites.

Maricopa County: White Tank Mountains, Caterpillar Tractor testing grounds, as massive to poorly crystalline material with zircon crystals in a pegmatite (Phil Hooker, pers. commun., 1985).

Mohave County: Cerbat Mountains, Kingman Feldspar mine, as scattered masses weighing up to 50 lb, in pegmatite. Near the Aquarius Mountains, east of the Big Sandy Wash and south of Burro Creek, in pegmatites as small pockets or kidneys (Shaw, 1959).

Navajo County: Holbrook district, Hugh Baron claim.

Pima County: Sierrita Mountains, New Year's Eve mine, associated with molybdenite and chalcopyrite.

F

FAIRBANKITE

Lead tellurite, $PbTeO_3$. An extremely rare mineral formed by the oxidation of other tellurium-bearing minerals. The Tombstone occurrence is the type locality.

Cochise County: Tombstone district, restricted to one fist-sized specimen found on the waste dump of the Grand Central mine. As tiny (less than 0.5 mm), clear, colorless crystals in a thin crust plastered on the walls of voids left by the leaching of galena. Closely associated with oboyerite. An analysis by Marjorie Duggan (Williams, S.A., 1979) gave the following results (wt %). The analysis was recalculated to 100% to allow for cerussite contamination.

PbO	58.3
TeO_3	41.7
TOTAL	100.0

FAIRCHILDITE

Potassium calcium carbonate, $K_2Ca(CO_3)_2$. Found in clinkers formed in partly burned trees, with bütschliite and calcite. Because the characterization of the species was based on material from Arizona as well as from Idaho, the deposit noted below constitutes a co–type locality.

Coconino County: Grand Canyon National Park. Discovered by Ranger William J. Kennedy in an unspecified, partly burned tree "at a fire on the north side of Kanabownits Canyon one-quarter mile from the Point Sublime road and one-half mile from the North Entrance road" (Milton, 1944; Milton and Axelrod, 1947; Mrose et al., 1966).

#FAIRFIELDITE

Calcium manganese iron phosphate hydrate, $Ca_2(Mn^{2+},Fe^{2+})(PO_4)_2 \cdot 2H_2O$.

Formed in granite pegmatite.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites (London, 1981).

FAMATINITE

Copper antimony sulfide, Cu_3SbS_4. Less common than enargite, which is typically associated with it and is similar to it in structure. Typically formed in moderate-temperature replacement deposits and veins with other sulfides.

Cochise County: Tombstone district, in small amounts in the Ingersoll and Toughnut mines (Butler, B.S., et al., 1938b). Warren district, Campbell mine, as rounded grains and blades, largely confined to chalcocite and bornite but also associated with tetrahedrite, tennantite, and enargite; may form coarse, graphic intergrowths with chalcocite (Schwartz and Park, 1932).

Pinal County: Reported in the Pioneer district, Magma mine, with the hypogene ores (Hammer and Peterson, 1968).

FAYALITE (see also Olivine)

Iron magnesium silicate, $(Fe,Mg)_2SiO_4$. Present in small amounts in certain felsic and alkaline volcanic and plutonic igneous rocks; also formed during the regional metamorphism of iron-rich sedimentary rocks.

Gila County: Near Peridot and Tolklai, as a minor constituent of volcanic bombs and stream gravels (Mason, 1968).

FERBERITE (see WOLFRAMITE)

FERGUSONITE

Yttrium niobium tantalum oxide, $Y(Nb,Ta)O_4$. A rare mineral found in granite pegmatites with other rare earth minerals, niobates, and tantalates.

Mohave County: Aquarius Mountains, Rare Metals mine, in pegmatite; the sample showed an X-ray diffraction pattern that resembled fergusonite upon ignition (Heinrich, 1960).

Yavapai County: Near Yarnell, Mica-Feldspar quarry northwest of the highway maintenance camp on White Spar Road.

FERNANDINITE

Calcium vanadium iron oxide hydrate, $Ca(V^{5+},V^{4+},Fe^{2+})_8O_{20}\cdot 4H_2O$. A rare vanadium mineral that may be of primary origin.

Apache County: Monument Valley, Monument No. 2 mine, with doloresite and other oxidized vanadium minerals (Witkind and Thaden, 1963).

#FERRICOPIAPITE

Iron sulfate oxide hydroxide hydrate, $Fe^{2+}Fe_4^{3+}(SO_4)_6O(OH)\cdot 20H_2O$. One of several yellowish secondary iron sulfates formed through the breakdown of pyrite; probably the result of oxidation of part of the ferrous iron of copiapite.

Cochise County: Bisbee, Warren district, with the sulfide minerals of the Campbell orebody, as silky-yellow to greenish-yellow, rounded crystals (Graeme, 1993).

#FERRIERITE

Sodium potassium magnesium aluminum silicate hydroxide hydrate, $(Na,K)_2Mg\text{-}Al_3Si_{15}O_{36}(OH)\cdot 9H_2O$. An uncommon member of the zeolite group of silicates.

Maricopa County: In road cuts on the new Lake Pleasant Road, in vugs in basalt (William Hunt, pers. commun., 1992).

Pima County: Ajo, New Cornelia open-pit mine, in a dike, with heulandite and calcite (Thomas, W.J., and Gibbs, 1983; UA 12291); as microcrystals (UA x3495).

FERRIMOLYBDITE

Iron molybdate hydrate, $Fe_2(MoO_4)_3\cdot 8H_2O$(?). A secondary mineral typically formed by alteration of molybdenite.

Cochise County: Warren district, along the Dividend Fault, in the Lavender pit (Graeme, 1993).

Gila County: Globe-Miami district, Castle Dome and Copper Cities mines (Peterson, N.P., et al., 1951; Peterson, N.P., 1962).

Mohave County: Kingman area, as short fibrous material encrusting quartz (H 95978; also UA 8207-8211). Mineral Park district, in the oxide zone at Ithaca Peak as a common replacement product of molybdenite (Eidel et al., 1968).

Pima County: South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Santa Rita Mountains, near Madera Canyon, as hairlike crystals and tufts. The composition (wt %) of this material, based on the average of two analyses (Guild, 1907), is as follows:

Fe_2O_3	21.835	MoO_3	60.805	H_2O	17.355
				TOTAL	99.995

These results yielded the formula $Fe_2(MoO_4)_3\cdot 7H_2O$. Sierrita Mountains, Pima district, New Year's Eve Breccia, Esperanza pit, with tungsten-rich rutile, as black crystals up to 1 cm long, with molybdenite (Kuck, 1978); Twin Buttes mine, East pit (Kuck, 1978).

Pinal County: Galiuro Mountains, Copper Creek district, Childs-Aldwinkle mine, as yellow powder and radiating crystal aggregates (Kuhn, 1941). Tortolita Mountains, Rare Metals mine (UA 9488).

Santa Cruz County: Patagonia Mountains, Red Mountain mine (Schrader and Hill, 1915).

Yavapai County: Copper Basin district, in the oxidized portions of sulfide deposits (Johnston, W.P., and Lowell, 1961). Crazy Basin property near Cleator, as yellow fibrous masses in vugs in quartz, with molybdenite.

#FERRO-ACTINOLITE

Calcium iron magnesium silicate hydroxide, $Ca_2(Fe^{2+},Mg)_5Si_8O_{22}(OH)_2$.

Typically formed in regionally or contact-metamorphosed rocks, especially those with a high amount of iron.

Gila County: As compact, radiating aggregates in the southwestern workings of the Kullman-McCool group; identified by electron microprobe analysis (Jeff Roberts, pers. commun., 1991).

#FERRO-COLUMBITE

Iron niobium oxide, $Fe^{2+}Nb_2O_6$. Formed in granite pegmatites.

Maricopa County: Mummy Mountain in Phoenix, as microscopic crystals with niobian rutile in pegmatite.

Pima County: Ajo district, San Antonio group, Valentine 1, 2, and 3 claims, as massive material (MM 7866 is identified as ferrocolumbite; MM 7865 is identified as ferrotantalite).

Yavapai County: White Picacho district, Midnight Owl pegmatite mine.

#FERROKAERSUTITE

Sodium calcium iron magnesium titanium aluminum silicate hydroxide, $NaCa_2(Fe^{2+},Mg)_4TiSi_6Al_2O_{22}(OH)_2$. Forms a series with kaersutite. A rock-forming silicate mineral of the amphibole group.

Gila County: San Carlos Indian Reservation, Soda Springs vent, as megacrysts up to 6 cm long in a mugearite (rock) with kaersutite, anorthoclase, ulvöspinel, and ferroan biotite (Caporuscio, 1980).

#FERROTAPIOLITE (both a group and mineral name).

Iron magnesium manganese zinc niobium antimony tantalum oxide, $(Fe^{2+},Mg,Mn,Zn)(Nb,Sb,Ta)_2O_6$. A rare mineral found in granite pegmatites and as a detrital mineral derived from them.

Yavapai County: Bradshaw Mountains, in stream gravels on Castle Creek. This occurrence is most likely the specific mineral ferrotapiolite.

#FERVANITE

Iron vanadate hydrate, $Fe^{3+}_4(VO_4)_4 \cdot 5H_2O$. Found among the uranium-vanadium ores of the Colorado Plateau.

Apache County: Monument No. 2 mine, where H.T. Evans identified it in a Triassic fossilized tree (Haynes, 1991).

FIBROFERRITE

Iron sulfate hydroxide hydrate, $Fe(SO_4)(OH) \cdot 5H_2O$. A secondary mineral formed through the oxidation of pyrite. Typically associated with other iron-bearing sulfates such as jarosite, copiapite, and melanterite.

Cochise County: Warren district, 700-ft level of the Shattuck mine, abundant as crusts on pyritic ores. The mineral is readily recognizable by its peculiar gummy or sectile behavior.

#FILLOWITE

Sodium calcium manganese iron phosphate, $Na_2Ca(Mn,Fe^{2+})_7(PO_4)_6$. From granite pegmatites.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites (London, 1981).

FLAGSTAFFITE

Cis-terpin monohydrate, $C_{10}H_{18}(OH)_2 \cdot H_2O$. A mineral formed in fossil logs.

Coconino County: In debris washed down from the San Francisco Mountains, a few miles north of Flagstaff, as a filling in radial cracks of certain buried tree trunks; a yellowish resinous material probably derived from natural resins of the tree through hydration or oxidation; as orthorhombic crystals up to 1 mm long in drusy cavities (Guild, 1920, 1921, 1922; Strunz and Contag, 1965). This is the type and only reported locality.

Flint (see QUARTZ)

FLUORAPATITE (see APATITE)

FLUORITE

Calcium fluoride, CaF_2. A widespread and common mineral. Commonly formed as a primary mineral in veins, of which it is the chief constituent, or in the gangue of lead, zinc, and silver ores. It is also found in sedimentary rocks such as limestones and dolomites, and in plutonic igneous rocks such as granites and monzonites.

Cochise County: Tombstone district, locally abundant in some silicified areas, particularly at the Empire mine (Butler, B.S., et al., 1938b). Reported near Government Draw, as purple crystals with quartz. Chiricahua Mountains, as small quantities mined from quartz veins near Paradise. Little Dragoon Mountains, in a granite pegmatite, with hübnerite (Guild, 1910; Palache, 1941a; Cooper and Huff, 1951; Cooper and Silver, 1964). Whetstone Mountains, in a vein west of San Juan siding (Hewett, 1964).

Gila County: Payson district, Oxbow mine, with epidote (Lausen and Wilson, 1925). Eastern Tonto Basin, Packard claims, as white, light-blue, and purple masses in veins (Batty et al., 1947). Globe district, Castle Dome mine, in small amounts in open fractures, associated with barite (Peterson, N.P., et al., 1951).

Graham County: Aravaipa district, Grand Reef mine and in veins of the Landsman group (Simons, 1964). Stanley Butte, as crystals in barite veins (Ross, C.P., 1925a).

Greenlee County: In gouge in veins in andesite at several properties near Duncan (Allen, M.A., and Butler, 1921b; Ladoo, 1923), especially the Luckie and Fourth of July mines, where fluorite is covered by mammillary layers of psilomelane (Hewett et al., 1963; Hewett, 1964); Ellis mine (Batty et al., 1947).

La Paz County: Trigo Mountains, Silver district, as crystalline masses and dense, varicolored bands coating quartz, and as vein material with quartz and barite; Padre Kino mine, as microcrystals with willemite and wulfenite (Peter Megaw, UA x2478); Silver King mine, as microcrystals (Peter Megaw, UA x1829). Eastern slopes of the Plomosa Mountains, in most barite veins, which form in association with manganese-oxide veins (Hewett, 1964). Buckskin Mountains, Chicago and Mammoth properties, with barite. McWilliams group near Bouse, as purple octahedra up to 1 cm on an edge (MM L530).

Maricopa County: Harquahala Mountains, Snowball property, in veins in Precambrian rocks, with barite (Denton and Kumke, 1949; Hewett, 1964). Vulture Mountains, west of Morristown, in veins. Reported in the White Tank Mountains. In a quartz quarry at Pinnacle Peak, east of Paradise Valley. Painted Rock Mountains, Rowley mine near Theba, in small amounts as colorless to violet masses in quartz veins; commonly as cubic or dodecahedral microcrystals, some of which are elongated on [1 1 1] (Wilson, W.E., and Miller, 1974). High crest of the Belmont Mountains, in the Belmont Granite, as small, purple crystals in miarolitic cavities with quartz crystals, muscovite, biotite, and epidote (Reynolds et al., 1985).

Mohave County: Black Mountains, northern part of the Oatman (San Francisco) district, as white to pale-green bands or as linings of cavities (Schrader, 1909); Skinner lode, south of Silver Creek, "as beautiful octahedral crystals of green, white, and purple . . . in a quartzose and feldspathic gangue with occasional gray spots of minutely diffused sulphide of silver"; at other smaller properties of the district, including the Caledonia, Dayton, Quackenbush, and Knickerbocker properties (Silliman, 1866). Cerbat Mountains, Wallapai district, Alta and Tintic mines, as a late gangue mineral known from two veins in a belt of sulfide-containing fissure vein deposits, associated with a granite porphyry stock (Thomas, B.E., 1949). Artillery Peak, Artillery Mountains district, with barite in veins that contain manganese oxides and cut the Artillery Formation (Hewett and Fleischer, 1960; Hewett, 1964). Potts Mountain, Owens district, as purple material, cementing breccia (Robert O'Haire, pers. commun., 1972). Boriana mine, of a rich purple color, in quartz veins (Hobbs, 1944). Near Wright Creek Ranch (about 15 miles south of Peach Springs), Blue Bird or Bountiful Beryl prospect, in several irregular pegmatite dikes in schist and granite, with sphene, garnet, schorl, and beryl, and in microcline-albite-quartz pegmatite (Schaller et al., 1962).

Pima County: Santa Rita Mountains, Helvetia-Rosemont district, New York mine (Hewett, 1964); Gunsight mine, as microcrystals (William Kurtz, UA x4414). Silver Bell Mountains, at several properties (Guild, 1910). Sierrita Mountains, Neptune property, as veins from a few inches to 2 ft wide (Allen, M.A., and Butler, 1921b); Mission pit, as microcrystals, with tetrahedrite and dolomite (UA x2548). As geodes in the southern Santa Catalina Mountains (UA 1571) and as microcrystals at the Old Spanish mine (William Kurtz, UA x436).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, abundant as microscopic crystals in the lower levels; as crystals up to 1 in. on an edge (Peterson, N.P., 1938; Fahey, 1955; Bideaux, 1980).

Santa Cruz County: Patagonia Mountains, Harshaw district, Alta mine, as red material with embolite and chlorargyrite (Schrader and Hill, 1915; Schrader, 1917).

Yavapai County: Eureka district, Bagdad copper mine, in small pockets in pegmatite, associated mainly with triplite and a green mica (Hurlbut, 1936). Bradshaw Mountains, Pine Grove district, Springfield group; Castle Creek district, Swallow mine. McCloud Mountains, at a prospect near the Leviathan mine from which fluorite has been shipped. Northeast of Congress Junction, as dodecahedral crystals 3 to 4 in. in diameter, in pegmatite dikes (Jahns, 1953). Black Rock district, Monarch copper mine, common as white and green octahedral crystals up to 5 cm.

Yuma County: Castle Dome Mountains, Castle Dome district, as greenish, purple, and rose-colored crystals and clear cleavable masses up to several inches in diameter, locally associated with galena, barite, and wulfenite; dark-blue to almost black fluorite from this district, particularly from the Hull mine, is photosensitive and changes to light gray or pink on exposure to sunlight (Ladoo, 1923; Wilson, E.D., 1933; Batty et al., 1947; Peterson, N.P., 1947); Big Dome claim (Allen, M.A., and Butler, 1921b). Kofa district, in deposits in layered volcanic rocks (Hewett, 1964).

FORNACITE

Lead copper chromate arsenate hydroxide, $(Pb,Cu)_3[(Cr,As)O_4]_2(OH)$. A rare secondary mineral found at few localities in the world.

Cochise County: Warren district, Shattuck shaft (Graeme, 1981).

Gila County: Dripping Springs Mountains, Banner district, at the 79 mine (UA 12173), and as microcrystals (UA x2319).

La Paz County: New Water Mountains, Eagle Eye mine, as small crystalline rosettes.

Pima County: Amole district, Old Yuma mine, on hematite and quartz (Bideaux et al., 1960), as microcrystals (William Kurtz, UA x3978). Gila Monster mine, with cerussite and wulfenite (Richard L. Jones, pers. commun.). Ajo, 0.5 mile south of the New Cornelia pit, with cerussite and chlorargyrite as films coating fracture surfaces in altered andesite. Copper Point prospect, as microcrystals (UA x3361).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, with wulfenite and fluorite, as crystals up to several millimeters long (Bideaux et al., 1960; Bideaux, 1980; UA 3401), and as fiberlike microcrystals with creaseyite (Bruce Maier, UA x1933). Slate Mountains, in dumps near the Roadside mine, as sharply formed crystals with shattuckite and cerussite. Vekol mine, with wulfenite and chlorargyrite.

Yavapai County: Constellation, with crocoite (John S. White, Jr., pers. commun.).

FORSTERITE (see also Olivine)

Magnesium iron silicate, $(Mg,Fe)_2SiO_4$. The magnesium-rich portion of the olivine series, of which fayalite is the iron-rich end member. Forsterite is associated with dunites, peridotites, some basalts, and olivine-rich, layered intrusive rocks. It is also formed during thermal and contact metamorphism of dolomites and magnesium-bearing limestones.

Cochise County: Little Dragoon Mountains, near Johnson Camp, with epidote, zoisite, garnet, and other silicates, as a product of contact metamorphism of dolomitic rocks around the Texas Canyon stock (Cooper, 1957).

Gila County: Banner district, Christmas mine, as an important constituent of skarns formed in the Martin Formation and Escabrosa Limestone; associated with garnet, idocrase, calcite, anhydrite, and xanthophyllite (Perry, D.V., 1969).

Maricopa County: North end of the Estrella Mountains, at the contact between marble and pelitic schists, with zoisite, diopside, and tremolite (Sommer, 1982).

Pima County: Pima district, Twin Buttes mine, in garnetite (Stanley B. Keith, pers. commun., 1973); in skarns or tactites where the altered limestones were relatively pure (McNew, 1981).

Pinal County: Lakeshore mine, abundant in some portions of the metadolomite.

FOURMARIERITE

Lead uranium oxide hydrate, $PbU_4O_{13}\cdot 4H_2O$. A secondary mineral formed from lead and uranium derived from the alteration of uraninite; also formed as a constituent of gummite through alteration of uraninite.

Apache County: Monument Valley, Monument No. 2 mine, as small, reddish grains in uraninite, with schoepite and becquerelite (Frondel, C., 1956; Witkind and Thaden, 1963).

#FRAIPONTITE

Zinc aluminum silicate hydroxide, $(Zn,Al)_3(Si,Al)_2O_5(OH)_4$. An uncommon clay mineral of the kaolinite-serpentine group.

Cochise County: Near Gleeson, on the dumps of the Defiance–Silver Bill mines (Foord et al., 1983). Silver Bill mine, as microcrystals (UA x4357).

#FREIBERGITE

Silver copper iron antimony arsenic sulfide, $(Ag,Cu,Fe)_{12}(Sb,As)_4S_{13}$. A member of the tetrahedrite solid-solution series (see also this mineral description); some deposits of tetrahedrite-group minerals in mines yielding silver-rich ores are probably freibergite, although only the localities listed here are known to be authenticated.

Cochise County: Warren district, in the sulfide minerals of the Campbell orebody (Graeme, 1993).

Pinal County: Pioneer district, Silver King mine, as microcrystals (David Shannon, UA x4344).

Yavapai County: Big Bug district, Arizona National mine, in galena with acanthite and in cavities with wire silver (Lindgren, 1926).

FREIESLEBENITE

Silver lead antimony sulfide, $AgPbSbS_3$. A rare, medium- to low-temperature mineral formed in veins with acanthite, galena, siderite, and ruby silvers.

Yuma County: Castle Dome Mountains, from which a small amount was mined and shipped with other argentiferous ores.

#FRIEDRICHITE

Lead copper bismuth sulfide, $Pb_5Cu_5Bi_7S_{18}$.

Cochise County: Northeast flank of the Johnny Lyon Hills, as microscopic beads in vein quartz of metamorphic origin.

FROHBERGITE

Iron telluride, $FeTe_2$. An uncommon mineral formed in hydrothermal veins with gold, copper sulfides, and other tellurides.

Cochise County: Tombstone district, in one rock from the dump of the Joe shaft. The host rock is brecciated Bisbee Group shale cemented by granular pyrite (Williams, S.A., 1980b).

Fuchsite (chromian MUSCOVITE)

G

GADOLINITE

Beryllium Yttrium iron silicate, $Y_2FeBe_2SiO^{10}$. A rare mineral principally formed in granites and granite pegmatites.

Mohave County: Aquarius Mountains, Rare Metals mine, 30 miles south of Hackberry, in pegmatites from which several tons of the mineral have been mined (Heinrich, 1960). Near Kingman and in the northern part of the county, as fragments in sand dunes. Cerbat Mountains, Chloride district, as black, vitreous, rough prismatic crystals a few inches long, with beryl in pegmatite (Thomas, B.E., 1953).

Pima County: North side of the Rincon Mountains, with xenotime in biotite gneiss (Bideaux et al., 1960).

GAHNITE

Zinc aluminum oxide, $ZnAl_2O_4$. An uncommon member of the spinel group. Formed in schists, high-temperature replacement bodies in metamorphic rocks, and granite pegmatites.

Maricopa and Yavapai Counties: White Picacho district, as small, blue-gray to deep-green crystals in pegmatites that also contain greenish-black crystals of the ferroan variety of spinel, pleonaste (Jahns, 1952).

GALENA

Lead sulfide, PbS. A widely distributed primary mineral typically associated with zinc and copper sulfides and silver minerals. The most important ore mineral of lead; not uncommonly silver-bearing.

Apache County: Lukachukai Mountains, associated with secondary uranium and vanadium minerals in bedded deposits in the Salt Wash Member of the Morrison Formation (Joralemon, 1952).

Cochise County: Warren district, Campbell mine, from which considerable quantities were mined from 1945 to 1949 (Wilson, E.D., et al., 1950); Junction and Irish Mag mines. Tombstone district, in the orebodies of both the "roll" deposits and the fissure veins; extensively replaced by cerussite and to a lesser extent, by anglesite (Hewett and Rove, 1930; Butler, B.S., et al., 1938b; Rasor, 1939). Dragoon Mountains, Turquoise district, as scattered bunches in copper sulfide ores; Mystery mine (UA 7188). Little Dragoon Mountains, Primos mine, Johnson Camp area (Wilson, E.D., et al., 1950; Cooper and Huff, 1951; Cooper and Silver, 1964). Huachuca Mountains, Reef mine (Palache, 1941a). Chiricahua Mountains, Humboldt mine (Hewett and Rove, 1930); State of Texas and Panama mines (Wilson, E.D., et al., 1951). Swisshelm Mountains, as replacements in Naco Limestone (Wilson, E.D., et al., 1951).

Coconino County: Grand Canyon, on the South Rim near Bright Angel Lodge, associated with the uranium component of copper-uranium-lead ores in Coconino Sandstone (Isachsen et al., 1955).

Gila County: Globe-Miami district, in sparse amounts in all deposits (Peterson, N.P., 1962); Castle Dome mine (Brush, 1873; Peterson, N.P., et al., 1946; Peterson, N.P., 1947); Defiance mine, as remnants enclosed in shells of anglesite and cerussite (Wilson, E.D., et al., 1950). Dripping Spring Mountains, Banner district, 79 mine, as the most abundant hypogene ore mineral, commonly coated with smithsonite (Kiersch, 1949; Wilson, E.D., et al., 1951; Lewis, D.V., 1955; Keith, 1972); Christmas mine, in small amounts in orebodies replacing dolomite (Perry, D.V., 1969).

Graham County: Aravaipa district (Denton, 1947b), Head Center, Iron Cap, and Grand Central mines (Ross, C.P., 1925a; Simons and Munson, 1963; Simons, 1964; Wilson, W.E., 1988).

Greenlee County: Clifton-Morenci district, gold-bearing in the ores of the King mine; Stevens group of claims.

La Paz County: Trigo Mountains, Black Rock, Chloride, Silver King, and Silver Glance properties. Silver district, Red Cloud mine, highly argentiferous, probably contains acanthite (Hamilton, P., 1884; Foshag, 1919). Harquahala Mountains, Bonanza mine (Bancroft, H., 1911; Wilson, E.D., 1933; Wilson, E.D., et al., 1951). Plomosa Mountains, in barite veins with manganese oxides in layered volcanic rocks (Hewett, 1964).

Maricopa County: Painted Rock Mountains, Rowley mine (Wilson, W.E., and Miller, 1974; UA 4005). South of Wickenburg, Moon Anchor mine, Potter-Cramer property, and Rat Tail claim, where oxidization has produced a variety of secondary lead and chromium minerals (Williams, S.A., et al., 1970).

Mohave County: Common at many properties of the Cerbat Mountains (Haury, 1947; Tainter, 1947c) and Grand Wash Cliffs area (Schrader, 1909; Thomas, B.E., 1949). Sacramento district, from veins in metamorphic rocks (Silliman, 1866). Ithaca Peak area, with pyrite, chalcopyrite, and sphalerite in veins in a quartz monzonite stock (Eidel, 1966).

Pima County: Santa Rita Mountains, abundant at several properties, including the Ridley mine near Helvetia. Empire Mountains, Chief, Prince, and other properties of the Hilton group (Schrader and Hill, 1915; Schrader, 1917; Wilson, E.D., et al., 1950, 1951). Cerro Colorado Mountains, Cerro Colorado mine, with stromeyerite, tetrahedrite, and silver. Sierrita Mountains, Pima district; Papago district, Sunshine mine, as the main ore mineral (Ransome, 1922). Olive Camp, Helmet Peak area. South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Tucson Mountains, Old Yuma mine, with sparse tetrahedrite and supergene anglesite (Guild, 1917; Stanley B. Keith, pers. commun., 1973).

Pinal County: Pioneer district, Silver King mine (Guild, 1917); in fairly large bodies in the Belmont mine and in the ores of the Magma mine (Short et al., 1943). Mammoth district, Mammoth–St. Anthony mine, in the sulfide zone and altered to anglesite and cerussite in the oxidized zone (Peterson, N.P., 1938a,b; Wilson, E.D., et al., 1950; Fahey, 1955). Galiuro Mountains, Blue Bird mine, as the principal ore mineral (Simons, 1964); Saddle Mountain district, Adjust mine, silver-bearing; Saddle Mountain and Little Treasure properties. Dripping Spring Mountains, in several vanadium prospects near Kearny (Stanley B. Keith, pers. commun., 1973).

Santa Cruz County: Santa Rita Mountains, in many districts, including the Tyndall district, Glove mine (Olson, H.J., 1966). Patagonia Mountains, abundant in nearly all districts; Mowry mine, in ore having silver values up to 3,800 oz/ton; Flux mine, as excellent specimens of cubo-octahedral crystals; Holland mine (Marshall and Joensuu, 1961); Harshaw district, Trench mine, Haggin shaft, with sphalerite, alabandite, and rhodochrosite (Hewett and Rove, 1930); Stella mine near Duquesne, with chalcopyrite, diopside, and quartz (Stanley B. Keith, pers. commun., 1973). Oro Blanco Mountains, Montana mine, with sphalerite (Wilson, E.D., et al., 1951).

Yavapai County: Bradshaw Mountains, at several properties in the Walker, Hassayampa, Tiger, Tip Top, and Castle Creek districts, in many places with tetrahedrite; Big Bug district, Iron King mine, as the most abundant ore mineral (Creasey, 1952; Anderson, C.A., and Creasey, 1958). Eureka district, Hillside (Axelrod et al., 1951) and Bagdad mines (Anderson, C.A., 1950). Black Hills, Verde district, Shea property; Black Hills district, Shylock mine.

Yuma County: Castle Dome Mountains, Flora Temple, Señora, Little Dome, Hull, Lincoln, and Adams properties.

#GARRONITE

Sodium calcium aluminum silicate hydrate, $Na_2Ca_5Al_{12}Si_{20}O_{64}{\cdot}27H_2O$. An uncommon silica-poor zeolite, typically accompanied by other silica-poor zeolites, in silica-poor rocks.

Pinal County: About 5.5 miles south of Superior, in a middle Tertiary cinder cone, in olivine bombs and scoria, with cowlesite, levyne, and phillipsite (Tschernich, 1992, p. 187).

GEARKSUTITE

Calcium aluminum hydroxide fluoride hydrate, $CaAl(OH)F_4 \cdot H_2O$. An uncommon mineral, formed in pegmatites, hydrothermal veins, sedimentary rocks, and as a result of hot-spring activity.

Graham County: Aravaipa district, Grand Reef mine, as porcelaneous masses and powder, associated with barite, linarite, and other minerals in quartz-lined vugs (Jones, R.W., 1980).

GEDRITE

Magnesium iron aluminum silicate hydroxide $(Mg,Fe,Al)_7(Al,Si)_8O_{22}(OH)_2$. Similar to the species anthophyllite but containing aluminum (Deer et al., 1962). Typically restricted to metamorphic rocks.

Santa Cruz County: Patagonia Mountains, Duquesne–Washington Camp area, Westinghouse property, in contact-metamorphosed limestone (Schrader and Hill, 1915).

#GEIKIELITE

Magnesium titanium oxide, $MgTiO_3$. A mineral of the ilmenite group, commonly formed in magnesium-rich metamorphic rocks and serpentines.

Cochise County: Skeleton Canyon, near the New Mexico border, as lustrous black crystals up to 1 in. across in silicified tuff, found as float (David Garske, pers. commun.).

GERHARDTITE

Copper nitrate hydroxide, $Cu_2(NO_3)(OH)_3$. A rare secondary mineral formed under oxidizing conditions in copper deposits in arid and semiarid regions. Associated with minerals such as atacamite, brochantite, malachite, and azurite. Originally described by H.L. Wells and Penfield (1885) from the United Verde mine.

Greenlee County: Chase Creek Canyon, on cliffs of granite porphyry, as bright-green coating of small, rough, mammillary forms (Lindgren and Hillebrand, 1904; Lindgren, 1905; Guild, 1910). Morenci, as microcrystals (Carl Richardson, UA x4675).

Pima County: Pima district, Mineral Hill mine, Daisy shaft, as thin seams of granular material in cuprite, which is coated by aurichalcite (Williams, S.A., 1961).

Yavapai County: United Verde mine, as crystals up to 0.25 in., on fractures in massive cuprite (Wells, H.L., and Penfield, 1885). The composition (wt %), based on an analysis by H.L. Wells, nitric oxide by difference, is as follows:

CuO	66.26	N_2O_5	22.25	H_2O	11.49
				TOTAL	100.00

#GERSDORFFITE

Nickel arsenic sulfide, NiAsS. An uncommon mineral found in a few hydrothermal vein deposits formed at moderate temperatures.

Mohave County: Hack No. 2 mine, a uranium property (Casebolt et al., 1986).

GIBBSITE

Aluminum hydroxide, $Al(OH)_3$. A secondary mineral derived from the alteration of aluminous minerals; locally the chief constituent of bauxite deposits formed by weathering of aluminous rocks. Also formed as a low-temperature hydrothermal mineral in veins or cavities in igneous rocks.

Cochise County: Warren district, Sacramento pit, as massive, pale-blue botryoidal material, formed as an alteration product of chalcoalumite (see also this mineral description; Williams, S.A., and Khin, 1971).

Greenlee County: Clifton-Morenci district, reported as massive, white granular material.

GILALITE

Copper silicate hydrate, $Cu_5Si_6O_{17}{\cdot}7H_2O$. A retrograde metamorphic or mesogene silicate. Christmas is the type locality.

Gila County: Banner district, Christmas mine, abundant as green to blue-green coatings or thick botryoidal crusts on fracture surfaces or embedded in the rock, replacing diopside; as microscopic green spheres (Gene Wright, UA x1260); common as a matrix mineral with kinoite, junitoite, and ruizite. Based on the average of two closely agreeing analyses by Marjorie Duggan (Cesbron and Williams, 1980), the composition (wt %) is as follows:

CuO	36.2	SiO_2	41.5	CaO	3.8
FeO	—	H_2O	14.6	MnO	0.5
MgO	2.3			TOTAL	98.9

GIRDITE

Hydrogen lead tellurite tellurate, $H_2Pb_3(TeO_3)(TeO_6)$. A very rare species formed during oxidation of tellurium-bearing minerals. The mine dump at the Grand Central mine, Tombstone, is the type locality.

Cochise County: Tombstone district, in small amounts in the waste dumps of the Grand Central mine, associated with many other tellurites and tellurates, of which only emmonsite and rodalquilarite are common; common as dense, chalky spherules up to 3 mm in diameter, exceptionally up to 6 mm. Based on analyses by Marjorie Duggan (Williams, S.A., 1979), the composition (wt %) is as follows. These values are the average of two analyses recalculated to 100%.

PbO	63.2	TeO_3	18.2	H_2O	2.1
TeO_2	16.5			TOTAL	100.0

GISMONDINE

Calcium aluminum silicate hydrate, $Ca_2Al_4Si_4O_{16}\cdot 9H_2O$. A member of the zeolite group. Typically associated with lavas, especially basalts.

La Paz County: Near Salome, with dioptase (William Panczner, pers. commun., 1972).

#GLADITE

Lead copper bismuth sulfide, $PbCuBi_5S_9$. Of hydrothermal origin.

Cochise County: Dos Cabezas Mountains, Comstock mine, as small beads strung along the margins of pekoite prisms, which gladite appears to be replacing.

GLAUBERITE

Sodium calcium sulfate, $Na_2Ca(SO_4)_2$. A constituent of sedimentary salt deposits; also formed as isolated crystals in sedimentary rocks and associated with fumarolic activity.

Mohave County: Detrital Valley, in secs. 12 and 13, T. 29 N., R. 21 W., as crystals associated with halite and anhydrite in fine-grained sediments in the subsurface (H. Wesley Peirce, pers. commun., 1973).

Yavapai County: About 2 miles southwest of Camp Verde and in nearby Copper and Lucky Canyons, abundant as tabular crystals up to 2 to 3 in. long, as loose fragments in silts and clays and in masses of thenardite in the Verde Formation. Commonly replaced by gypsum, calcite, and aragonite to form pseudomorphs (Snyder, 1971; Thompson, J.R., 1983; see also Blake, W.P., 1890; Guild, 1910).

GLAUCONITE

Potassium sodium aluminum iron magnesium silicate hydroxide, $(K,Na)(Al,Fe^{3+},Mg)_2(Al,Si)_4O_{10}(OH)_2$. A member of the mica group. Formed during marine diagenesis under restricted conditions in arenaceous sedimentary rocks; the typical coloring agent in "greensands." Believed to have formed by the alteration of other silicate minerals.

Cochise County: North of the Swisshelm Mountains, in certain beds in the Cambrian Bolsa Quartzite.

Greenlee County: Clifton-Morenci district, in shale of the Morenci Formation and in green shales above the Coronado Quartzite (Lindgren, 1905).

Mohave County: Valley of the Big Sandy, east of Wikieup, as extensive sand beds of glauconite-coated analcime grains (Wilson, E.D., 1944; Robert O'Haire, pers. commun., 1973).

GMELINITE

Sodium calcium aluminum silicate hydrate, $(Na_2,Ca)Al_2Si_4O_{12}\cdot 6H_2O$. A member of the zeolite group, commonly formed in cavities in basaltic and related igneous rocks.

Cochise County: Reported near Bowie (Ted H. Eyde, pers. commun.).

GOETHITE

Iron oxide hydroxide, FeO(OH). Trimorphous with lepidocrocite and akaganeite. After hematite, the most common and abundant of the iron oxides. Formed under a wide range of oxidizing conditions but most typically as a weathering product of iron-bearing minerals. The abundant component of limonites. So abundant near mineralized areas in Arizona as to be practically ubiquitous.

Cochise County: Warren district, Shattuck and Copper Queen mines, as thick botryoidal crusts having fibrous structure; may be mixed with cuprite, copper, or tenorite (Frondel, C., 1941).

Greenlee County: Clifton-Morenci district, Morenci open-pit mine, as the most abundant oxidation product, with hematite (Moolick and Durek, 1966).

La Paz County: Cerbat Mountains, Wallapai district, in widespread limonites in the oxidized zones of vein sulfide deposits; may be associated with hematite, jarosite, and plumbojarosite (Thomas, B.E., 1949).

Pima County: Cerro Colorado district, Princess claim (UA 7472). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Ajo district, New Cornelia mine, as fine, earthy powder (Gilluly, 1937). Pima district, Twin Buttes open-pit mine, abundant in the oxidized capping (Stanley B. Keith, pers. commun., 1973).

Pinal County: Mineral Creek district, Mineral Creek deposit, northeast of Ray Hill, in copper-rich Holocene gravels, associated with hematite, azurite, malachite, cuprite, and tenorite (Phillips et al., 1971). Mammoth district, San Manuel mine, abundant in surface rocks that have been stained red by hematite (Schwartz, 1953).

Yuma County: Near Parker, as well-crystallized sheaves and fanlike aggregates, with malachite and hematite (Robert O'Haire, pers. commun., 1972).

GOLD

Gold, Au. Widely distributed, but commonly only in very small amounts. Rarely combines with other elements to form minerals, with the important exception of the gold tellurides. Most typically formed in hydrothermal quartz veins and, because of its superior chemical inertness and mechanical resistivity, in placer deposits derived from them. Also associated with copper sulfide deposits, especially in the oxidized zones.

In early times, American Indians and Spanish explorers of the Southwest had worked placer gold deposits. The mineral wealth of Arizona was not substantially exploited, however, until the middle and latter half of the 19th century, after the rediscovery of these deposits, especially those in Mohave, Yuma, and Cochise Counties. As the limited placer and lode deposits were rapidly depleted and modern copper-mining techniques were developed, especially for the huge, low-grade sulfide orebodies, more and more gold was produced as a by-product of the smelting of base-metal ores. Most of the placer gold in the state had been mined out by 1885 (Moore, R.T., 1969c), and the total output only slightly exceeded 400,000 oz (Elsing and Heineman, 1936). Since the late 1930's, almost all of the gold produced in the state has come from secondary sources. Shortly before World War II, gold production in Arizona reached an all-time-high annual rate of about 300,000 oz. Arizona ranks among the top gold producers in the United States.

The number of lode and placer gold mines and prospects in the state is large, and only a few are listed here. For more detailed information, the reader is referred to Bulletins 137 (lode deposits; Wilson, E.D., et al., 1934), 168 (placer deposits; Wilson, E.D., et al., 1961), and 180 (general; U.S. Geological Survey et al., 1969), published by the Arizona Bureau of Mines (now called the Arizona Geological Survey).

Lode Deposits

Cochise County: Warren district, with ores of copper, lead, and silver (UA 9525), on bornite; Shattuck mine, as rich, spongy, gold matte in conglomerate (Ransome, 1904; Bain, 1952; S 95730). Turquoise district, with copper, silver, and lead ores. Tombstone district, with lead-silver ores (Butler, B.S., et al., 1938b). Pearce district, Commonwealth mine, in broad splotches and leaf form (Endlich, 1897). Dos Cabezas Mountains, Dos Cabezas and Teviston districts. Huachuca and Swisshelm Mountains.

Gila County: Globe-Miami district, with ores of copper and silver (Ransome, 1903a; Peterson, N.P., 1962), as fine specimens from the Old Dominion mine. Dripping Spring Mountains, Barnes district, with copper, lead, and silver ores. Payson district. In a prospect 1/8 mile east of the Cowboy mine, about 8 miles northwest of Christmas (Stanley B. Keith, pers. commun., 1973).

Graham County: Galiuro Mountains, Rattlesnake district (Blake, W.P., 1902).

Pinaleño Mountains, Aravaipa and Stanley districts. Gila Mountains. Santa Teresa Mountains.

Greenlee County: Clifton-Morenci district, with copper and silver ores (Lindgren, 1905).

La Paz County: Harquahala Mountains, with ores of copper and lead, rich in quartz (H 100665). Williams Mountains, Cienega district, with copper ores. Plomosa and Trigo Mountains. Bouse area, Dutchman mine, as flecks on massive, red, earthy hematite (S R15089). Dome Rock and Laguna Mountains. Gila Bend Mountains, Fortuna mine (Blake, W.P., 1897).

Maricopa County: Vulture district (Metzger, 1938), with lead and silver ores, with wulfenite (H 100312). Cave Creek district. Phoenix Mountains. Big Horn Mountains.

Mohave County: Black Mountains, San Francisco (Silliman, 1866; Ransome, 1923) and Katherine (Gardner, 1936) districts; Ruth vein, 0.25 mile south of the Moss mine, massive in quartz (Lausen, 1931a,b; H 81355). Cerbat Mountains, Chloride, Cerbat, Stockton Hill, Mineral Park, and Wallapai districts (Thomas, B.E., 1949). Hualapai Mountains, Maynard district, with silver ores. Gold Basin district (Schrader, 1907). Williams Fork of the Colorado River (Blake, W.P., 1865).

Pima County: Ajo district, with copper and silver ores (Gilluly, 1937); New Cornelia pit, cementing some fractures in bornite. South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Cahuabi mine, as flecks in quartz, with limonite, galena, and malachite (Raphael Pumpelly collection, H 81380). Santa Catalina Mountains, Molino Basin, in quartz stained with chrysocolla and shattuckite. Tucson Mountains, on limonite that is pseudomorphous after magnetite (UA 9724). Arivaca district, Sungold mine. Santa Rita Mountains, Greaterville area, Golden Gate mine (UA 344); as rusty wire gold (Schrader, 1917; UA 6734); Yuba mine, Gold Ledge claim, as excellent small specimens of wire gold collected by Dewey Keith in about 1955 (Wilson, W.E., 1987a).

Pinal County: Superior and Ray districts, with copper, silver, and lead ores. Mammoth district, Mammoth–St. Anthony mine, as flecks in andesite(?) porphyry (Peterson, N.P., 1938a,b; H 99916); near Oracle, from John's Ranch, as hackly gold in quartz (S R221); in rusty pockets in quartz, with brochantite (H 108579). Casa Grande district, with copper and silver ores. Goldfield Mountains, Goldfield district. Pinto Creek, as stout, 1-in. wires (H 100386).

Santa Cruz County: Santa Rita and Patagonia Mountains (Schrader, 1917). Oro Blanco Mountains, with ores of lead, silver, and copper; as crystalline flakes of "white gold," the color of which was reportedly due to small amounts of gallium (Engineering Mining Journal, 1900). Nogales district, Little Annie mine (UA 2180).

Yavapai County: Verde district, with copper and silver ores. Bradshaw Mountains, Big Bug, Peck, Walker, and Tiger districts, with ores of copper, silver, and lead (Anderson, C.A., and Creasey, 1958); Hassayampa and Black Canyon (Guiteras, 1936) districts, with lead-silver ores; Pine Grove and Agua Fria districts, with copper-silver ores; Groom Creek, Turkey Creek, Bradshaw, and Tip Top districts, with silver ores; Copper Basin district (Johnston, W.P., and Lowell, 1961). Santa Maria Mountains, Eureka district, with copper-silver-lead ores. Date Creek Mountains, Martinez district (Metzger, 1938). Wickenburg Mountains, Black Rock district (Lindgren, 1926).

Yuma County: Kofa (Jones, E.L., 1915) and Gila Mountains, with silver ores. Castle Dome Mountains, with lead-silver ores. Dome Rock and Laguna Mountains. Gila Bend Mountains, Fortuna mine (Blake, W.P., 1897).

Placer Deposits

Cochise County: Dos Cabezas, Teviston, Huachuca, Gleeson, Pearce, Gold Gulch (Bisbee), and Hartford (Huachuca) placers, produced in small amounts. Ash Canyon, 10 miles south of Hereford, as coarse placer gold (Robert O'Haire, pers. commun., 1972).

Coconino County: White Mesa district, near Lee's Ferry, Paria Creek, in the shales of the Chinle Formation, as flakes associated with small amounts of mercury (Lausen, 1936).

Gila County: Green Valley, Dripping Spring, Barbarossa, Globe-Miami, and Payson placers, produced in small amounts.

Greenlee County: Clifton-Morenci placers, along San Francisco and Chase Creeks.

La Paz County: La Paz, Plomosa, Trigo, and Harquahala districts.

Maricopa County: Cave Creek, Agua Fria, Pikes Peak, Big Horn, Vulture, San Domingo, and Hassayampa (Carter, T.L., 1911) placers. Near Phoenix, in a gravel pit near the Salt River, as a waterworn nugget weighing 3.5 oz (Scott Williams collection, H 106179).

Mohave County: Gold Basin, Chemehuevis, Lost Basin, Lewis, Wright Creek, Lookout, and Silver Creek placers.

Pima County: Greaterville, Quijotoa, Horseshoe Basin, Arivaca, and Papago placers; a nugget valued at $228 was found at Greaterville in 1924. Las Guijas, Old Baldy, Old Hat, Baboquivari, Armagosa, and Alder Creek placers, as less commercially important deposits. Tohono O'odham (Papago) Indian Reservation, Golden Green mine, where William Coplen discovered a placer nugget that weighed slightly more than 8 oz *(Arizona Daily Star,* March 1967). Northwest flank of the Santa Catalina Mountains, Cañada del Oro placers.

Santa Cruz County: In many small placer deposits, including the Oro Blanco, Mowry, Harshaw, Patagonia, Tyndall, Nogales, and Palmetto placers.

Yavapai County: Weaver Creek, Rich Hill, Lynx Creek, Big Bug, Minnehaha, Hassayampa, Groom Creek, Copper Basin, Placerita, and Black Canyon (Guiteras, 1936) areas, as the most important localities; a nugget weighing 271 g was found on Weaver Creek in 1930, and in 1932–33 several nuggets weighing 3 oz or more were recovered from that area. Weaver district, Red Bank, where coarse, gold-bearing quartz veins yielded a nugget shaped like a human molar that measured 53 × 47 mm and weighed 270.90 g (Heineman, 1931). Placers near Congress Junction, where a nugget weighing 4.81 oz was produced (UA 3470).

Yuma County: Dome, Castle Dome, and Muggins districts. Kofa and Fortuna districts, as less important deposits. Near Yuma, Myers claim on the Colorado River, where a waterworn nugget, 0.5 in. across, was produced in July 1863 by dry washing (S 5549).

#GOLDFIELDITE

Copper tellurium antimony arsenic sulfide, $Cu_{12}(Te,Sb,As)_4S_{13}$. Formed in epithermal precious-metal veins.

Cochise County: Warren district, with the sulfide ores of the Campbell mine (Graeme, 1993).

#GONNARDITE

Sodium calcium aluminum silicate hydrate, $Na_2CaAl_4Si_6O_{20}\cdot 7H_2O$. Formed in vesicular basalts as well as in metamorphic rocks; commonly associated with other zeolites.

Pima County: Santa Catalina Mountains, Golder Dam spillway, collected by Douglas Shakel.

#GORMANITE

Iron aluminum phosphate hydroxide hydrate, $Fe^{2+}_3Al_4(PO_4)_4(OH)_6\cdot 2H_2O$. Associated with quartz and other phosphates at the type locality, Yukon Territory, Canada. The Arizona occurrence is apparently only the second known locality in the world.

Cochise County: Bisbee, Warren district, in drill core as dark-green rosettes in open fractures cutting an equigranular tonalite, as isolated radial sprays or prisms up to 1 cm long; the green color belies the spectacular pleochroism seen in thin section; associated with chlorite, calcite, and quartz (Graeme, 1993). The composition (wt %), based on a partial analysis (by Marjorie Duggan) of 8.72 mg, is as follows:

FeO	24.7	Al_2O_3	21.9	P_2O_5	30.5
H_2O	12.4			Rem.	7.4

GOSLARITE

Zinc sulfate hydrate, $ZnSO_4 \cdot 7H_2O$. A water-soluble secondary mineral formed through the alteration of sphalerite; common as efflorescences on the walls of old mine openings.

Cochise County: Warren district, locally abundant as a postmine mineral (Graeme, 1981).

Gila County: Globe-Miami district, Continental and Old Dominion mines, as efflorescences; Castle Dome mine (Peterson, N.P., et al., 1951; Peterson, N.P., 1962).

Greenlee County: Clifton-Morenci district, as efflorescences; Arizona Central mine (Lindgren, 1905; Guild, 1910).

Mohave County: Cerbat Mountains, Chloride district, de la Fontaine property.

Pima County: Silver Bell district, as cuprogoslarite in old mine workings. South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963).

GRAEMITE

Copper tellurite hydrate, $CuTeO_3 \cdot H_2O$. A rare secondary mineral known only from the two Arizona localities noted here as well as from Moctezuma, Sonora, Mexico. The Cole mine is the type locality.

Cochise County: Warren district, Cole mine, in a specimen from the 1,200-ft level; the graemite is attached to the surface of and has partially replaced teineite crystals embedded in malachite associated with a loose spongy aggregate of cuprite crystals (Williams, S.A., and Matter, 1975). Based on the average of several analyses, the composition (wt %) is as follows:

CuO	31.0	TeO_2	61.2	H_2O	8.2
				TOTAL	100.4

Density: 4.13

Shattuck shaft, replacing and overgrown by teineite (Graeme, 1993).

La Paz County: Dome Rock Mountains, in a small prospect, associated with goethite, gypsum, and teineite in small cavities in djurleite in quartz-tourmaline gangue; as at Bisbee, the graemite appears to replace teineite (Williams, S.A., and Matter, 1975).

#GRANDREEFITE

Lead sulfate fluoride, $Pb_2SO_4F_2$. Associated with galena and fluorite from which it is thought to have formed by interaction with supergene fluids. The Grand Reef mine is the type and, at the time of this publication, only known locality.

Graham County: Aravaipa district, Grand Reef mine, as colorless, striated, prismatic orthorhombic crystals in quartz-lined vugs, associated with galena, fluorite, and anglesite (Kampf et al., 1989).

GRAPHITE

Carbon, C. Formed by the reduction of carbon-containing compounds during metamorphism or hydrothermal activity; possibly also formed as a primary constituent in igneous rocks.

Cochise County: Dos Cabezas Mountains, in thin veins or streaks in gold quartz veins. Near Benson, as graphitic clay (Guild, 1910). Warren district (Richard Graeme, pers. commun., 1973).

Coconino County: Canyon Diablo and Elden meteorites, as small nodules (Ksanda and Henderson, 1939).

Gila County: Northwestern region, Rainbow deposit, as uraniferous graphite in the Dripping Spring Quartzite (Granger and Raup, 1969).

Mohave County: Cerbat Mountains, Canyon Station Wash, disseminated in Precambrian schist (Schrader, 1907).

GREENOCKITE

Cadmium sulfide, the hexagonal dimorph of CdS. A rare mineral most commonly formed as coatings on sphalerite; rarely in cavities in mafic igneous rocks. It is probable that much of what has been called greenockite is hawleyite, the cubic dimorph of CdS.

Cochise County: Reported in the Warren district, as a yellow coating on sphalerite. Middlepass district, San Juan mine, as minute needles (Bruce Maier, UA x3364).

Coconino County: Cameron district, Huskon mine, with pitchblende, marcasite, pyrite, calcite, and siliceous gangue, replacing wood structures as well as forming cement in sandstones of the Chinle Formation (Bollin and Kerr, 1958; Maucher and Rehwald, 1961).

GROSSULAR

Calcium aluminum silicate, $Ca_3Al_2(SiO_4)_3$. A member of the garnet group. Typically a product of thermal and contact metamorphism of calcareous and aluminous rocks.

Cochise County: Warren district, as rounded crystals in unoxidized pyritic ores. Tombstone district, cinnamon-brown, in contact metamorphic zones; forms massive beds at Comstock Hill (Butler, B.S., et al., 1938b). Little Dragoon Mountains, Johnson area, as a gangue mineral with copper ores (Kellogg, 1906; Cooper and Huff, 1951; Cooper, 1957; Cooper and Silver, 1964).

Pima County: Pima district, Pima mine, abundant in limestone hornfels, with diopside and tremolite (Journeay, 1959; Himes, 1972); in the skarns of the Twin Buttes mine (Stanley B. Keith, pers. commun., 1973). Silver Bell district, Atlas mine area, abundant in tactites as a product of pyrometasomatic alteration of limestone (Agenbroad, 1962). Helvetia-Rosemont district, Peach-Elgin copper deposit, with garnet and diopside, as bedded replacements (Heyman, 1958).

Santa Cruz County: Santa Rita and Patagonia Mountains, in the latter range at Duquesne and Washington Camp, in limestone in contact metamorphic deposits associated with other contact silicate minerals (Schrader, 1917).

Yavapai County: Bagdad, with fluorite (UA 8039).

GROUTITE

Hydrogen manganese oxide, $HMnO_2$. Originally described from the iron ranges of Minnesota, where it formed in the iron ores with manganite in vuggy cavities.

Cochise County: Warren district, Campbell mine, as tiny dark-brownish-black crystals coating sooty manganese oxides.

La Paz County: Sheep Tank mining district, as the chief manganese mineral in one vein (Cousins, 1972).

Navajo County: Near Holbrook, as needles in petrified wood.

Pinal County: Superior district, Magma mine, as coatings of small prismatic crystals (ASDM x1331).

Yuma County: Kofa district, No. 2 vein of the North Star mine, with psilomelane, bixbyite, todorokite, and manganite (Hankins, 1984); King of Arizona mine, with todorokite, chalcophanite, aurorite, and pyrolusite in the King of Arizona vein, and with nsutite in the No. 5 vein (Hankins, 1984).

GRUNERITE

Iron magnesium silicate hydroxide, $(Fe,Mg)_7Si_8O_{22}(OH)_2$. A member of the amphibole group; common in iron-rich, regionally metamorphosed rocks; also formed in contact metamorphic rocks with fayalite, hedenbergite, and almandine.

Graham County: Santa Teresa Mountains, in contact-metamorphosed limestone.

Yavapai County: Tip Top district, north of the Foy mine.

GUILDITE

Copper iron sulfate hydroxide hydrate, $CuFe^{3+}(SO_4)_2(OH)\cdot 4H_2O$. A very rare mineral formed during a mine fire in the United Verde mine at Jerome, which is the type and only locality.

Yavapai County: Black Hills, United Verde mine, formed under fumarolic conditions as a result of burning pyritic ores; as relatively rare crystals up to 5 mm (Lausen, 1928; Laughon, 1970).

Gummite

Uranium oxide hydrates. A generic term for colorful uranium oxides whose true identity is unknown; commonly contains lead, thorium, and relatively large amounts of water. The term is similar in usage to *wad* and *limonite*. Gummites are typically formed by the alteration of uraninites.

Apache County: Monument Valley, Monument No. 2 mine, with other oxidized uranium and vanadium minerals (Mitcham and Evensen, 1955).

Pima County: Linda Lee claims, with torbernite and hematite in a vein cutting arkose (Robinson, R.L., 1955).

GYPSUM

Calcium sulfate hydrate, $CaSO_4 \cdot 2H_2O$. A common mineral of widespread and abundant distribution. Formed by the evaporation of inland seas and salt lakes and by the hydration of anhydrite. A common constituent of the oxidized zones of sulfide ores.

Apache and Navajo Counties: Monument Valley, in the copper-uranium-vanadium ores in channels at the base of the Shinarump Conglomerate (Mitcham and Evensen, 1955).

Cochise County: Tombstone district, widespread as small crystals and scales lining small fissures in shale and as coatings in mine stopes (Butler, B.S., et al., 1938b). Near Douglas, where it was quarried (Santmyers, 1929). Sulphur Springs Valley, as beds in recent lake sediments. San Pedro Valley, both north and south of Benson (Guild, 1910). Warren district, as excellent examples of the curved "rams horn" variety (UA 294); Gleeson district, Shannon mine (UA 6790).

Coconino County: Along the eastern bank of the Little Colorado River, between Cameron and Leupp, as beds of varying thickness alternating with mudstones, in the Moenkopi Formation (Anthony et al., 1955; Baldwin, 1971).

Gila County: Globe-Miami district, Copper Cities mine, as large crystals in the lower levels (Peterson, N.P., 1962).

Greenlee County: Clifton-Morenci district, common in oxidized deposits in limestone (Lindgren, 1905; Guild, 1910).

La Paz County: Plomosa Mountains, Mudersbach Camp, as a bed several feet thick. As beds at the eastern base of the Harquahala Mountains. Silver district, massive and crystalline in the upper portions of veins (Wilson, E.D., 1933); Red Cloud mine, as gangue in veins in andesite, with fluorite, calcite, and barite (Foshag, 1919).

Maricopa County: About 15 miles south of Gila Bend, as beds in sandstone and conglomerate, with celestite. Reported in the Superstition Mountains.

Mohave County: Abundant in the Virgin Valley badlands, as thick beds in South Mountain and Quail Canyon. Bill Williams River, in beds northeast of the Planet mine. Mammoth claim, 60 miles southeast of Kingman, as satin spar.

Navajo County: Near Winslow, mined as large plates of selenite in the upper member of the Permian Supai Formation (Peirce, H.W., and Gerrard, 1966; Moore, R.T., 1968).

Pima County: Empire and Santa Rita Mountains, as Permian beds up to 50 ft thick (Schrader and Hill, 1915). Santa Catalina Mountains foothills, north of Tucson. In recent sediments near Vail (Guild, 1910). Pima district, Minnie mine (UA 7162) and near San Xavier mine, as clear crystals up to 3 or 4 in. Mission mine, enclosing copper and, rarely, chalcotrichite (UA 9198). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963).

Pinal County: East side of the San Pedro River near Feldman, as thick beds in lake deposits (Hardas, 1966). Galiuro Mountains, Copper Creek district, as layers in Gila Conglomerate.

Santa Cruz County: Santa Rita Mountains, Montosa Canyon area, as thick Permian beds (Anthony, 1951); Cottonwood Canyon, Glove mine, as a secondary mineral (Olson, H.J., 1966).

Yavapai County: Verde Valley, in salt deposits (Guild, 1910), as pseudomorphs after glauberite (UA 9872). United Verde mine, abundant in decomposed dikes (Lindgren, 1926). Eureka district, Hillside mine, in the oxidized portion of the vein, associated with secondary uranium minerals (Axelrod et al., 1951).

Yuma County: Castle Dome district, massive and crystalline in the upper portions of veins (Wilson, E.D., 1933).

GYROLITE

Calcium silicate hydroxide hydrate, $Ca_2Si_3O_7(OH)_2{\cdot}H_2O$. A secondary mineral formed through the alteration of calcium-bearing silicate minerals.

Cochise County: Tombstone district, Lucky Cuss mine, as light-green spherules (resembling prehnite) composed of thin, interlocking tabular crystals. The spherules may attain 6 to 7 mm in diameter. The gangue minerals are mainly quartz-natrolite hosting alamosite and queitite.

Maricopa County: One mile south of Horseshoe Dam, as rare, 2- to 3-mm, rose-like crystal clusters, with apophyllite (Shannon, D.M., 1983b).

H

HALITE

Sodium chloride, NaCl. The source of common salt; found in sedimentary beds formed by the evaporation of inland seas and salt lakes. Commonly associated with gypsum, anhydrite, and other salts of sodium and potassium.

Apache and Navajo Counties: Southern regions, in the subsurface of the Supai

Salt Basin, which embraces about 2,300 square miles; with anhydrite, dolomite, and clastic red beds (Peirce, H.W., and Gerrard, 1966; Peirce, H.W., 1969).

Cochise County: San Simon Basin, 7 miles northeast of Bowie, in bedded lake deposits, associated with thenardite and a variety of zeolite minerals (Regis and Sand, 1967).

Gila and Maricopa Counties: Salt River Valley, as incrustations derived from evaporation of saline springs (Guild, 1910; Wilson, E.D., 1944).

Maricopa County: A well drilled in sec. 19, T. 2 N., R. 1 W., revealed substantial thicknesses of halite at a depth of 2,350 ft in Cenozoic rocks; probably a large deposit, it is being mined by solution methods (Peirce, H.W., 1969).

Mohave County: In the badlands of the Virgin River Valley, near the Nevada border, with gypsum (Wilson, E.D., 1944). In the subsurface of Detrital and Hualapai Valleys, in secs. 12 and 13, T. 29 N., R. 21 W., with anhydrite and glauberite; the deposits south of Red Lake flat are at least 1,200 ft thick (Peirce, H.W., 1969; H. Wesley Peirce, pers. commun., 1973), and those northwest of the flat are 500 to 700 ft thick (Pierce, W.G., and Rich, 1962).

Pima County: Tohono O'odham (Papago) Indian Reservation.

Pinal County: West of the Picacho Mountains, in sec. 5, T. 8 S., R. 8 E., a drill hole sunk by the Humble Oil and Refining Co. in 1972 penetrated 80 ft of halite and about 6,000 ft of anhydrite (H. Wesley Peirce, pers. commun., 1973).

Yavapai County: Verde Valley, in the salt deposits, some of which are deep purple, associated with glauberite, gypsum, mirabilite, and thenardite (Blake, W.P., 1890; Guild, 1910).

HALOTRICHITE

Iron aluminum sulfate hydrate, $FeAl_2(SO_4)_4{\cdot}22H_2O$. Water soluble, formed from the weathering of pyritic and aluminous rocks in old mine workings. Commonly associated with gypsum and other secondary sulfate minerals.

Cochise County: Tombstone district.

Coconino County: Cameron district, as cross-fiber veins in carbonaceous fossil wood and in the surrounding sediments, some stained inky blue by ilsemannite(?) (Austin, 1964).

Gila County: Banner district, 79 mine, as an abundant secondary mineral throughout the oxidized portions, commonly as arching whiskers up to 12 in. long growing from the walls of the workings and twisting in all directions; growth rates of up to 3 in./yr have been measured for the currently forming mineral (Keith, 1972).

Pinal County: Mineral Creek district, Ray mine, as microcrystals (David Shannon, UA x4319).

Santa Cruz County: Patagonia Mountains (UA 4992); Harshaw district, Chief mine (UA 9592); Denver mine, as microcrystals (David Shannon, UA x4420).

HARMOTOME

Barium potassium aluminum silicate hydrate, $(Ba,K)(Al,Si)_2Si_6O_{16}\cdot 6H_2O$. A member of the zeolite group. Typically formed in cavities and veins in igneous rocks.

Greenlee County: Unspecified locality near Duncan (UA 5991).

HAUSMANNITE

Manganese oxide, Mn_3O_4 or $Mn^{2+}Mn_2^{3+}O_4$. Typically found in high-temperature veins. Also a contact metamorphic mineral formed as a recrystallization product of preexisting manganese minerals under conditions of regional metamorphism.

Cochise County: Warren district, White Tail Deer mine, replacing limestone that contains braunite.

Pima County: Arivaca district, COD mine, in veinlets cutting a matrix of braunite (Hewett, 1972).

Santa Cruz County: Tyndall district, Cottonwood Canyon, Glove mine, as a constituent of fine-grained, brownish manganese oxides (Bideaux et al., 1960; Olson, H.J., 1966). Harshaw district, Hardshell mine, as a constituent of manganese ores (Davis, S.R., 1975).

#HAWLEYITE

Beta cadmium sulfide, β-CdS. The cubic dimorph of greenockite. Commonly formed as an earthy coating on sphalerite.

Cochise County: Dragoon Mountains, Buena Vista mine, as a yellow powder derived from sphalerite, which coats fractures in a quartz-rich garnet tactite.

#HAXONITE

Iron nickel carbide, $(Fe, Ni)_{23}C_6$. Associated with kamacite and taenite, in particles up to 40 microns in diameter.

Coconino County: Meteor Crater near Winslow, in the Canyon Diablo meteorite; this is the "type locality" (Scott, 1971).

#HECTORITE

Sodium magnesium lithium silicate fluoride hydroxide, $Na_{0.3}(Mg,Li)_3Si_4O_{10}(F,OH)_2$. A member of the group of swelling clays.

Yavapai County: Mined at the Lyles Hectorite deposit near Hillside (Eyde, 1986).

HEDENBERGITE

Calcium iron silicate, $CaFeSi_2O_6$. A member of the pyroxene group. Typically formed in contact-metamorphosed limestones, associated with other calcium silicates.

Graham County: Stanley Butte (UA 6987). Aravaipa district, Iron Cap mine, as a manganoan variety associated with johannsenite and other manganese-rich skarn minerals (Reiter, 1980, 1981).

Pima County: Silver Bell district, Atlas mine area (Agenbroad, 1962). Sierrita Mountains, Pima district, common as gangue in contact-metamorphosed limestones (Eckel, 1930a; Irvin, 1959).

Santa Cruz County: Patagonia Mountains, Westinghouse property, with diopside and other contact silicates (Schrader and Hill, 1915; Schrader, 1917).

HELVITE

Manganese iron zinc beryllium silicate sulfide, $(Mn,Fe,Zn)_4Be_3(SiO_4)_3S$. Formed in granites and granite pegmatites and in contact metamorphic rocks, where it may be associated with other beryllium-bearing minerals.

Cochise County: Dragoon Mountains, Abril and Gordon (San Juan) mines, with beryllium-bearing epidote(?), in tactite in a limestone replacement deposit (Warner, L.A., et al., 1959; Meeves, 1966). S.J. Jordan mine, as microcrystals (Marvin Deshler, UA x1851).

HEMATITE

Iron oxide, Fe_2O_3. A mineral formed in many ways, in igneous, metamorphic, and sedimentary rocks; in the latter, as bedded deposits of commercial significance. Also in hydrothermal veins and in the gossans or leached cappings of base-metal deposits. Only a few typical localities are listed here.

Cochise County: Near Willcox, as fine-grained, massive specularite. Tombstone district, near the Lucky Cuss mine, as radiating crystal aggregates in a vein in granodiorite (Butler, B.S., et al., 1938b). Warren district, Lavender pit (UA 7827). Dragoon Mountains, Black Diamond claim (UA 7357).

Gila County: Globe-Miami district, as massive bodies of specularite along the veins of the Old Dominion fault system, as replacements of limestone or diabase; Buckeye, Black Oxide, Big Johnnie, Stonewall, and other veins (Sanders, 1911; Peterson, N.P., 1962). Fort Apache Indian Reservation, Bear Spring Canyon, as extensive deposits with chert beds in the Mescal Limestone (Burchard, 1930, 1943). Aztec Peak area, reniform (Sinkankas, 1964).

Gila and Navajo Counties: Canyon Creek area, extensive deposits in the middle member of the Precambrian Mescal Limestone, interbedded with ferruginous cherts, sandstones, and shales (Moore, R.T., 1968).

Graham County: Grand Reef area, as specularite, very abundant in the Lead King and Cobre Grande mines (Simons, 1964).

Greenlee County: Clifton-Morenci district, Manganese Blue mine (Lindgren, 1905).

La Paz County: Buckskin Mountains, Planet mine, as extensive replacement deposits with carbonate and silicate copper ores in limestone (Cummings, 1946b). Dome Rock Mountains, Big Bertha Extension mine (also called Crystal Caverns claim and Veta Grande claim), as high-quality crystals up to 6.5 cm across; these crystals, some of which are mirror-bright and twinned, with quartz crystals, may be the finest U.S. specimens (Sprunger, 1980; UA 8640). Locality southeast of Quartzsite, as well-formed "iron roses" up to 2.5 cm across. BBC mine near Bouse, as grouped crystals, some of which are up to 4 cm, with some quartz and rarely cummingtonite tufts. Burro Hill prospect, 2 miles north of the BBC mine, as large, lustrous masses of crystals (MM 9797).

Maricopa County: Pikes Peak area, northeast of Beardsley, as replacements in schist (Farnham and Havens, 1957). Painted Rock Mountains, Rowley mine near Theba, where the powdery mineral is responsible for the ubiquitous red coloration (Wilson, W.E., and Miller, 1974).

Mohave County: Cerbat and Aquarius Mountains, widely distributed, chiefly as the specular variety (Blake, W.P., 1865); Chloride, as red ocher (UA 1836).

Navajo County: Sierra Ancha Mountains, Canyon Creek, as a large deposit of siliceous hematite, estimated at 10 million tons, ranging from soft, pulverulent, bright-red material to hard, dark-blue oxide (Stewart, L.A., 1947).

Pima County: Santa Rita Mountains, Cuprite mine area. Empire Mountains, Hilton mines, as red ocher (UA 7388). Pima district, Copper Glance mine (UA 7389); Twin Buttes mine (Stanley B. Keith, pers. commun., 1973). Ajo district, New Cornelia mine, as specularite in brilliant adamantine crystals up to 2 in. across, of hypogene origin; as the earthy variety, of supergene origin (Gilluly, 1937).

Pinal County: Near Winkelman, as an iridescent variety. Mammoth district, Mammoth–St. Anthony mine, as glistening black masses in the lower levels of the Collins vein (Peterson, N.P., 1938a,b).

Santa Cruz County: Santa Rita Mountains, Tyndall district, Montosa Canyon, Isabella mine, as massive material of the specular variety with cerussite ("sand carbonate"), replacing Permian limestones (Schrader and Hill, 1915; Anthony, 1951). Patagonia Mountains, widely distributed in mines and prospects; Patagonia district, Mowry mine, at Duquesne and Washington Camp, in limestone in contact metamorphic deposits; as a primary mineral in numerous siliceous veins filling fault fissures (Schrader, 1917).

Yavapai County: McBride claims, 17 miles south of Seligman, as large deposits of earthy material that form irregular lenses in limestone near the contact with diorite. Near Townsend Butte and the Howard copper property, in high concentrations with magnetite, in schist. Near Camp Wood. Verde district, United Verde mine, as the specular variety, in late-stage veinlets that cut massive sulfides; south of Jerome, common in Precambrian rocks (Anderson, C.A., and Creasey, 1958).

HEMIHEDRITE

Lead zinc chromate silicate fluoride, $Pb_{10}Zn(CrO_4)_6(SiO_4)_4F_2$. A rare secondary mineral formed in the oxidized portions of galena-sphalerite veins.

Maricopa County: Wickenburg district, at several localities, including the Pack Rat claim, Moon Anchor mine, and Potter-Cramer property; formed by alteration of galena in the oxidized portion of galena-bearing quartz veins that cut andesite agglomerate; associated with phoenicochroite, vauquelinite, willemite, and mimetite; crystals are orange to nearly black (McLean and Anthony, 1970; Williams, S.A., and Anthony, 1970; Williams, S.A., et al., 1970).

Pinal County: Tortilla Mountains, Florence Lead-Silver mine, in the oxidized zone of lead-bearing veins that cut strongly brecciated Precambrian limestone intruded by an altered latite porphyry, and Precambrian quartzite containing a diabase dike. Associated primary minerals include galena, sphalerite, pyrite, and tennantite; oxidation products include cerussite, phoenicochroite, vauquelinite, wulfenite, and willemite. Hemihedrite forms contemporaneously with wulfenite, after the formation of cerussite, and may be replaced by wulfenite. Crystals are bright orange to henna-brown to nearly black (Williams, S.A., and Anthony, 1970). This is the type locality.

Yavapai County: Near the confluence of Amazon Wash and the Hassayampa River, with phoenicochroite, mimetite, and descloizite (William Hunt, pers. commun., 1985).

HEMIMORPHITE

Zinc silicate hydroxide hydrate, $Zn_4Si_2O_7(OH)_2{\cdot}H_2O$. A secondary mineral formed in the oxidized portion of zinc deposits; commonly associated with smithsonite, cerussite, anglesite, galena, and sphalerite.

Cochise County: Tombstone district, Empire and Toughnut mines, as sparse, radiating aggregates in oxidized ore (Butler, B.S., et al., 1938b). Warren district, with aurichalcite (UA 9343) and rosasite (UA 8685). Turquoise district, Mystery and Silver Bill mines, as incrustations and druses. Little Dragoon Mountains, Cochise district, Johnson Camp (Cooper and Huff, 1951). Gunnison Hills, as small colorless crystals; Texas-Arizona mine, as the most abundant oxidized ore mineral (Cooper, 1957; Cooper and Silver, 1964).

Gila County: Globe-Miami district, Irene, Albert Lea, and Defiance deposits, common in the oxidized zones of veins (Peterson, N.P., 1962); Castle Dome mine, as tiny rounded grains in clay (Peterson, N.P., et al., 1951). Cherry Creek area, Horseshoe deposit, sparingly coating fracture surfaces (Granger and Raup, 1969). Banner district, 79 mine, as very fine specimens in a variety of habits, associated with rosasite, chrysocolla, and cerussite (UA 1164, 8307), and altering to chrysocolla, as pseudomorphs on wad (UA 7587); as odd, blue but in some places white, hollow, eggshell-like balls on matrix (Keith, 1972).

Greenlee County: Clifton-Morenci district, Shannon mine, as small transparent crystals in decomposed garnet rock (Lindgren and Hillebrand, 1904; Lindgren, 1905).

La Paz County: Silver district, Red Cloud mine, as small crystal groups (Edson, 1980).

Maricopa County: White Picacho district, as a supergene mineral after sphalerite; also associated with hydrozincite (Jahns, 1952).

Mohave County: McCracken mine near Signal, with fluorite (UA 9271).

Pima County: Empire Mountains, Hilton mines, as small colorless crystals in smithsonite; Total Wreck mine, with plattnerite on limonite (Bideaux et al., 1960). Pima district, as light-green-blue mammillary crusts on mine dumps (Therese Murchison, pers. commun., 1972); San Xavier West mine (Arnold, 1964); Queen mine (UA 5634). Waterman Mountains, Silver Hill mine (UA 6005). Tucson Mountains, north base of Amole Peak, as botryoidal crusts (Robert O'Haire, pers. commun., 1972).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as porous to compact masses and as slender needles bristling from quartz crystals on the walls of open cavities (Peterson, N.P., 1938a,b; Palache, 1941b; Fahey, 1955). Banner district, northeast workings of the Kullman-McCool (Finch, Barking Spider) mine, as light-green to blue, botryoidal masses, associated with wulfenite.

Santa Cruz County: Patagonia district, Flux mine, on limonite with aurichalcite (Thomas Trebisky, pers. commun., 1972).

Yavapai County: Eureka district, Hillside mine, in the oxidation zone of a sulfide-bearing vein in mica schist, associated with silver, anglesite, cerussite, chlorargyrite, and smithsonite (Axelrod et al., 1951).

#HENRYITE

Copper silver telluride, $Cu_4Ag_3Te_4$. A rare species associated with primary sulfide and telluride minerals. The Campbell orebody at Bisbee is the type locality.

Cochise County: Bisbee, Warren district, Campbell orebody, very sparingly in sulfide ores, associated with hessite, petzite, sylvanite, altaite, rickardite, and pyrite (Criddle et al., 1983).

HERCYNITE

Iron magnesium aluminum oxide, $(Fe,Mg)Al_2O_4$. A member of the spinel group; most common in metamorphosed argillaceous sediments.

Gila County: Unspecified locality near Rice, in olivine bombs (UA 3701).

HERSCHELITE

Sodium calcium potassium aluminum silicate hydrate, $(Na,Ca,K)AlSi_2O_6{\cdot}3H_2O$. The uncommon sodic end member of the chabazite-herschelite solid-solution series; a member of the zeolite group.

Cochise County: San Simon Basin, 7 miles northeast of Bowie, as minute spherules and crystal aggregations formed by alteration of volcanic pyroclastic material, in bedded lake deposits, with analcime, chabazite, erionite, clinoptilolite, halite, and thenardite. The composition of the herschelite varies laterally with its position within the deposit; Regis and Sand (1967) list the following composition: $(0.91Na_2,0.05K_2,0.04Ca)O{\cdot}Al_2O_3{\cdot}6.4SiO_2{\cdot}7.6H_2O$.

Maricopa County: One mile south of Horseshoe Dam, as transparent to flesh-colored hexagonal plates with analcime and phillipsite (Shannon, D.M., 1983b).

Yavapai County: Along a dirt road between U.S. Highway 93 and State Highway 96, on the south side of the Santa Maria River, in basalt with phillipsite (William Hunt, pers. commun., 1985).

HESSITE

Silver telluride, Ag_2Te. Formed in veins with other tellurides, gold, and tellurium.

Cochise County: Tombstone district (Romslo and Ravitz, 1947); West Side mine, as bands and disseminations in quartz, with chlorargyrite and gold (Genth, 1887a); Flora Morrison mine, altering to silver (Butler, B.S., et al., 1938b; Rasor, 1938). Warren district, Campbell orebody, sparingly in the sulfide ores (Graeme, 1993).

Yavapai County: Verde district, United Verde mine, as small blebs with probable zincian tennantite in chlorite matrix.

HETAEROLITE

Zinc manganese oxide, $ZnMn_2O_4$. A rare secondary mineral associated with other oxidized manganese and zinc minerals.

Cochise County: Tombstone district, Lucky Cuss mine, as tiny veinlets in manganite (Butler, B.S., et al., 1938b; Rasor, 1939; Hewett and Fleischer, 1960). Warren district, Campbell (UA 7717) and Junction mines, as splendent, botryoidal and stalactitic masses and coatings; 1,300-ft level of the Cole shaft (Graeme, 1981); White Tail Deer mine, as crystals in calcite (Wilson, W.E., 1987b).

Gila County: Banner district, 79 mine, as massive encrustations on hemimorphite in the stope system above the 470-ft level (Keith, 1972).

Pinal County: Pioneer district, Domeroy property, 4 miles north of Superior, with psilomelane and pyrolusite (Dean et al., 1952).

HEULANDITE

Sodium calcium aluminum silicate hydrate, $(Na,Ca)_{2-3}Al_3(Al,Si)_2Si_{13}O_{36}\cdot 12H_2O$. A member of the zeolite group. Common in vesicles in basaltic rocks. Also formed by low-temperature alteration.

Gila County: Globe-Miami district, Black Copper portion of the Inspiration orebody, interlayered with chrysocolla in some schist outcrops (Throop and Buseck, 1971).

Greenlee County: Along road cuts on U.S. Highway 666, 5 miles south of Hannagan Meadow, in vesicles in basalt, with phillipsite.

Mohave County: Unspecified locality near Oatman, with thomsonite in andesite (UA 8476).

Pinal County: Mineral Creek district, Ray mine, mixed with green and black chrysocolla (Throop and Buseck, 1971). In a railway cut in Malpais Hill, north of Mammoth, as crystals with calcite in vesicles (Bideaux et al., 1960). Mammoth district, Mammoth–St. Anthony mine, as rare, twinned microcrystals, with wulfenite (Bideaux, 1980).

Santa Cruz County: Sierrita Mountains, as microcrystals, with epidote (George Sanders, UA x1306).

HEWETTITE

Calcium vanadium oxide hydrate, $CaV_6O_{16}\cdot 9H_2O$. A rare secondary mineral formed in the oxidized portions of vanadium or uranium-vanadium deposits.

Apache County: Monument Valley, Monument No. 2 mine, moderately abundant as individual crystals up to 15 mm long and about 0.5 mm thick, as cross-fibrous seams, and in crusts up to 10 cm thick (Weeks et al., 1955; Witkind and Thaden, 1963). Carrizo Mountains, as hairlike crystals and as fibrous incrustations in sandstone, with carnotite. Lukachukai Mountains, in the Salt Wash Member of the Morrison Formation (Chenoweth, 1967).

Navajo County: Monument Valley, Monument No. 1 and Mitten No. 2 mines (Evensen and Gray, 1958; Holland et al., 1958; Witkind, 1961; Witkind and Thaden, 1963).

HEXAHYDRITE

Magnesium sulfate hydrate, $MgSO_4\cdot 6H_2O$. An uncommon secondary mineral found sparingly in mine workings with epsomite, from which it may form by dehydration.

Cochise County: Warren district, Campbell shaft (Graeme, 1981).

Coconino County: In breccia pipes mined for uranium (Wenrich and Sutphin, 1988).

Pinal County: Mammoth district, 2,015- and 2,700-ft levels of the San Manuel mine, with epsomite, starkeyite, and an unknown selenium-bearing aluminum sulfate hydrate mineral (material collected by Joseph Urban; Anthony and McLean, 1976).

HIDALGOITE

Lead aluminum sulfate arsenate hydroxide, $PbAl_3(SO_4)(AsO_4)(OH)_6$. A rare member of the beudantite group; of secondary origin.

Yavapai County: Silver Crown mine, in the oxidized zone of massive sulfide ores, as a white crust on silicified schist. Unit cell constants: a = 7.012Å; c = 17.272Å.

HILLEBRANDITE

Calcium silicate hydroxide, $Ca_2SiO_3(OH)_2$. A rare mineral formed during contact metamorphism of limestone.

Cochise County: Tombstone district, Lucky Cuss mine, with monticellite and vesuvianite (Butler, B.S., et al., 1938b).

HINSDALITE

Lead aluminum phosphate sulfate hydroxide, hexagonal $PbAl_3(PO_4)(SO_4)(OH)_6$. A rare primary or early supergene mineral, formed in sulfide veins.

Mohave County: Ithaca Peak mine, as spherical clusters of pearly-white, scaly tablets, in voids on corroded, sooty sulfides; abundant in a vein with pyrite, sphalerite, bornite, minor amounts of galena, and abundant supergene chalcocite. Mineral Park mine, as hexagonal microcrystals (Wilkinson et al., 1980; UA x629).

HISINGERITE

Iron silicate hydroxide hydrate, $Fe^{3+}Si_2O_5(OH)_4 \cdot 2H_2O$. A secondary mineral formed by alteration in mineral deposits or weathering in iron-bearing silicates in rocks.

Gila County: Globe-Miami district, Castle Dome mine, a supergene mineral associated with malachite, limonite, jarosite, and wulfenite (Peterson, N.P., 1947; Peterson, N.P., et al., 1951).

Pima County: South Comobabi Mountains, Cababi district, Mildren and Steppe claims, with a variety of secondary minerals, which are products of the oxidation of sulfide ores in quartz veins cutting andesite (Williams, S.A., 1963).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, in the central parts of radiating, fibrous creaseyite spherules (Bideaux, 1980).

#HOCARTITE

Silver iron tin sulfide, Ag_2FeSnS_4. An uncommon tin-bearing mineral, commonly formed as small grains in other sulfides and typically associated with other tin minerals such as stannite.

Cochise County: Bisbee, Warren district, in the sulfide ores of the Campbell mine (Graeme, 1993).

#HODRUSHITE

Copper bismuth sulfide, $Cu_8Bi_{12}S_{22}$. In polymetallic ore deposits of subvolcanic type, in quartz veins developed in propylitized pyroxenite andesite.

Cochise County: Bisbee, Warren district, with the sulfide ores of the Campbell mine, as steel-gray laths up to 0.5 mm long, with pyrite, chalcopyrite, and arsenosulvanite (Graeme, 1993).

HOLLANDITE

Barium manganese oxide, $Ba(Mn^{2+},Mn^{4+})_8O_{16}$. Associated with several other manganese oxide minerals that form both in veins and as bedded deposits.

Coconino County: Peach Springs district; fine-grained, massive, and intimately associated with cryptomelane; contains 0.23% thallium and 5.5% BaO (Crittenden et al., 1962).

Gila County: Sierra Ancha district, Apache mine, one of several manganese oxides concentrated in breccia zones of a sandstone conglomerate; botryoidal, intimately associated with cryptomelane; contains 0.34% thallium, about 9% BaO, and about 2% K_2O (Crittenden et al., 1962; Hewett et al., 1963). Banner district, as a constituent of wad in the 79 mine (Keith, 1972).

Mohave County: Artillery Mountains, as one of the most abundant minerals in the Black Jack and Priceless deposits, where it formed very fine anhedral grains and needles and is associated with cryptomelane, psilomelane, pyrolusite, coronadite, ramsdellite, and lithiophorite; Price vein; Maggie Canyon bedded deposit (Mouat, 1962).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as the most widespread manganese oxide mineral. Mineral Hill district, Reymert mine, with the other manganese oxide minerals, psilomelane, coronadite, chalcophanite, and todorokite (Wilson, K.S., 1984).

Yuma County: Sheep Tanks district, Sheep Tanks mine, Booth Bonanza deposit, as black fibers in calcite as part of banded black calcite veins (Cousins, 1972).

Hornblende (See MAGNESIO-HORNBLENDE)

#HÖRNESITE

Magnesium arsenate hydrate, $Mg_3(AsO_4)_2{\cdot}8H_2O$. Formed in blocks of metamorphosed limestone in volcanic tuff at the type locality in Banat, Hungary.

Mohave County: West side of Peach Springs Canyon, in a cave as radiating white crystals, with talmessite, powellite, carnotite, conichalcite, calcite, and aragonite, among bright white encrustations with green bands and spotty yellow patches (Wenrich and Sutphin, 1989).

HÜBNERITE (see WOLFRAMITE)

HUMMERITE

Potassium magnesium vanadium oxide hydrate, $KMgV_5O_{14}{\cdot}8H_2O$. A rare water-soluble secondary mineral that forms as veins and efflorescences in sedimentary rocks.

Apache County: Lukachukai Mountains, Mesa No. 1 mine.

#HUNTITE

Calcium magnesium carbonate, $CaMg_3(CO_3)_4$. Typically a weathering product of magnesian rocks such as dolomites and some limestones, precipitated at low temperatures from aqueous solutions in cavities and vugs.

Pima County: Cimarron Mountains, Tohono O'odham (Papago) Indian Reservation, as nodular masses in altered limestone with magnesite (James Vacek, pers. commun., 1986) and as microcrystals (David Shannon, UA x4333).

HUREAULITE

Hydrogen manganese phosphate hydrate, $H_2Mn_5(PO_4)_4{\cdot}4H_2O$. Formed by alteration of primary phosphate minerals such as triphylite and associated with other secondary phosphates in granite pegmatites.

Yavapai County: White Picacho district, locally formed between crystals of lithiophilite and triphylite and as a coating on sicklerite; also as crystalline aggregates and in fractures in these crystals; amber- to flesh-colored (Jahns, 1952). Eureka district, 7U7 Ranch west of Hillside, associated with bermanite in triplite seams and with metastrengite and leucophosphite (Leavens, 1967).

HYDROBASALUMINITE

Aluminum sulfate hydroxide hydrate, $Al_4(SO_4)(OH)_{10}\cdot 36H_2O$(?). A rare secondary mineral associated with basaluminite, to which it alters on dehydration.

Cochise County: Warren district, Holbrook pit, as pearly-white flakes with basaluminite and other aluminum sulfates encrusting silicified limestones.

HYDROBIOTITE

Potassium iron aluminum silicate hydroxide, a mixed-layer mica composed of interstratified sequences of vermiculite and biotite.

Cochise County: Warren district, as an alteration product associated with the intrusion of a quartz monzonite.

Pinal County: Mammoth district, San Manuel mine, as a minor constituent of hydrothermal alteration of monzonite and quartz monzonite porphyries in the marginal, less intense alteration areas (Schwartz, 1958; Creasey, 1959; Lowell, J.D., 1968). Cottonwood Canyon district, southeast of Apache Junction, abundant in selvages of ore veins containing lead and copper.

HYDROCERUSSITE

Lead carbonate hydroxide, $Pb_3(CO_3)_2(OH)_2$. A rare mineral of secondary origin commonly associated with other products of the alteration of galena.

Cochise County: Warren district, as a coating on cerussite in a quartz-galena vein west of the Lavender pit (Graeme, 1993).

Gila County: C and B mine, with cerussite.

La Paz County: Red Cloud mine, associated with galena.

Maricopa County: Wickenburg district, Potter-Cramer mine, as thin, milky films on cerussite.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, Collins vein, as snow-white, hexagonal, pyramidal crystals, accompanied by diaboleite and leadhillite. These steep-sided crystals are up to nearly 1 in. long and are the finest specimens of the mineral (Fahey et al., 1950; Bideaux, 1980).

HYDROHETAEROLITE

Zinc manganese oxide hydrate, $Zn_2Mn_4O_8\cdot H_2O$. A common oxide-zone mineral in the Southwest, formed from the oxidation of zinc ores in carbonate rocks.

Cochise County: Tombstone district, Emerald mine, common as dark-brown fibrous masses or chaotic aggregates of slender prisms in partly silicified limestones.

#HYDROMAGNESITE

Magnesium carbonate hydroxide hydrate, $Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$. A secondary mineral formed by the alteration of magnesian rocks such as dolomites and serpentines.

Coconino County: At mile 34.8 in the Grand Canyon, as white crusts in a cave in Nautiloid Canyon, a few hundred meters from the Colorado River.

Hydromuscovite (see Illite)

HYDRONIUM JAROSITE

Hydronium iron sulfate hydroxide, $(H_3O)Fe_3(SO_4)_2(OH)_6$. At an occurrence in Poland, the origin of the mineral is ascribed to the low alkali content of mine waters due to the more rapid breakdown of sulfide than of rock-forming minerals. Moss (1957) and Van Tassel (1958) showed that the mineral previously termed *carphosiderite* was actually hydronium jarosite (Brophy and Sheridan, 1965).

Pinal County: Cherry Creek area, Black Brush deposit (Granger and Raup, 1969).

#HYDROXYAPOPHYLLITE

Potassium calcium silicate hydroxide fluoride hydrate, $KCa_4Si_8O_{20}(OH,F) \cdot 8H_2O$. Primarily a secondary mineral in amygdules in basalts, commonly associated with zeolites, pectolite, prehnite, datolite; also formed in contact-metamorphosed limestones bordering intrusives.

Maricopa County: Near Horseshoe Dam, as clear, tabular crystals of an unusual habit for apophyllite, up to 10 mm, in basalt, with natrolite (Hidemichi Hori, pers. commun., 1991; see previous listing under APOPHYLLITE, this work.)

#HYDROXYLAPATITE

Calcium phosphate hydroxide, $Ca_5(PO_4)_3(OH)$. Formed in a variety of talc-schist and diallage-serpentine metamorphosed rocks and in pegmatites.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites (London, 1979).

HYDROZINCITE

Zinc carbonate hydroxide, $Zn_5(CO_3)_2(OH)_6$. A secondary mineral formed in the oxidized portions of mineral deposits by the alteration of sphalerite; commonly associated with smithsonite, hemimorphite, and cerussite.

Cochise County: Tombstone district, west side of the Quarry "roll," in a small seam with aurichalcite and hemimorphite (Butler, B.S., et al., 1938b). Gunnison Hills, Texas-Arizona mine, in metamorphosed limestone as white, chalky masses up to 6 × 24 in. (Cooper, 1957; Cooper and Silver, 1964).

Coconino County: Havasu Canyon, with other secondary lead and zinc minerals.

Maricopa County: White Picacho district, as a supergene mineral formed from the alteration of sphalerite and associated hemimorphite, in pegmatites (Jahns, 1952).

Pinal County: Pioneer district, 1,600-ft level of the Magma mine, as a white film on sphalerite (Short et al., 1943); Hancock property near Superior. Slate Mountains, Jackrabbit mine, intimately associated with pulverulent yellow limonite and formed as fracture fillings (Hammer, 1961).

Yuma County: Castle Dome Mountains, Señora claims, in fissures with gypsum; Castle Dome district, in vugs and channels, associated with smithsonite, wulfenite, vanadinite, and mimetite (Wilson, E.D., 1933).

HYPERSTHENE

Magnesium iron silicate, $(Mg,Fe)SiO_3$. An orthorhombic pyroxene intermediate in composition between enstatite and orthoferrosilite; associated with many ultramafic rocks, especially norites; as a metamorphic mineral in charnockites.

Apache County: Monument Valley, Garnet Ridge, as sparse crystals in ejection boulders of garnet gneiss (Gavasci and Kerr, 1968).

Navajo County: About 20 miles west of Dilkon, as monomineralic hypersthenite dikes in shale.

Yavapai County: Near the summit of Mingus Mountain, in tholeiitic basalts (McKee, E.H., and Anderson, 1971).

I

Idocrase (see VESUVIANITE)

Illite

Potassium hydronium aluminum magnesium iron silicate hydroxide hydrate, $(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,H_2O]$. Structurally similar to muscovite, but contains more hydroxide and less potassium and aluminum. The name is widely used to signify clay minerals that have either the muscovite or biotite structure. A widespread and common mica component of clays, illites are especially abundant on the Colorado Plateau. They are a major constituent of the Salt Wash Member of the Morrison Formation (Keller, 1962), as well as the dominant clay mineral in most of the Moenkopi Formation. In the latter unit, illite is typically associated with kaolinite, chlorite, or montmorillonite, in places forming mixed-layer assemblages of illite-montmorillonite and chlorite-illite (Schultz, 1963). Illite is a common constituent of many clay-bearing sedimentary rocks throughout the state and is a widespread product of hydrothermal alteration of some mineral deposits, especially certain porphyry copper orebodies. Only a few localities are listed.

Cochise County: Warren district, Sacramento Hill, in a hydrothermally altered granite porphyry stock with sericite, kaolinite, allophane, and alunite, as an alteration of feldspar; in dikes that cut limestones peripheral to the stock (Schwartz, 1947).

Gila County: Globe-Miami district, Miami orebody, associated with kaolinite, halloysite, and sericite as a product of hydrothermal alteration of granite porphyry and schist (Schwartz, 1947).

Greenlee County: Morenci district, as pseudomorphs after plagioclase, with sericite, in the intensely altered porphyry orebody, with a large suite of hydrothermal alteration products, including kaolinite, leucoxene, and allophane (Schwartz, 1947, 1958).

Pinal County: Ray area, in a hydrothermally altered stock within the orebody, as pseudomorphs after plagioclase phenocrysts, associated with sericite, allophane, and kaolinite, and as pseudomorphs after biotite (Schwartz, 1947, 1952). Mammoth district, San Manuel mine, as an abundant minor constituent, in hydrothermally altered monzonite and quartz monzonite porphyries (Schwartz, 1947, 1958; Creasey, 1959); Kalamazoo orebody (Lowell, J.D., 1968).

ILMENITE

Iron titanium oxide, $FeTiO_3$. Formed in close association with mafic igneous rocks as veins, disseminated deposits, and dikes. Common as an accessory mineral in certain igneous rocks and, locally, as an important detrital constituent of black sands.

Apache County: Monument Valley, Garnet Ridge, as fragments in a breccia dike piercing sediments; as needles, the most common inclusions in garnets (Gavasci and Kerr, 1968).

Gila and Pinal Counties: As a constituent of the Pinal Schist and diabase (Peterson, N.P., 1962). Near Castle Dome, as tabular pieces in quartz (Peterson, N.P., et al., 1946, 1951). Sierra Ancha Mountains, intimately associated with hematite in Precambrian quartzite (Peterson, E.C., 1966). Mazatzal Mountains, Three Bar Wildlife Management Area, in quartz veins with chalcopyrite (MM 7383).

Graham County: Galiuro Mountains, in disseminated form in the northern part of the range.

Maricopa County: White Tank Mountains, as grains and intergrowths with magnetite in Precambrian schist and in pegmatites (Harrer, 1964). Big Horn district, with titaniferous magnetite constituting about 3 to 7% of extensive placer deposits (Harrer, 1964).

Pima County: Ajo district, formed both as a primary constituent of the Cornelia Quartz Monzonite and by alteration of sphene (Gilluly, 1937).

Pinal County: Red Rock–Florence Junction area, with titaniferous magnetite in widespread alluvial deposits (Harrer, 1964).

Santa Cruz County: Patagonia Mountains, especially at Duquesne and Washington Camp, in several contact metamorphic deposits (Schrader, 1917).

Yavapai County: Eureka district, with magnetite, as dikes and irregular bodies in gabbro (Ball and Broderick, 1919). Reported near the Bagdad mine, as a large, low-grade deposit. Bradshaw Mountains, in granite pegmatite near Cleator. Chino Valley, Paulden quadrangle, as minute lamellae intimately intergrown with pyroxene-garnet assemblages, in xenoliths in the Sullivan Butte Latite (Krieger, 1965; Schulze et al., 1978).

ILSEMANNITE

Molybdenum oxide hydrate, $Mo_3O_8 \cdot nH_2O$(?). A secondary mineral formed by oxidation of molybdenite and other molybdenum minerals. In places, of postmine origin.

Apache County: Monument Valley, Monument No. 2 mine, as dispersed, powdery, fine-grained material associated with corvusite, navajoite, hewettite, uraninite, and gypsum (Witkind and Thaden, 1963).

Cochise County: Warren district, in a prospect pit near Warren, as blue stains on intensely silicified, brecciated limestone, with fluorite and scheelite.

Coconino County: Cameron area, Huskon No. 11 mine, with marcasite in sandstone, as ink-blue masses and stains; Huskon No. 10 mine, as ink-blue stain on halotrichite. (AEC mineral collection.) East of Jacob Lake, Sun Valley mine, abundant on the walls of older mine workings, in uranium deposits in a paleo-stream channel filled with Shinarump Conglomerate (Petersen et al., 1959).

ILVAITE

Calcium iron silicate hydroxide, $CaFe^{2+}_2Fe^{3+}Si_2O_7O(OH)$. Formed in contact metamorphic deposits, typically in limestones and dolomites, with other calcium silicate minerals.

Cochise County: Dragoon Mountains, Middlemarch Pass, abundant in hedenbergite hornfels in several mines, as poorly developed crystals up to 0.5 in. long, associated with sphalerite and fluorite.

Graham County: Aravaipa district, Iron Cap mine, as vitreous, fine-grained material associated with fluorite, sphalerite, and quartz (Don Burt, pers. commun., 1971).

#INGODITE

Bismuth tellurium sulfide, Bi_2TeS.

Cochise County: Blue Bird mine (S C7073), as small tabular, cleavable, silver-gray crystals in scheelite-bearing garnetite.

IODARGYRITE (Iodyrite)

Silver iodide, AgI. A secondary mineral formed in the oxidized zone of silver deposits; alters to silver.

Cochise County: Pearce Hills, Commonwealth mine, with chlorargyrite, bromargyrite, embolite, and acanthite (Endlich, 1897; Guild, 1910). Warren district, Campbell shaft, with mottramite, argentite, silver, and kettnerite (Graeme, 1993).

Mohave County: Silliman (1866) reported the presence of "iodyrite" in quartz veins in "ash-colored feldspathic porphyry" in Mohave County, associated with "fluorspar, green carbonate of copper, free gold, and abundant iron gossan in cellular quartz." San Francisco district, in several lodes in the Caledonia, Dayton, Quackenbush, and Knickerbocker properties. Cerbat Mountains, Wallapai district, as the chief near-surface ore mineral in oxidized sulfide vein deposits (Thomas, B.E., 1949).

Pima County: Cerro Colorado Mountains, Cerro Colorado mine (Guild, 1910). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1960).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as pale-green droplets, with caledonite and boleite (Bideaux, 1980).

Santa Cruz County: Patagonia district, World's Fair mine, as small, isolated crystals, globules, and specks in "contour boxwork" limonite deposits, which were derived from tetrahedrite (Blanchard and Boswell, 1930).

Iodobromite (iodian BROMARGYRITE)

Iodyrite (see IODARGYRITE)

Iolite (a variety of CORDIERITE)

#IRANITE

Lead copper chromate silicate fluoride hydroxide, $Pb_{10}Cu(CrO_4)_6(SiO_4)_2(F,OH)_2$. Closely related to hemihedrite chemically and structurally but differs by having a cation site principally occupied by copper rather than zinc. Formed in the oxidized zone of lead- and chromium-bearing veins.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as small crystals on older specimens (Richard W. Thomssen, pers. commun., 1987; UA 10550).

#IRIGINITE

Uranyl molybdenum oxide hydrate, $(UO_2)Mo_2O_7.3H_2O$. An uncommon mineral, presumably of secondary origin.

Coconino County: East of Cameron, in some uranium prospects.

Iron (see KAMACITE and TAENITE)

J

JADEITE

Sodium aluminum iron silicate, $Na(Al,Fe)Si_2O_6$. A member of the pyroxene group.

Apache County: Monument Valley area, Garnet Ridge, as diopsidic jadeite with an appreciable proportion of aegirine, coexisting with pyrope-almandine garnet in eclogite inclusions from kimberlite pipes (Watson, K.D., and Morton, 1969).

#JAHNSITE

Calcium manganese iron magnesium phosphate hydroxide hydrate, $CaMn^{2+}(Fe^{2+},Mg)_2Fe^{3+}_2(PO_4)_4(OH)_2 \cdot 8H_2O$. Formed in pegmatites. Because the ferrous iron: magnesium ratio of the Arizona deposit is unknown, the formal suffix "-(CaMnFe)" or "-(CaMnMg)" to the mineral name is unclear.

Maricopa County: White Picacho district, Midnight Owl mine near Wickenburg, in lithiophilite (UA 6916; previously reported as salmonsite).

#JALPAITE

Silver copper sulfide, Ag_3CuS_2. Formed under low-temperature hydrothermal conditions.

Cochise County: Bisbee, Warren district, with the sulfide ores of the Campbell mine (Graeme, 1993).

Pinal County: Reymert mine, with acanthite and silver in quartz veins (Wilson, K.S., 1984).

JAMESONITE

Lead iron antimony sulfide, $Pb_4FeSb_6S_{14}$. Formed in hydrothermal veins formed under low to moderate temperatures; typically associated with galena, sphalerite, stibnite, tetrahedrite, and other sulfosalts.

Yavapai County: Reported in the Bradshaw Mountains, in some of the ores, with free gold.

JAROSITE

Potassium iron sulfate hydroxide, $KFe_3(SO_4)_2(OH)_6$. A member of the alunite group. A secondary mineral widely distributed throughout the Southwest. Formed in the oxidized cappings of base-metal deposits; may be a major component of the limonites of gossans.

Apache County: Monument Valley, Monument No. 2 mine, in Shinarump Conglomerate (Mitcham and Evensen, 1955; Witkind and Thaden, 1963).

Cochise County: Tombstone district, abundant in the Toughnut and Empire mines (Butler, B.S., et al., 1938b). Turquoise district, as small, flaky bunches. Commonwealth mine at Pearce, with chlorargyrite and silver. Warren district, Sacramento Hill, in the hydrothermally altered granite porphyry stock (Schwartz, 1947). Dragoon Mountains, Red Cloud Peak, as microcrystals (Peter Megaw, UA x3365).

Coconino County: Cameron area, very abundant in the uranium deposits (Austin, 1964).

Gila County: Globe-Miami district, Castle Dome and Copper Cities mines, as an abundant supergene mineral (Peterson, N.P., 1947, 1962; Peterson, N.P., et al., 1951). Sierra Ancha Mountains, Little Joe deposit; Cherry Creek, Shepp 2 deposit (Granger and Raup, 1969). Dripping Spring Mountains, Arizona Apex mine, as sharp, brown crystals up to 0.5 mm (David Shannon, pers. commun., 1988).

Graham County: Gila Mountains, Lone Star district, Safford area, with pseudomalachite, malachite, brochantite, antlerite, and other secondary oxidized minerals (Hutton, 1959b); Safford porphyry copper deposit, in fractures and veins as a replacement of primary minerals, fault gouge, and clay, and intimately associated with turquoise and alunite (Robinson, R.F., and Cook, 1966).

Greenlee County: Clifton-Morenci district, Morenci open-pit mine, where it is "widespread but most dramatic as an oxidation product of pyritic veinlets in areas of weak (copper) mineralization" (Moolick and Durek, 1966).

Maricopa County: Vulture Mountains, Vulture mine, as "fine, transparent, yellow and dark-brown rhombic crystals" filling cavities formed from the oxidation of pyrite; associated with gold particles (Silliman, 1879). An analysis by S.F. Penfield (1881) gave the following results (wt %):

SO_3	30.42	K_2O	8.53	Na_2O	0.28
Fe_2O_3	48.27	H_2O	12.91	TOTAL	100.41

Specific gravity: 3.09

Vulture district, Black Rock mine.

Mohave County: Cerbat Mountains, Wallapai district, as a secondary mineral (Thomas, B.E., 1949; Field, 1966).

Navajo County: Monument Valley, Monument No. 1 mine, in the largely oxidized uranium-vanadium ores, associated with torbernite, carnotite, corvusite, and tyuyamunite (Holland et al., 1958).

Pima County: Empire Mountains, Total Wreck mine, with wulfenite, vanadinite, chlorargyrite, cerussite, and smithsonite; Jerome No. 2 mine, Hilton group of claims, in lead-zinc veins (Schrader and Hill, 1915). Silver Bell Mountains, Silver Bell mine, with alunite (Kerr, 1951). Sierrita Mountains, Pima district, Mineral Hill area (UA 7857). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963), as lovely color-zoned tablets, up to 5 mm across, in vugs in milky quartz. Ajo district, where it is largely confined to weathered capping of areas of notably pyritic ore (Gilluly, 1937). Helvetia-Rosemont district (Schrader, 1917). Pima district, Twin Buttes open-pit mine (Stanley B. Keith, pers. commun., 1973); San Xavier North mine, in drill cores as fracture coatings and botryoidal masses in open spaces (Koenig, B.A., 1978).

Pinal County: Mineral Creek deposit near Ray, as one of the oxidized iron minerals in a copper-rich, Holocene gravel deposit leached from a nearby secondary copper sulfide blanket; may be associated with goethite, hematite, malachite, azurite, cuprite, and tenorite (Phillips et al., 1971). Copper Creek region, as a minor oxidation product of pyrite (Simons, 1964). Mammoth district, San Manuel deposit, in small amounts, formed from the breakdown of pyrite (Schwartz, 1953).

Santa Cruz County: Red Mountain near Patagonia, as small (less than 0.5 mm), honey-brown, transparent crystals coating breccia and altered porphyritic rock (Kenneth Bladh, pers. commun., 1974). Patagonia Mountains, Mowry mine; Harshaw district, Flux mine.

Yavapai County: Copper Basin district, in the oxidized zone of mineralized breccia pipes, with hematite, limonite, chrysocolla, and other secondary minerals (Johnston, W.P., and Lowell, 1961). Eureka district, Bagdad, in leached cappings of sulfide deposits, with goethite (Anderson, C.A., 1950). Jerome, United Verde mine, in minor amounts dusted over yavapaiite and other secondary sulfides formed from the burning of pyritic ores (Hutton, 1959a).

Yuma County: Copper Mountains, Engesser prospect (Wilson, E.D., 1933).

Jefferisite (a variety of VERMICULITE)

JEROMITE

Arsenic sulfide selenide, near $As(S,Se)_2$(?). An amorphous substance of uncertain nature formed as a result of a mine fire at Jerome. Its validity as a mineral species had previously been questioned.

Yavapai County: Jerome, United Verde mine, as "a coating on fragments of rock beneath iron hoods placed over vents from which sulfur dioxide gases are issuing," a product of burning sulfide ores; formed as black, globular, opaque masses, translucent on thin edges. This is the type and only known locality (Lausen, 1928). A chemical analysis (by T.F. Buehrer), recalculated after deduction of insoluble silica, gave the following results (wt %):

S	42.9	As	49.2
Se	7.9	TOTAL	100.00

JOHANNITE

Copper uranyl sulfate hydroxide hydrate, $Cu(UO_2)_2(SO_4)_2(OH)_2 \cdot 6H_2O$. A secondary mineral typically formed by the alteration of uraninite in sulfide veins.

Yavapai County: Hillside mine, with several other uranium minerals (Axelrod et al., 1951).

JOHANNSENITE

Calcium manganese iron silicate, $Ca(Mn,Fe)Si_2O_6$. A member of the pyroxene group, near diopside-hedenbergite in properties and paragenesis, but much less common.

Graham County: Aravaipa district, Black Hole prospect, NW1/4 sec. 36, T. 5 S., R. 19 E., in tabular bodies and irregular masses replacing limestone, as radiating or spherulitic aggregates of prisms or needles a few centimeters in diameter and larger masses a few feet thick and several tens of feet long, associated with neotocite, chalcopyrite, galena, and sphalerite (Simons and Munson, 1963); Iron Cap mine, as the major pyroxene, both as massive material and as crystals (Reiter, 1980, 1981).

Santa Cruz County: Washington Camp–Duquesne districts, near the Dudley Standard mine, as radiating clusters (Lehman, 1978).

JORDISITE

Amorphous molybdenum sulfide, MoS_2. A poorly characterized, black, powdery, amorphous material, which may alter to ilsemannite. Said to be trimorphous with molybdenite.

Coconino County: East of Jacob Lake, Sun Valley mine, in a uranium deposit located in a bend in a paleo-stream channel filled with Shinarump Conglomerate, associated with uraninite, ilsemannite, pyrite, sphalerite, and hematite (Petersen, 1960).

JUNITOITE

Calcium zinc silicate hydrate, $CaZn_2Si_2O_7 \cdot H_2O$. Probably of late-stage hydrothermal origin; known only from its type locality at Christmas.

Gila County: Banner district, in the open-pit mine at Christmas, in tactite ores with kinoite and apophyllite, as clear, platy crystals up to 5 mm across, typically associated with pink smectite (clay) in rings around nuggets of unaltered sphalerite (Williams, S.A., 1976); its crystal structure has been elucidated by R.D. Hamilton and Finney (1985).

JURBANITE

Aluminum sulfate hydroxide hydrate, $Al(SO_4)(OH)\cdot 5H_2O$. A sparse secondary mineral formed at the San Manuel mine under conditions of high humidity. Associated with other water-soluble secondary sulfates, including epsomite, pickeringite, and an uncharacterized, presumably new, mineral species. The San Manuel mine is the type locality. Also known from the Cetine mine, Tuscany, Italy.

Pinal County: Mammoth district, 2,075-ft level of the San Manuel mine, as sparse, minute, clear, colorless crystals, intimately associated with epsomite, hexahydrite, pickeringite, and starkeyite deposited on lagging and overhead pipes (Anthony and McLean, 1976).

K

KAERSUTITE

Calcium sodium potassium magnesium iron titanium aluminum silicate oxide hydroxide fluoride, $Ca_2(Na,K)(Mg,Fe^{2+},Fe^{3+})_4Ti(Si_6Al_2)O_{22}(O,OH,F)_2$. May be regarded as a titanian oxy-hornblende; a member of the amphibole group. Formed in volcanic and alkalic plutonic rocks.

Cochise County: San Bernardino Valley, in xenoliths formed in alkali-olivine basalts and basanites of the Quaternary Geronimo lavas (Evans, S.H., and Nash, 1979; Lynch, D.J., 1976).

Coconino County: San Francisco Mountain, as microcrystals (Kenneth Bladh, UA x1672).

Gila County: Near San Carlos on the San Carlos Indian Reservation, associated with spinel and augite. Mason (1968) thoroughly studied the mineral from xenocrysts in a basalt flow (see also Cross and Holloway, 1974); Garcia et al. (1980) discussed details of the chemistry of its volatile content. An analysis by Joseph Nelen gave the following results (wt %):

SiO_2	39.63	FeO	10.36	Na_2O	2.96
TiO_2	4.93	MnO	0.14	K_2O	1.60
Al_2O_3	14.36	MgO	10.90	$H_2O(+)$	0.72
Fe_2O_3	3.20	CaO	10.93	$H_2O(-)$	0.10
		TOTAL (incl. 1.0% ilmenite)			99.83

Mohave County: Minnesota district, about 8 miles south of Hoover Dam on U.S. Highway 93, as large (up to 15 cm long) phenocrysts in a camptonite dike (Campbell and Schenk, 1950; Garcia et al., 1980). At the southern end of the Uinkaret Plateau, as large poikilitic crystals in ultramafic inclusions in geologically young flows and associated cinder cones of basanitic composition (Best, 1970).

KAMACITE

Alpha nickel iron, α-(Ni,Fe). Has a body-centered, cubic structure and contains about 5.5% nickel. As a major constituent of iron meteorites, including those found in Arizona. Commonly associated with taenite.

#KANONAITE

Manganese aluminum silicate, $(Mn^{3+},Al)AlSiO_5$. Formed in manganese-rich metamorphic schists.

Maricopa County: Southwestern slope of Squaw Peak, Phoenix, as green porphyroblasts in quartz muscovite schist; kanonaite from this locality has a range of compositions and may be distinguished from the local manganese-rich andalusite only through chemical analysis (Thorpe, 1980).

KAOLINITE

Aluminum silicate hydroxide, $Al_2Si_2O_5(OH)_4$. The most important member of the kaolinite group of clay minerals, which also includes dickite, nacrite, halloysite, and endellite. Members of the group are formed by hydrothermal processes during alteration accompanying mineral-deposit formation; they are also extensive in sedimentary formations, to which they have been introduced either by transportation from previously weathered rocks or by in situ weathering of feldspathic rocks. Only a few Arizona localities can be listed.

Apache County: Monument No. 2 mine, associated with the uranium-vanadium ores (Witkind and Thaden, 1963).

Cochise County: Warren district, second level of the Copper Queen mine, as nearly pure kaolinite in white, waxy masses; Sacramento Hill, in hydrothermally altered, granite porphyry stock, with sericite, hydromuscovite, allophane, and alunite, as an alteration product of feldspar (Schwartz, 1947, 1958). Tombstone district, Toughnut mine (Butler, B.S., et al., 1938b). Turquoise district, Silver Bill mine. Willcox Playa, very sparse in clays near the surface (Pipkin, 1968).

Colorado Plateau: Prevalent in certain sedimentary formations, including the sandstone of the Shinarump Member of the Chinle Formation (Schultz, 1963) and the Salt Wash Member of the Morrison Formation (Keller, 1962).

Gila County: Globe-Miami district, Old Dominion mine, with chalcocite in the oxidized zones; Castle Dome mine, associated with halloysite and endellite, as small masses filling open fractures in quartz monzonite (Schwartz, 1947); Miami and Inspiration orebodies, as a product of hydrothermal alteration (Schwartz, 1947).

Greenlee County: Clifton-Morenci district, widespread as a product of pervasive hydrothermal alteration (Schwartz, 1947, 1958; Moolick and Durek, 1966); in large masses at the Longfellow mine, and in snow-white mammillary masses with azurite and malachite at the Copper Mountain and Mammoth mines (Lindgren, 1905); Humboldt, Ryerson, and other properties.

Maricopa County: Vulture district, on the west side of the Hassayampa River, associated with alunite, making up a major phase within a hydrothermally altered rhyolite (Sheridan and Royse, 1970).

Navajo County: Along the eastern and southeastern edge of Black Mesa, as cement or matrix of sandstones in the Westwater Canyon Member of the Morrison Formation and in the Cow Springs and Mesa Verde Formations. Near Coal Mine Canyon and the Hopi Mesas (Kiersch, 1955).

Pima County: Silver Bell Mountains, upper levels of the El Tiro mine, as large masses in wall rock (Kerr, 1951). Pima district, Twin Buttes mine, as a product of hydrothermal alteration (Stanley B. Keith, pers. commun., 1973). Ajo, Well No. 1 of the Phelps Dodge Corp., as the variety anauxite (William Thomas, pers. commun., 1988).

Pinal County: Mammoth district, San Manuel mine, as a common product of hydrothermal alteration of igneous rocks; with alunite, it makes up most of the rock in the intensely altered zones (Schwartz, 1947, 1953, 1958; Creasey, 1959). Ray area, with sericite, hydromuscovite, and alunite, in hydrothermally altered granitic rocks (Ransome, 1919; Schwartz, 1947, 1952).

KASOLITE

Lead uranyl silicate hydrate, $Pb(UO_2)SiO_4 \cdot H_2O$. A secondary mineral, probably formed by the reaction of silica-bearing meteoric waters with earlier-formed secondary uranium minerals.

Maricopa County: South of Buckeye, in a pegmatite, associated with polycrase.

Navajo County: Seven Mile Canyon, Shinarump 1B mine, as yellow specks on gray sandstone (AEC mineral collection).

Santa Cruz County: Santa Rita Mountains, Kinsley property, east of Amado (UA 2704); Duranium claims, disseminated in arkosic sandstone with uranophane and autunite (Robinson, R.L., 1954; Shawe, 1966). Nogales district, White Oak property, as good crystalline material, with uranophane, dumontite, and autunite, associated with oxidized lead ore in a shear zone in rhyolite (Granger and Raup, 1962). Walnut Canyon, as incrustations along fractures in felsite porphyry (Robert O'Haire, pers. commun., 1972).

#KESTERITE

Copper zinc iron tin sulfide, $Cu_2(Zn,Fe)SnS_4$. In quartz-sulfide hydrothermal veins in tin deposits.

Cochise County: Warren district, Campbell mine, among the sulfide minerals (Graeme, 1993).

#KETTNERITE

Calcium bismuth carbonate oxide fluoride, $CaBi(CO_3)OF$. Found in quartz veins with other bismuth minerals and fluorite.

Cochise County: Bisbee, Warren district, Campbell orebody, with aikinite, argentite, and silver (Graeme, 1993).

Graham County: Prospect northwest of Bowie, as abundant, yellowish-tan, tabular crystals up to 5 mm. An analysis by S.A. Williams gave the following results (wt %):

CaO	14.3	Bi_2O_3	57.2
CO_2	27.5	TOTAL	99.0

The strongest X-ray lines are as follows: 13.55Å (10), 2.905 (8), 1.726 (5), 3.660 (4), 3.310 (4), 2.687 (4). These data differ from the original description, which was based on inadequate X-ray diffraction techniques that did not record all of the reflections. The kettnerite is associated with bismutite, malachite, and duhamelite as pseudomorphs after very large (up to 3 in. long) prisms of a bismuth sulfosalt, which cannot be characterized because of its weathered condition.

La Paz County: Three Musketeers mine, as masses in quartz veins, with other secondary bismuth minerals (collected by David Shannon).

KHINITE

Copper lead tellurate hydroxide, $Cu_3PbTeO_4(OH)_6$, dimorphous with parakhinite. An extremely rare secondary mineral formed by oxidation of other tellurium minerals in acid waters. Known only from Tombstone, which is the type locality.

Cochise County: Tombstone district, in dump material of the Old Guard mine, as corroded, deep-green, minute (up to 0.15 mm) crystals that form rings on fracture surfaces of silicified granodiorite. The centers of the rings are composed of massive chlorargyrite, whereas the outer portions have been replaced by sparkling druses of minute dugganite crystals. Associated with parakhinite, xocomecatlite, bromargyrite, and a number of other tellurates and tellurites. An analysis by Marjorie Duggan (Williams, S.A., 1978) yielded the following results (wt %):

CuO	33.2	TeO_3	24.5	PbO	32.4
H_2O	(7.6)			TOTAL	97.7

Density: 6.69

#KIDDCREEKITE

Copper tin tungsten sulfide, Cu_6SnWS_8. A very rare primary sulfide mineral, found in only two localities worldwide. The Campbell mine in Bisbee is, with the Kidd Creek mine in Timmins, Ontario, Canada, a co–type locality.

Cochise County: Bisbee, Warren district, Campbell mine, as minute grains in the sulfide orebody. This occurrence was reported simultaneously with that of the Kidd Creek mine in Timmins, Ontario (Harris et al., 1984).

KINOITE

Calcium copper silicate hydrate, $Ca_2Cu_2Si_3O_{10}\cdot 2H_2O$. Found in skarns formed late in the paragenetic sequence, with apophyllite and copper. The Santa Rita Mountains occurrence is the type locality.

Gila County: Banner district, Christmas open-pit mine, almost everywhere coated by apophyllite.

Pima County: Northern Santa Rita Mountains, between Helvetia and Rosemont on claims owned by ASARCO, in a core from diamond-drill holes, which penetrated contact-metamorphosed Paleozoic limestones and dolomites; with apophyllite, copper, djurleite, bornite, and chalcopyrite, as small tabular euhedral crystals and in veinlets (Anthony and Laughon, 1970; Laughon, 1971). A chemical analysis by H.M. Ochs on type material gave the following results (wt %):

CuO	31.10	CaO	23.55	MgO	0.15
SiO_2	35.90	H_2O	8.16	TOTAL	98.86

Pima district, Twin Buttes mine, as microcrystals, with apophyllite (Gene Wright, pers. commun., 1980; UA x1448); as crystals up to 0.5 cm, with stringhamite, copper, and apophyllite in wollastonite (William Hefferon, pers. commun., 1983).

#KOECHLINITE

Bismuth molybdenum oxide, Bi_2MoO_6. With other bismuth minerals in quartz veins; also formed by the alteration of tetradymite.

Gila County: Reported in the Inspiration mine, as yellowish tabular crystals on chrysocolla (William Roberts, pers. commun., 1986).

KORNELITE

Iron sulfate hydrate, $Fe_2(SO_4)_3\cdot 7H_2O$. An uncommon secondary mineral formed by the oxidation of pyrite; found as efflorescences in old mine workings.

Cochise County: Warren district, Copper Queen mine, as irregular porous crusts (Merwin and Posnjak, 1937).

KOSMOCHLOR (formerly Ureyite)

Sodium chromium silicate, $NaCr^{3+}Si_2O_6$. A rare member of the pyroxene group, known from iron meteorites.

Coconino County: Canyon Diablo area, near Meteor Crater, with krinovite in graphite nodules in the Canyon Diablo octahedrite meteorite; also associated with roedderite, high albite, richterite, and chromite (Olsen and Fuchs, 1968).

#KOSTOVITE

Copper gold telluride, $CuAuTe_4$. An uncommon primary mineral formed with sulfides and other tellurium minerals.

Cochise County: Bisbee, Warren district, as minute grains in the sulfide ores of the Campbell mine, with pyrite, chalcopyrite, altaite, goldfieldite, and melonite (Graeme, 1993).

KRENNERITE

Gold telluride, $AuTe_2$. An uncommon mineral in hydrothermal gold ores.

Cochise County: Bisbee, Warren district, in the ores of the Campbell mine, associated with other tellurides (Graeme, 1993). Tombstone district, Joe mine, in an ore specimen, as a small patch of granular material oxidizing to gold and paratellurite; probably a common, original constituent of the primary ores but readily oxidized, even to the lowest mine levels.

KRINOVITE

Sodium magnesium chromium silicate, $NaMg_2CrSi_3O_{10}$. Identified in iron meteorites.

Coconino County: Canyon Diablo area, near Meteor Crater, in the Canyon Diablo octahedrite meteorite, as minute, deep-emerald-green, subhedral grains disseminated within graphite nodules, associated with roedderite, high albite, richterite, kosmochlor, and chromite (Olsen and Fuchs, 1968); this is the type locality.

KTENASITE

Copper zinc sulfate hydroxide hydrate, $(Cu,Zn)_3(SO_4)(OH)_4{\cdot}2H_2O$. A rare secondary mineral, previously known from the Kamaresa mine, Laurium, Greece, where it is associated with serpierite and glaucocerinite on smithsonite, and from localities in Colorado and Norway.

Cochise County: Bisbee, Warren district, Campbell mine, as thin crystalline crusts on pyrite-chalcopyrite ores (Graeme, 1993).

Gila County: Banner district, 79 mine, abundant as blue crusts in the 31 stope area (Thomas Trebisky, pers. commun., 1975); Kullman-McCool mine (also known as the D.H. claims), in the southwestern workings, as very small tabular crystals and rosettes of crystals, with serpierite and gypsum.

#KULANITE

Barium iron manganese magnesium aluminum phosphate hydroxide, $Ba(Fe^{3+},Mn,Mg)_2Al_2(PO_4)_3(OH)_3$. Found in pegmatites with other phosphate minerals.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites (London, 1981).

#KURAMITE

Copper tin sulfide, Cu_3SnS_4. An uncommon hydrothermal sulfide mineral.

Cochise County: Bisbee, Warren district, in the sulfide ores of the Campbell mine, associated with pyrite, altaite, and melonite (Graeme, 1993).

#KUTNOHORITE

Calcium manganese magnesium iron carbonate, $Ca(Mn,Mg,Fe^{2+})(CO_3)_2$. A member of the dolomite group. Formed in some mineral deposits as gangue, as it has at the Arizona locality.

Graham County: Iron Cap mine, as pale-pink to white botryoidal coatings on quartz (Reiter, 1980).

KYANITE

Aluminum silicate, Al_2SiO_5. Typically formed in schist and gneiss as a product of thermal metamorphism of aluminous rocks. Commonly associated with its trimorphs, andalusite and sillimanite.

La Paz County: Locality 3 miles southeast of Quartzsite, with dumortierite. Granite Wash Mountains, west flank of Salome Peak, as large (up to 6 cm long) blades (Stephen Reynolds, pers. commun., 1989), and at several other localities (Reynolds et al., 1988). Dome Rock Mountains, at several localities, with muscovite and one or more of the following: rutile, hypersthene, tourmaline, dumortierite, pyrophyllite, and sillimanite (Reynolds et al., 1988). Edge of the Trigo Mountains, 1 mile west of the lower Yuma Wash, as blades up to 1 × 5 cm, with pyrophyllite and tourmaline (Gordon Haxel, pers. commun., 1989). Near Clip, as long-bladed crystals in quartzose schist in Colorado River terrace gravels, associated with dumortierite (Wilson, E.D., 1933). An analysis (by W.F. Hillebrand) of Clip material (Schaller, 1905) gave these results (wt %):

SiO_2	36.30	FeO	—
$Al_2O_3(+TiO_2)$	62.51	CuO	tr.
Fe_2O_3	0.70	Loss on Ign.	0.40
		TOTAL	99.91

Specific gravity at 18.5°C: 3.656

Maricopa County: Phoenix area, Squaw Peak, where 38 tons of kyanite were reportedly mined (Wilson, E.D., and Roseveare, 1949).

Mohave County: The Arizona Bureau of Mines (currently the Arizona Geological Survey) received specimens from an unknown locality in the county.

Yuma County: Gila Mountains, about 8 miles west of Wellton, on the east side of the range.

L

#LANARKITE

Lead sulfate oxide, $Pb_2(SO_4)O$. A secondary mineral formed in lead deposits.

Gila County: C & B mine (Crowley, 1980).

LANGITE

Copper sulfate hydroxide hydrate, $Cu_4(SO_4)(OH)_6 \cdot 2H_2O$. A secondary mineral formed by the oxidation of copper sulfides; commonly associated with gypsum.

Cochise County: Warren district, uncommon but widely distributed in the deeper workings of mines, as thin, sky-blue crusts of small tabular crystals on fractures in or near chalcopyrite, associated with greenish films of brochantite.

Coconino County: Horseshoe Mesa, Grand Canyon National Park, Grandview (Last Chance) mine, as silky greenish crusts lining cavities (Leicht, 1971).

LAUMONTITE

Calcium aluminum silicate hydrate, $CaAl_2Si_4O_{12} \cdot 4H_2O$. A member of the zeolite group. Formed in veins and cavities in igneous rocks, where it is of hydrothermal origin, in skarns, and as a product of incipient metamorphism in sedimentary rocks.

Cochise County: Huachuca Mountains, 1.5 miles east of Sunnyside, as the variety leonhardite, formed as pinkish crystals up to 1 in. long, with calcite crystals (H 107581). Warren district, as a product of hydrothermal alteration.

Gila County: Christmas mine, variety leonhardite, in vugs and veinlets in diorite and replacing garnet in skarn (Perry, D.V., 1969).

Maricopa County: Wickenburg district, at several localities, including the Moon Anchor mine and Potter-Cramer property (Williams, S.A., 1968).

Navajo County: Hopi Buttes volcanic field, Seth-La-Kai diatreme, in volcanic sandstone and tuffs, with limonite, gypsum, celadonite, and montmorillonite, with weak uranium mineralization (Lowell, J.D., 1956).

Pima County: Sierrita Mountains, Twin Buttes district, Twin Buttes mine, with epidote in calcite veinlets (Fellows, 1976). Ajo district, New Cornelia mine, as elongate pink crystals with calcite in andesite dikes (Thomas, W.J., and Gibbs, 1983).

Pinal County: Tortilla Mountains, Azurite mine, with stilbite in quartz veins with copper silicates (Bideaux et al., 1960).

#LAURELITE

Lead fluoride chloride hydroxide, $Pb(F,Cl,OH)_2$. Associated with galena and fluorite, from which it is thought to have formed by interaction with supergene fluids. The Grand Reef mine is the type, and at the time of this writing, only known locality.

Graham County: Aravaipa district, Grand Reef mine, as colorless, slightly flexible fibers up to 1 cm long, in quartz-lined vugs, associated with galena, quartz, fluorite, and anglesite (Kampf et al., 1989).

LAUSENITE

Iron sulfate hydrate, $Fe_2(SO_4)_3 \cdot 6H_2O$. A rare mineral originally named *rogersite;* found only at Jerome, where it formed as a result of a mine fire. This is the type and only known locality.

Yavapai County: United Verde mine, formed as a result of the burning of a pyritic orebody (Butler, G.M., 1928; Lausen, 1928). The chemical analysis that T.F. Buehrer made on "rogersite" gave the following results (wt %):

H_2O	20.64	Fe_2O_3	28.07	K_2O	0.06
SO_3	47.90	Al_2O_3	1.40	Na_2O	1.23
				TOTAL	99.30

#LAUTITE

Copper arsenic sulfide, CuAsS. Found in hydrothermal deposits formed at moderate temperatures.

Coconino County: As a relatively late-stage, primary sulfide mineral in uranium-bearing breccia pipes (Wenrich and Sutphin, 1988).

LAWRENCITE

Iron chloride, $FeCl_2$. A rare mineral found in meteoric and terrestrial iron and associated with volcanic fumarolic action. Reported from some of the iron meteorites of Arizona.

Coconino County: Small seams and pods of barringerite in the Canyon Diablo meteorite have altered in part to schreibersite, followed by wüstite, and then lawrencite (David Shannon specimen).

#LAWSONITE

Calcium aluminum silicate hydroxide hydrate, $CaAlSi_2O_7(OH)_2.H_2O$. A low-temperature metamorphic mineral.

Apache County: Garnet Ridge, with garnet and pyroxene in eclogite inclusions in kimberlite pipes (Watson, K.D., and Morton, 1969).

LAZULITE

Magnesium iron aluminum phosphate hydroxide, $(Mg,Fe)Al_2(PO_4)_2(OH)_2$. A member of the lazulite-scorzalite $[(Fe,Mg)Al_2(PO_4)_2(OH)_2]$ solid-solution series. Formed in granite pegmatites, quartz veins, and aluminous, high-grade, thermally metamorphosed rocks.

La Paz County: Near Quartzsite, in quartzite, with kyanite, andalusite, pyrophyllite, and dumortierite (Bideaux et al., 1960).

Maricopa County: Reported in a locality on the Phoenix-Cave Creek road, 1.2 miles north of Hyatt's Camp.

Pima County: Santa Rita Mountains, on a ridge between Stone Cabin and Madera Canyons (Robert O'Haire, pers. commun., 1972).

LEAD

Lead, Pb. Uncommon as the metallic element in the oxidized zone of lead-bearing vein deposits. All localities noted below, except Tubac, require confirmation.

Maricopa County: Reported in the benches of Oxbow Creek, Old Woman Gulch, and Little San Domingo Creek, in red sands with magnetite.

Santa Cruz County: Tubac, replacing tree roots (UA 8577).

Yavapai County: Reported in Gold Crater, 15 miles west of Congress, in fist-sized masses; also reported at La Paz, in red-stained quartz.

LEADHILLITE

Lead sulfate carbonate hydroxide, $Pb_4(SO_4)(CO_3)_2(OH)_2$. A rare secondary mineral formed in oxidized lead deposits.

Cochise County: Warren district, Campbell mine, 1,800-ft level, and Cole mine, with malachite and silver on chalcocite (H 94731, 94733). Tombstone district, a fine specimen was found in 1942 on the dump of the old Manila mine on the Tombstone-Charleston road, adjoining the Gallagher properties, about 1 mile from the Charleston railroad crossing.

Graham County: Aravaipa district, Grand Reef mine, as tabular and pseudohexagonal twinned crystals up to 1 cm across (Jones, R.W., 1980).

Maricopa County: Painted Rock Mountains, Rowley mine near Theba, sparingly as fine, water-clear, highly modified, platelike crystals up to 6 mm across; associated with caledonite and anglesite (Wilson, W.E., and Miller, 1974). The crystals are sky blue, yellow, or pale green; some are probably paramorphous after susannite. Osborn district, Tonopah-Belmont mine, as crystal crusts and coatings on cerussite, with caledonite and linarite (Allen, G.B., and Hunt, 1988).

Pima County: South Comobabi Mountains, Cababi district, Mildren and Steppe claims, with a wide variety of other oxidized minerals (Williams, S.A., 1963).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, 400-ft level of the Collins vein, with other rare oxide-zone minerals; as crystals up to 1 in., with basal cleavage having brilliant luster. Some of the crystals are prismatic, composed of sectors of monoclinic symmetry; others are pseudorhombohedral or tabular, composed of two, three, or six individuals, twinned after the Artini law (Palache, 1941b; Fahey et al., 1950; Bideaux, 1980; H 104513).

Lechatelierite (fused silica)

Fused silica (glass). Formed by the application of intense heat (as by lightning strokes) to rock and soil containing quartz. Also formed as a result of intense heat generated by meteoric impact into quartz sandstone. Commonly noted beneath power lines, where it has formed by electrical discharge between the earth and the conductors during electrical storms.

Coconino County: Meteor Crater, west of Winslow, where it was formed by fusion of fine-grained Coconino Sandstone (Rogers, A.F., 1930). Several fulgurites, as black to green, obsidianlike coatings and tubes, have been found on the summit of Humphreys Peak and other peaks of the San Francisco Mountains near Flagstaff; the composition of these fulgurites has not been established (Davis, D.G., and Breed, 1968).

Pima County: Numerous fulgurites, formed by lightning activity, have been noted under power lines along Ajo Road, near the road to Tucson Mountain Park. Such electrical discharges have, in some instances, followed the roots of desert plants downward into the soil, carbonizing the plant material and forming a sheaf of fused soil or rock (which may include lechatelierite) in and near the root.

Leonhardtite (see STARKEYITE)

LEPIDOCROCITE

Gamma iron oxide hydroxide, γ-FeO(OH). Formed under essentially the same conditions as goethite, with which it is commonly associated. Probably far more abundant in Arizona than indicated by the few localities noted.

Cochise County: Warren district, with goethite (UA 8969).

Gila County: Banner district, 79 mine, as a constituent of the limonites formed in the oxidized portions of the deposit (Keith, 1972).

Graham County: Lone Star district near Safford, as a minor constituent of metasomatized volcanic rocks (Hutton, 1959b).

Pima County: South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963).

Pinal County: Reported but unconfirmed in the Mammoth district, Mammoth–St. Anthony mine. Superior district, Magma mine.

LEPIDOLITE

Potassium lithium aluminum silicate fluoride hydroxide, $K(Li,Al)_3(Si,Al)_4O_{10}(F,OH)_2$. A member of the mica group. A typical constituent of lithium-bearing granite pegmatites; associated with spodumene and amblygonite.

Maricopa County: White Picacho district, as light pinkish-gray to deep lilac or lavender compact aggregates and small books, in lithium-bearing pegmatites (Jahns, 1952). Southwest of Wickenburg, Boyd-Fortner claims. Garcia Mountains, west of Morristown. Eastern Vulture Mountains. Harquahala Mountains, in masses that are nearly identical in appearance to muscovite.

Yavapai County: Eureka district, in pegmatites of the Bagdad area. Castle Creek district, Weatherby Beryl mine, as pink crystals with elbaite and muscovite (MM 9461).

LEUCITE

Potassium aluminum silicate, $KAlSi_2O_6$. Leucite typically forms in potassium-rich, silica-poor, volcanic flow rocks, as well as in chemically equivalent hypabyssal rocks.

Apache County: Navajo Indian Reservation, in certain olivine-rich dikes (Williams, H., 1936).

LEUCOPHOSPHITE

Potassium iron phosphate hydroxide hydrate, $KFe_2(PO_4)_2(OH)\cdot 2H_2O$. An uncommon secondary mineral found in pegmatites; also of sedimentary origin.

Yavapai County: Eureka district, 7U7 Ranch, with bermanite in seams in triplite, also associated with phosphosiderite (metastrengite) and hureaulite (Leavens, 1967).

#LEUCOSPHENITE

Barium sodium titanium boron silicate, $BaNa_4Ti_2B_2Si_{10}O_{30}$. Abundant as well-formed crystals in the Green River Formation of Wyoming.

Pima County: Silver Bell open-pit mine, as microcrystals (Roe, A., 1980).

#LEVYNE

Calcium sodium potassium aluminum silicate hydrate, $(Ca,Na_2,K_2)Al_2Si_4O_{12}\cdot 6H_2O$. A zeolite-group mineral, typically formed in cavities in basalt.

Greenlee County: As microcrystals in a road cut 3 miles north of Clifton (Roe, A., 1980).

Pinal County: South of Superior, as microcrystals in Arnett Creek (Robert Mudra, UA x167).

#LEWISITE

Calcium iron sodium antimony titanium oxide, $(Ca,Fe^{2+},Na)_2(Sb,Ti)O_7$. Found in veins that cut a lepidolite-fluorite-magnetite rock.

Cochise County: Johnny Lyon Hills, at a prospect along the banks of Tres Alamos Wash, abundant as an alteration product of tetrahedrite. The lewisite typically forms cell walls in the pseudomorphs, whereas the interiors are filled with partzite. The tetrahedrite crystals must have been spectacular, as euhedra 1 in. or more, before oxidation occurred. Mineralization is confined to milky quartz veins that cut limestone.

LIBETHENITE

Copper phosphate hydroxide, $Cu_2(PO_4)(OH)$. An uncommon secondary mineral formed in the oxidized zones of copper deposits.

Apache County: Fort Defiance area, as microcrystals (Jessie Hardman, UA x3011).

Cochise County: Unspecified locality in the Little Dragoon Mountains (Robert O'Haire, pers. commun., 1972).

Gila County: Globe-Miami district, Castle Dome mine, as crusts composed of small, emerald-green prismatic crystals or as drusy mats of acicular crystals along open fractures (Peterson, N.P., et al., 1946, 1951). Jewell J. Glass, U.S. Geological Survey, noted that the mineral from the Castle Dome mine exhibited inclined extinctions similar to those of pseudomalachite, and therefore, should be termed *cli-*

nolibethenite (Peterson, N.P., 1962, p. 75). Banner district, 79 mine (Robert O'Haire, pers. commun., 1970).

Greenlee County: Morenci district, Coronado mine, as small crystals in cavities (identified by S.F. Penfield). This was the first discovery of the mineral in the United States (Lindgren and Hillebrand, 1904).

Pima County: Southern side of Saginaw Hill, about 7 miles southwest of Tucson, associated with other oxidized minerals, including cornetite, pseudomalachite, malachite, atacamite, and chrysocolla, coating fractures in chert; as pale-green, greasy masses surrounding cornetite crystals, in places apparently formed from partially corroded, fairly large, cornetite crystalline masses; also formed as clusters of yellowish-green prismatic crystals (Khin, 1970). Waterman district, Silver Hill mine, as microcrystals (ASDM x503). North end of the South Comobabi Mountains, on fractures in quartz monzonite, with pseudomalachite. Santa Rita Mountains near Rosemont (Bideaux et al., 1960). Silver Bell mine (Robert O'Haire, pers. commun., 1972); as microcrystals (Roe, A., 1980; Kenneth Bladh, UA x285; MM 958-959).

Pinal County: Copper Creek district, Old Reliable mine (UA 529, 9609). Ray area (UA 9611); many specimens with small, single prismatic crystals and crusts of crystals with dioptase and chrysocolla have come from the open-pit mine at Ray.

LIEBIGITE

Calcium uranium carbonate hydrate, $Ca_2U(CO_3)_4 \cdot 10H_2O$. An uncommon secondary mineral formed from alkaline carbonate solutions; may be associated with calcite, schröckingerite, bayleyite, and gypsum.

Colorado Plateau: Reported in a diatreme on the Hopi-Navajo Indian Reservation, but the exact location is unknown.

#LIME

Calcium oxide, CaO. First discovered at Mt. Vesuvius in Italy in blocks of calcareous rocks enveloped in the lava.

Cochise County: Bisbee, Warren district, Campbell mine (Graeme, 1981).

Limonite

A general term for mixtures of cryptocrystalline minerals, predominantly goethite and hematite. Most of the brownish material seen in the oxidized outcrops of copper and other base-metal deposits in Arizona is limonite. Note, however, that jarosite, alunite, and other secondary minerals may be common constituents of the so-called limonites that form in oxidized cappings (gossans). Abundant in the southwestern United States and found in all mineral deposits in the region containing iron-bearing minerals that have been subjected to oxidation. Deposited in bogs and marshes, forming low-grade iron deposits.

LINARITE

Lead copper sulfate hydroxide, $PbCu(SO_4)(OH)_2$. A sparse but widely distributed secondary mineral found in the oxidized zone of copper-lead deposits. Easily mistaken for azurite.

Cochise County: Tombstone district, Tranquility mine (H 101593). Turquoise district, as microcrystals at the Maid of Sunshine mine (Brian Bond, UA x2595).

Graham County: Aravaipa district, Ten Strike group of claims (Ross, C.P., 1925a); Grand Reef mine, as brilliant druses and splendent groups of crystals up to 1 in. long, associated with cerussite, anglesite, and leadhillite in quartz-lined cavities (Richard L. Jones, pers. commun., 1969; Jones, R.W., 1980).

Maricopa County: Painted Rock Mountains, Rowley mine near Theba, associated with atacamite and diaboleite (Wilson, W.E., and Miller, 1974), and as microcrystals (Carl Richardson, UA x4675). Osborn district, Tonopah-Belmont mine (Allen, G.B., and Hunt, 1988).

Pima County: South Comobabi Mountains, Cababi district, Mildren mine, in anglesite-cerussite aggregates with paratacamite, chlorargyrite, leadhillite, and matlockite, as excellent crystals whose forms include the following: {100}, {001}, {101}, {110}, {012}, {011}, {$\bar{1}$01}, {$\bar{2}$03}, {409}, {2.0.15}, and {$\bar{7}$04}. The crystals are flattened on {$\bar{1}$01} and elongated on [010] (Williams, S.A., 1962).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, in places as excellent crystals, as thin films filling crevices in brecciated rock, and as small to large, euhedral crystals up to 4 in. long; invariably associated with brochantite (Guild, 1911; Bideaux, 1980). Palache (1941b) noted the following forms: {110}, {101}, {$\bar{1}$01}, {001}, {111}, {201}, {2$\bar{1}$2} (see also Sinkankas, 1964); associated with malachite and brochantite (Omori and Kerr, 1963). Banner mine, as microcrystals with brochantite (William Hunt, pers. commun., 1985).

LINDGRENITE

Copper molybdate hydroxide, $Cu_3(MoO_4)_2(OH)_2$. An uncommon secondary mineral found in the oxidized portions of copper deposits.

Gila County: Globe-Miami district, Inspiration mine, Live Oak pit, as platy aggregates in hydrothermally altered schist, in seams with molybdenite, and rarely, associated with powellite (Fredrick E. Pough, pers. commun.; Peterson, N.P., 1962).

Maricopa County: Cave Creek district, with cuprotungstite (Schaller, 1932).

Pima County: Pima district, very sparse at the Esperanza mine (UA 6445).

Pinal County: Copper Creek district, Childs-Aldwinkle mine (Richard W.

Thomssen, pers. commun.; UA 488). Hull claims, south of Ray (H 108666). Superior (H 105628).

#LINNAEITE

Cobalt sulfide, $Co^{2+}Co_2^{3+}S_4$. Formed in hydrothermal veins with a variety of copper, iron, cobalt, and nickel sulfides and sulfosalts.

Coconino and Mohave Counties: In breccia pipes mined for uranium (Wenrich and Sutphin, 1988).

LITHARGE

Alpha lead oxide, α-PbO. One of four lead oxides, an uncommon mineral formed under highly alkaline and oxidizing conditions in deposits containing lead sulfide. Litharge is probably a more common mineral in oxidized environments containing lead than is generally supposed.

Maricopa County: Tonopah-Belmont mine, as pink replacements of cerussite and as microcrystals (David Shannon, UA x4316).

Pima County: South Comobabi Mountains, Cababi district, Mildren and Steppe claims, as an alteration product of wulfenite, associated with a large variety of secondary minerals formed during the oxidation of sulfide-bearing veins that cut andesite (Williams, S.A., 1962, 1963).

LITHIOPHILITE

Lithium manganese iron phosphate, $Li(Mn^{2+},Fe^{2+})PO_4$. A primary mineral formed in granite pegmatites. Probably forms a solid-solution series with triphylite ($LiFePO_4$).

Mohave County: Wikieup (UA 6437, 7889).

Yavapai County: White Picacho district, with triphylite, at the Midnight Owl and other pegmatites (Jahns, 1952; UA 5880).

LITHIOPHORITE

Aluminum lithium manganese oxide hydroxide, $(Al,Li)MnO_2(OH)_2$. Found in vein and bedded deposits with other, more common, manganese oxide minerals.

Mohave County: Artillery Mountains, Priceless vein, associated with cryptomelane, hollandite, pyrolusite, psilomelane, and coronadite; at the Plancha bedded deposits it is superimposed on hard, silvery manganese ore, and locally it may replace ramsdellite-pyrolusite grains (Mouat, 1962).

Yavapai County: About 5 miles north-northeast of Ash Fork, as blue-black coatings in cavities in limestones of the Kaibab Formation (UA 9152) and replacing calcite cement in red beds of the Toroweap Formation (Mullens, 1967; UA 9153).

#LIZARDITE

Magnesium silicate hydroxide, $Mg_3Si_2O_5(OH)_4$. A member of the serpentine group of silicate minerals. Most typically found with chrysotile in serpentines.

Pima County: Silver Bell mine, El Tiro pit.

LÖLLINGITE

Iron arsenide, $FeAs_2$. The composition departs from this ideal stoichiometric form. An uncommon mineral formed in mesothermal veins with iron and copper sulfides in calcite gangue.

Maricopa County: Disseminated in pegmatites throughout the White Picacho district (Jahns, 1952).

Mohave County: Copper World mine near Yucca, with sphalerite, chalcopyrite, and pyrrhotite (Rasor, 1946; H 104101). An analysis by Claude E. McLean gave the following results (wt %):

Fe	25.76	S	2.73	Al_2O_3	2.02
Co	0.10	Cu	0.40	SiO_2	1.30
Ni	1.55	Zn	0.15	MgO	0.14
As	65.57	Pb	0.05	CaO	0.11
				TOTAL	99.88

LONSDALEITE

Carbon, C. The hexagonal, wurtzitelike dimorph of diamond, lonsdaleite is known to have formed only in the Canyon Diablo meteorite.

Coconino County: Canyon Diablo area, near Meteor Crater, in the Canyon Diablo meteorite, as black cubes and cubo-octahedra coated with graphite, up to 0.7 mm. This is the "type locality" (Frondel, C., and Marvin, 1967a,b).

#LUDDENITE

Copper lead silicate hydrate, $Cu_2Pb_2Si_5O_{14}·nH_2O$. A rare secondary mineral found in a strongly oxidized fault breccia in a base-metal deposit. The Artillery Peak occurrence is the type locality.

Mohave County: Artillery Peaks area, in the oxidized copper-lead ores of a small prospect, associated with fluorite, alamosite, mimetite, wulfenite, wickenburgite, and cerussite. A chemical analysis by Marjorie Duggan (Williams, S.A., 1982) of the type material gave the following results (wt %):

CuO	13.2	PbO	35.1	SiO_2	25.7
H_2O	20.5	TiO_2	4.7	TOTAL	99.2

Specific gravity: 4.45

LUDWIGITE

Magnesium iron borate, $(Mg,Fe^{2+})_2Fe^{3+}BO_5$. An uncommon mineral apparently formed only in high-temperature contact metamorphic environments.

Pima County: Santa Catalina Mountains, Leatherwood mine group, in the contact zone near and west of the Control mine (James Post, pers. commun.).

LUETHEITE

Copper aluminum arsenate hydroxide hydrate, $Cu_2Al_2(AsO_4)_2(OH)_4 \cdot H_2O$. The aluminum analog of chenevixite, an oxide-zone mineral presently known only from its Arizona type locality.

Santa Cruz County: Patagonia district, near the Humboldt mine, in veinlets and vugs in rhyolite breccia, as small, tabular crystals of distinctive Indian blue color; associated with chenevixite, cornubite, and alunite (Williams, S.A., 1977). A chemical analysis by Marjorie Duggan (Phelps Dodge Corp.) gave the following results (wt %):

CuO	28.9	Al_2O_3	18.4
H_2O	9.3	As_2O_5	40.5
		TOTAL	97.1

#LUZONITE

Copper arsenic sulfide, Cu_3AsS_4. A hydrothermal mineral formed at moderate to low temperatures.

Cochise County: Warren district, Junction shaft, as massive, fine-grained material (Graeme, 1993).

M

MACKAYITE

Iron tellurium oxide hydroxide, $FeTe_2O_5(OH)$(?). A rare secondary mineral formed in the oxidized portions of tellurium-bearing base-metal deposits, with emmonsite and other secondary minerals.

Cochise County: Tombstone district, Toughnut-Empire mine, with tellurium and emmonsite (Bideaux et al., 1960).

#MACKINAWITE

Iron nickel sulfide, $(Fe,Ni)_9S_8$. Originally discovered at the Mackinaw mine in Washington. Valleriite is similar but without nickel. Presumably of hydrothermal origin at the type locality.

Coconino County: Meteor Crater near Winslow, in the Canyon Diablo meteorite, with troilite (Bunch, T.E., and Keil, 1969).

Yavapai County: About 5 km south of Bagdad, with cubanite, as fine-grained fracture fillings in chalcopyrite in a chamosite-bearing, fine-grained schist in the metamorphosed alteration zone associated with a massive volcanogenic sulfide deposit (Larson, 1976).

#MACPHERSONITE

Lead sulfate carbonate hydroxide, $Pb_4(SO_4)(CO_3)_2(OH)_2$. Formed under oxidizing conditions in hydrothermal lead deposits.

Maricopa County: Found on one specimen from the Moon Anchor mine, where tabular crystals up to 5 mm on an edge occupy voids in a granular cerussite matrix.

MACQUARTITE

Lead copper chromate silicate hydroxide hydrate, $Pb_3Cu(CrO_4)SiO_3(OH)_4 \cdot 2H_2O$. An extremely rare secondary mineral formed under oxidizing conditions at somewhat elevated temperatures. The Mammoth–St. Anthony mine is the type and only known locality. Easily mistaken for mimetite.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, on early collected (ca. 1940) specimens of dioptase (Williams, S.A., and Duggan, 1980).

MAGHEMITE

Gamma iron oxide, γ-Fe_2O_3. Maghemite has the magnetite structure but is deficient in iron. Formed from magnetite or lepidocrocite by slow oxidation at low temperatures and from the oxidation of meteoric iron.

Coconino County: Meteor Crater area, in elongate isotropic grains, alternating with a goethitelike iron oxide as a minor component of metallic spheroids formed by the impact of a large meteoric body (Mead et al., 1965).

Pima County: Tucson Mountains, as a thin, brownish, surface-alteration product on magnetite pebbles and boulders.

MAGNESIOCHROMITE

Magnesium chromium oxide, $MgCr_2O_4$. A member of the spinel group. Chiefly formed in peridotites and other ultramafic rocks as a primary crystallization product.

Apache County: Monument Valley, Garnet Ridge, as mineral fragments in a breccia dike that pierces sedimentary rocks (Gavasci and Kerr, 1968).

#MAGNESIOCOPIAPITE

Magnesium iron sulfate hydroxide hydrate, $MgFe_4^{3+}(SO_4)_6(OH)_2 \cdot 20H_2O$. Similar in most respects to the more common copiapite (see also this mineral description).

Santa Cruz County: Patagonia district, Denver mine, as microcrystals with halotrichite (identified by Bayliss and Atencia, 1985; UA x4321, collected by David Shannon).

MAGNESIO-HORNBLENDE

Calcium sodium magnesium iron aluminum silicate hydroxide, $(Ca,Na)_{2-3}(Mg,Fe^{2+},Fe^{3+},Al)_5(Al,Si)_8O_{22}(OH)_2$. The most common member of the amphibole group of rock-forming minerals. Found in a wide variety of igneous and metamorphic rocks. Some hornblende in igneous rocks is a product of the alteration of primary pyroxenes.

Cochise County: Tombstone district, as long, prismatic crystals in the Schieffelin Granodiorite (Butler, B.S., et al., 1938b).

Gila and Pinal Counties: In intrusive bodies near Picket Post Mountain near Superior, as the principal constituent of the greenschist facies of the Pinal Schist.

Greenlee County: Clifton-Morenci district, abundant in diorite porphyry.

La Paz County: Harcuvar Mountains, as crystals more than 1 in. long, near dikes in Precambrian granite.

Pima County: Ajo, as bodies of hornblendite, the largest of which is about 2,000 × 1,000 ft in planar dimensions, in the Cardigan Gneiss (Gilluly, 1937). Empire Mountains, Prince mine, as phenocrysts in a diorite porphyry dike. Near Vail (UA 5556). Quinlan Mountains, 40 miles southwest of Tucson (UA 5459).

Yavapai County: Lenticular bodies composed largely of hornblende are found at many places in the Yavapai Schist.

MAGNESITE

Magnesium carbonate, $MgCO_3$. A member of the calcite group. Magnesite forms as a product of the metamorphism of magnesian rocks, through the alteration of calcite by magnesium-bearing waters, as sedimentary deposits, and rarely, as a hydrothermal gangue mineral.

Greenlee County: Sparingly in beds of the Longfellow Limestone.

Mohave County: Oatman district, in veins with brucite and serpentine (Wilson, E.D., 1944). Lower Burro Creek Wilderness Area, as white cryptocrystalline material in moundlike masses of up to 90% (volume %) magnesite and 10 to 40 ft thick (Miller, R.J., et al., 1967).

Pima County: Cimarron Mountains, Tohono O'odham (Papago) Indian Reservation, with huntite.

MAGNETITE

Iron oxide, Fe_3O_4. The most abundant and widespread member of the spinel group. An accessory mineral in many igneous rocks, abundant in metamorphic rocks, and widely distributed in sedimentary rocks and in sands as a detrital mineral. Only a few representative localities can be noted.

Cochise County: Dragoon Mountains, Black Diamond mine, as granular masses with chalcopyrite and ilvaite.

Coconino County: Grand Canyon, as octahedral crystals up to 1 in. in diameter, in pegmatite.

Gila County: Globe-Miami district, Asbestos Peak near Globe, as sharp, dodecahedral crystals up to 0.5 in. in diameter, in calcite with tremolite and serpentine (Sinkankas, 1964). Banner district, Christmas mine, a very abundant mineral in the lower Martin Formation orebody, locally abundant in the skarn rocks (Peterson, N.P., and Swanson, 1956; David Perry, pers. commun., 1967). Near Peridot, as large crystals in volcanic bombs of olivine.

Greenlee County: Clifton-Morenci district, abundant in metamorphosed limestone, with garnet, amphibole, pyroxene, and sulfides; mined as flux at the Manganese Blue and Arizona Central mines (Lindgren, 1905). Pyrolusite claims, 12 miles south of Morenci, with pyrolusite and psilomelane (Potter et al., 1946).

La Paz County: As microcrystals near Bouse (Robert Mudra, UA x951).

Maricopa County: Big Horn district, with ilmenite in extensive placer deposits up to 100 ft thick (Harrer, 1964).

Pima County: Santa Rita Mountains, at Rosemont, abundant in contact metamorphic copper ores (Schrader and Hill, 1915). Sierrita Mountains, Pima district, in contact metamorphic orebodies (Guild, 1934). In large amounts on the surface, 5 miles from Tule Wells, near pegmatite bodies containing copper sulfides (Gilluly, 1937). Tucson Mountains, as rounded, transported blocks, in many places pitted like meteorites (Guild, 1910). Santa Catalina Mountains, Pontotoc mine, in an ore deposit in gneiss associated with limestone (Guild, 1934).

Santa Cruz County: Patagonia Mountains, Line Boy mine near Duquesne, as lodestone in considerable quantities (Schrader, 1917).

Yavapai County: Bradshaw Mountains, Big Bug Creek, as large (up to 18 in.), stream-worn masses in a stream bed (David Shannon, pers. commun., 1971); near Townsend Butte and the Howard property, with hematite in schist; Pine Grove district, Springfield group, as large crystals with apatite and sphene in granodiorite; near Stoddard, as large pieces of lodestone (Lindgren, 1926). Eureka district, as titaniferous magnetite in dikes and irregular bodies in gabbro (Harrer, 1964). A partial analysis (Ball and Broderick, 1919) gave these results (wt %):

Fe	60.35	Ti	8.40	Mn	tr.

McBride claims, 17 miles south of Seligman, as segregations of titaniferous magnetite in gabbro.

MALACHITE

Copper carbonate hydroxide, $Cu_2(CO_3)(OH)_2$. Commonly formed as an alteration product in oxidized copper deposits. Generally associated with other secondary copper minerals, particularly azurite, cuprite, and tenorite, and commonly with limonite. Only a few localities can be listed.

Apache County: Garnet Ridge, in vein fillings and in cement in the Navajo Sandstone, associated with chrysocolla, calciovolborthite, tyuyamunite, limonite, chalcopyrite, and pyrite (Gavasci and Kerr, 1968).

Apache and Navajo Counties: Monument Valley, associated with uranium-vanadium ores in the Moenkopi Formation, the Shinarump Member of the Chinle Formation, and the DeChelly Member of the Cutler Formation (Mitcham and Evensen, 1955; Evensen and Gray, 1958).

Cochise County: The Warren district has produced some of the world's most remarkable malachite, and specimens hold places of honor in all of the major collections. Large masses of malachite were early noted in several mines in the district: Copper Queen mine (Kunz, 1885; Douglas, 1899; Ransome, 1903b; Lindgren, 1904; Palache and Lewis, 1927; Frondel, C., 1941); Campbell mine (Schwartz and Park, 1932); Cole mine (Trischka et al., 1929; Schwartz, 1934; Hutton, 1957); and Junction mine (Mitchell, 1920). Turquoise (Courtland-Gleeson) district, in large masses at the Maid of Sunshine mine, in some places as small but superb crystals; Silver Bill mine, as pseudomorphs after azurite up to 3 cm. Tombstone district, where it is widespread but not abundant (Butler, B.S., et al., 1938b). Sulphur Springs Valley, Pat Hills, in numerous calcite veins cutting porphyritic andesite flow rocks, associated with chrysocolla (Lausen, 1927b). Cochise district, Johnson Camp area, as an abundant mineral in tabular bodies with sulfides in contact-metamorphosed limestone (Kellogg, 1906; Cooper and Huff, 1951).

Coconino County: Kaibab Plateau, with azurite and chrysocolla as impregnations in extensive chert beds. Grand Canyon National Park, Horseshoe Mesa, Grand View (Last Chance) mine, as botryoidal crusts coating limestone and in fissures in clay (Leicht, 1971); Orphan mine, with azurite. White Mesa district, with chrysocolla, cementing Navajo Sandstone (Hill, 1914a; Mayo, 1955a). Apex mine, Jacob Lake, with azurite and minor amounts of chalcopyrite and chalcocite in the Kaibab Limestone (Tainter, 1947a). Cameron area, in mineralized silica plugs (Barrington and Kerr, 1963).

Gila County: Globe-Miami district, where it constitutes a considerable part of the ores at the Buffalo, Big Johnnie, Buckeye, and other mines, but nowhere found in large masses (Ransome, 1903a); Old Dominion mine (Schwartz, 1921, 1934); Castle Dome and Copper Cities deposits (Peterson, N.P., 1947); Inspiration mine, as beautiful aggregates of malachite, chrysocolla, and chalcedony (Ransome, 1919; Peterson, N.P., 1962; Sun, 1963). Payson district, Silver Butte mine, as stout, prismatic crystals in porous quartz (Lausen and Wilson, 1925). Banner district, Christmas mine, as a common supergene mineral in skarn developed in the Naco Formation (David Perry, pers. commun., 1967); 79 mine, where it is scattered throughout the supergene zone as veinlets and small spheres up to 0.25 in. in diameter (Keith, 1972). Blue Ball mine, as nodules of pure malachite, mixed azurite-malachite nodules, and fibrous malachite in hollow azurite geodes (Grant, 1989).

Graham County: Klondyke area, as a widespread but sparse mineral (Simons, 1964).

Greenlee County: Clifton-Morenci district, common in irregular deposits in limestone; mined at the Detroit, Manganese Blue, and Longfellow mines, and as fine, radiating groups of crystals at the Standard mine near Metcalf (Lindgren, 1903, 1904, 1905; Reber, 1916; Schwartz, 1934; Grout, 1946).

La Paz County: Buckeye Mountains, Planet district, Planet mine, associated with azurite and chrysocolla (Bancroft, H., 1911). Near Bouse (UA 3966).

Maricopa and Gila Counties: Mazatzal Mountains, in small quantities associated with mercury deposits, in schist (Lausen, 1926).

Mohave County: Bill Williams Fork (Genth, 1868). Cerbat Mountains, Wallapai district, widely distributed as an oxidation product of copper sulfide vein deposits and, locally, as cement in alluvium, with cuprite and copper (Thomas, B.E., 1949). Mineral Park district, in granite gneiss. Bentley district, Grand Gulch, Bronzell, and Copper King mines (Hill, 1914b).

Navajo County: Monument Valley, associated with uranium-vanadium deposits in sandstone (Holland et al., 1958).

Pima County: Santa Rita Mountains, Rosemont district, as globular masses and in veinlets; also widely distributed throughout the range in small amounts. Sierrita Mountains, abundant in the Pima district and the most important ore mineral at Mineral Hill (Schrader and Hill, 1915; Schrader, 1917); Twin Buttes open-pit mine, in the oxidized portion (Stanley B. Keith, pers. commun., 1973). Ajo district, the most common product of the weathering of copper-bearing minerals and the dominant mineral in the leaching ores (Joralemon, 1914; Gilluly, 1937); New Cornelia open-pit mine, in concentric structures with azurite and quartz in vugs, and covering the outside of porous nodules of cuprite which, in turn, surround copper (Schwartz, 1934); Copper Giant deposits, secs. 10, 11, and 15, T. 13 S., R. 6 W., in fanglomerate and volcanic rocks (Romslo and Robinson, 1952). Waterman Mountains, Silver Hill mine, with rosasite (UA 6709). Silver Bell Mountains, Silver Bell mine, with cuprite and azurite in limestone replacements (Engineering Mining Journal, 1904; Stewart, C.A., 1912).

Pinal County: Mineral Creek district, Ray area, with chrysocolla and tenorite cementing part of the White Tail Conglomerate south of Ray (Clarke, O.M., 1953); also cementing Holocene gravels with other oxidized copper and iron minerals in the Pearl Handle open-pit mine at Ray. This mineralization was shown to be not older than about 7,000 years, based on a radiocarbon date obtained from a fossil log incorporated in the mineralized area (Phillips et al., 1971). Pioneer district, Magma mine, with chrysocolla as the principal oxidized copper mineral (Short et al., 1943). Mammoth district, San Manuel mine, where it is present in the oxidized zone of the orebody but accounts for little of the copper values; associated with chrysocolla, cuprite, and azurite (Schwartz, 1949); Mammoth–St. Anthony mine, common as powdery masses and microcrystals and as pseudomorphs after azurite crystals, up to 4 in. long (Bideaux, 1980).

Santa Cruz County: Santa Rita and Patagonia Mountains, widespread as a product of the oxidation of sulfide copper minerals at numerous mines and prospects, especially in the Tyndall, Old Baldy, and Patagonia districts (Schrader and Hill, 1915; Schrader, 1917).

Yavapai County: Black Hills, Yeager mine, as fine specimen material with crystallized azurite; also common in the oxidized portions of all copper deposits in the region (Schwartz, 1934, 1938; Anderson, C.A., and Creasey, 1958). Walnut Grove district, Zonia copper mine (Kumke, 1947). Bradshaw Mountains, Piedmont mine, as fine malachite pseudomorphs after azurite, coated with clear to white quartz.

#MAMMOTHITE

Aluminum copper lead antimony sulfate chloride hydroxide, $AlCu_4Pb_6Sb(SO_4)_2Cl_4(OH)_{18}$. A rare secondary mineral found in the oxidized portion of a base-metal deposit with other secondary copper and lead minerals. The Mammoth–St. Anthony mine at Tiger is the type locality.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as bright-blue sprays of radial acicular crystals and flat plates embedded in anglesite and associated with phosgenite, wulfenite, leadhillite, and caledonite (Peacor et al., 1985).

MANANDONITE

Lithium aluminum boron silicate hydroxide, $LiAl_5BSi_2O_{10}(OH)_8$. A member of the chlorite group.

La Paz County: Near Quartzsite, as minute tablets in quartzite, with kyanite, andalusite, and dumortierite (Bideaux et al., 1960).

MANGANAXINITE

Calcium manganese iron aluminum boron silicate hydroxide, $Ca_2(Mn,Fe)Al_2BSi_4O_{15}(OH)$. A member of the axinite group. Commonly found in contact metamorphic aureoles formed where intrusive rocks have invaded sediments, especially limestones; typically associated with other calcium silicate minerals.

Graham County: Iron Cap mine, near Landsman Camp, as yellow-green bladed crystals that commonly have a black coating (Reiter, 1980, 1981), and as microcrystals (Marvin Deshler, UA x1850).

Pima County: North end of the South Comobabi Mountains, north of the Ko Vaya Hills, as yellow plates being replaced by withamite (a variety of clinozoisite); also in vesicles in andesite flow boulders (Bideaux et al., 1960).

#MANGANBABINGTONITE

Calcium manganese iron silicate hydroxide, $Ca_2(Mn,Fe^{2+})Fe^{3+}Si_5O_{14}(OH)$. Similar to babingtonite, but manganese is substituted for iron in the structure; very similar in provenance, i.e., in skarns, granite pegmatites, and hydrothermal veins; probably of low-temperature origin.

Graham County: Santa Teresa Mountains, Aravaipa district, Landsman claims, as exceptional, dark-brown, bladed, euhedral crystals up to 7 mm long, from a vein containing galena and sphalerite, in a contact metamorphic zone developed in limestone and shale; associated with euhedral diopside-hedenbergite and yellow garnet (material collected by Raymond Rhodes and Richard L. Schick in 1972); also associated with axinite and polylithionite. Iron Cap mine, as black, bladed crystals up to 1 cm long (Reiter, 1980, 1981).

MANGANITE

Manganese oxide hydroxide, MnO(OH). Typically associated with other manganese and iron oxide minerals in low-temperature veins and in deposits of secondary origin.

Cochise County: Tombstone district, as needlelike crystals in parallel groups and as soft fibers lining cavities (Butler, B.S., et al., 1938b; Rasor, 1939; Romslo and Ravitz, 1947; Needham and Storms, 1956).

Gila County: Globe-Miami district, where, with pyrolusite and psilomelane, it forms the bulk of the gangue in the manganese-zinc-lead-silver deposits (Peterson, N.P., 1962). Banner district, 79 mine, as irregular masses with oxidized copper ore (Kiersch, 1949).

La Paz County: Planet district, Planet mine. Artillery district, Kaiserdoom claims (Hewett et al., 1963). War Eagle claims, 26 miles north of Bouse (Havens et al., 1947).

Maricopa County: Bighorn Mountains, Aguila district, with pyrolusite and wad. White Picacho district, as crusts coating lithium phosphate minerals, in pegmatites (Jahns, 1952).

Mohave County: Rawhide Mountains, associated with a variety of manganese oxide minerals in the Artillery Peak deposit (Head, 1941).

Pinal County: Silver King mine, as crystals in barite (UA 7437).

Santa Cruz County: Patagonia Mountains, Harshaw district, Mowry mine (Havens et al., 1954); Tyndall district, Cottonwood Canyon, Glove mine (Olson, H.J., 1966).

Yavapai County: Northern Aguila district, with pyrolusite and wad. On the property of the Mohave Mining and Milling Co., east of Wickenburg, as shiny black crystals. White Picacho district, as thick crusts coating lithium phosphate minerals, in pegmatites (Jahns, 1952). Burmeister mine, 12 miles southeast of Mayer, with pyrolusite and psilomelane (Long et al., 1948).

MANJIROITE

Sodium potassium manganese oxide hydrate, $(Na,K)Mn_8O_{16}\cdot nH_2O$; the sodium analog of cryptomelane. Probably most commonly formed as a secondary mineral.

Cochise County: Tombstone district, Prompter mine, as large (0.5-in.) cleavable prisms, some of which have hollow, fibrous centers; crystals form large, black to dark-brown masses in a white crystalline limestone. Although cryptomelane is common at Tombstone (the co–type locality), in some areas the sodium content predominates over the potassium content. A specimen from the Prompter mine contained 75.5% sodium and 24.5% potassium.

MARCASITE

Iron sulfide, FeS_2. A low-temperature mineral formed under near-surface or surface conditions. Less common and less stable than pyrite, with which it is dimorphous. Generally in replacement deposits or as concretions in sedimentary rocks.

Apache County: Near Sander (UA 7285).

Cochise County: Cochise district, Johnson Camp area, in narrow seams and as crystals along faults (Cooper and Silver, 1964).

Coconino County: Cameron area, as cyclically twinned inclusions in amethystine quartz crystals in petrified wood; Alyce Tolino mine, enclosed by small cubes of cobalt-rich pyrite, associated with umohoite in sooty masses and in carbonaceous trash replacements (Hamilton, P., and Kerr, 1959); Huskon mines, with pitchblende, greenockite, pyrite, calcite, and siliceous gangue replacing wood of a Triassic conifer in the Chinle Formation (Maucher and Rehwald, 1961); Huskon No. 11 mine, in sandstone with ink-blue masses and stains of ilsemannite (AEC mineral collection).

Gila County: Northwestern region, common in veins in uranium deposits in the Dripping Spring Quartzite (Granger and Raup, 1969).

Mohave County: Cerbat Mountains, Wallapai district, as a primary mineral deposited in a belt of sulfide-bearing fissure veins, associated with arsenopyrite (Thomas, B.E., 1949). Black Mountains, Oatman district, Moss mine, as thin plates in quartz.

Pima County: Santa Rita Mountains, Old Baldy district (Schrader, 1917). Pima district, Copper Glance and Queen mines, as an alteration product of pyrrhotite (Webber, 1929); Mineral Hill and San Xavier mines, as thin coatings and veinlets.

Santa Cruz County: Tyndall district (Schrader, 1917).

Yavapai County: Bradshaw Mountains, Big Bug district, Iron Queen mine, as small colloform masses in partly oxidized ore (Lindgren, 1926). White Picacho district, in pegmatites (Jahns, 1952). Martinez district, Congress mine, in gold-bearing quartz veins with pyrite, associated with intrusive dikes in granite (Engineering Mining Journal, 1904).

MARIALITE (See Scapolite)

#MARICOPAITE

Lead calcium aluminum silicate hydrate, $Pb_7Ca_2Al_{12}Si_{36}O_{100}\cdot 32H_2O$. A secondary, zeolitelike mineral. The Moon Anchor mine is the type and only known locality.

Maricopa County: Vulture district, Moon Anchor mine near Tonopah, as sprays of translucent white, acicular crystals, associated with mimetite; discovered by William Hunt; characterized by Peacor et al. (1988).

Mariposite (chromian MUSCOVITE)

MASSICOT

Lead oxide, PbO. An uncommon mineral of secondary origin, dimorphous with litharge, formed by the alteration of galena or secondary lead-bearing minerals.

Gila County: Globe-Miami district, Albert Lea mine, as a yellow, powdery deposit on cerussite (Peterson, N.P., 1962). Payson district, Silver Butte mine, as an earthy yellow powder, associated with anglesite and galena (Lausen and Wilson, 1925).

Graham County: Aravaipa district, Dogwater mine, as yellow, earthy masses with wulfenite (David Shannon, pers. commun., 1988).

La Paz County: Trigo Mountains, Silver district, as an earthy powder associated with cerussite and smithsonite.

Maricopa County: Bighorn Mountains, Tonopah-Belmont mine, with minium.

South of Wickenburg, at the Moon Anchor mine, Potter-Cramer property, and Rat Tail claim (Williams, S.A., 1968).

Pima County: South Comobabi Mountains, Cababi district, Little Mary mine and Silver-Lead claim, as an earthy, yellow, alteration product of galena (Williams, S.A., 1962).

Santa Cruz County: Patagonia Mountains, Flux mine, with cerussite (Schrader and Hill, 1915; Wilson, E.D., 1933).

#MATILDITE

Silver bismuth sulfide, $AgBiS_2$. Formed in hydrothermal veins at moderate to high temperatures, and in pegmatites.

Cochise County: Warren district, with sulfide ores of the Campbell mine (Graeme, 1993).

MATLOCKITE

Lead fluoride chloride, PbFCl. A rare secondary mineral known from few localities in the world.

Gila County: Apache mine near Globe, with cerussite, brochantite, and boleite (Bideaux et al., 1960).

Pima County: South Comobabi Mountains, Cababi district, Mildren mine, as a single crystal in parallel growth with a prismatic anglesite crystal (Williams, S.A., 1962).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, Collins vein, as minute crystals and as massive nodules coated with cerussite (Fahey et al., 1950; Bideaux, 1980).

#MAWSONITE

Copper iron tin sulfide, $Cu^{1+}_6Fe^{3+}_2Sn^{4+}S_8$. In massive to disseminated copper ores within highly altered volcanic rocks at the Australian type locality.

Cochise County: Warren district, Campbell orebody (Graeme, 1993).

#MCKINSTRYITE

Silver copper sulfide, $(Ag,Cu)_2S$. Of hydrothermal origin, associated with chalcopyrite, stromeyerite, silver, and arsenopyrite.

Cochise County: Tombstone district; a specimen in the Smithsonian Institution (S 105199) labeled stromeyerite was shown to be mckinstryite (John S. White, Jr., pers. commun., 1989).

Meerschaum (a variety of SEPIOLITE)

MELANOTEKITE

Lead iron silicate, $Pb_2Fe_2Si_2O_9$. A very rare lead silicate mineral.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as minute, brownish spherules on diaboleite (Bideaux, 1980). Mineral Hill district, Reymert mine, as small spheres of black, platy crystals (Ray Demark, pers. commun., 1984).

MELANOVANADITE

Calcium vanadium oxide hydrate, $Ca(V_2^{4+}V_2^{5+})O_{10}{\cdot}5H_2O$. A rare mineral that may be of primary origin.

Apache County: Lukachukai Mountains, Mesa No. 1 and No. 5 mines; Kerr-McGee 4-1 mine.

MELANTERITE

Iron sulfate hydrate, $FeSO_4{\cdot}7H_2O$. Water soluble; commonly formed in old mine workings as a product of the oxidation of pyritic ores. Probably more common in abandoned mine workings than the localities mentioned below would suggest. Copper can substitute for iron in the structure up to about 1.89:1 or 18.3 wt% Cu (Palache et al., 1951).

Cochise County: Warren district, as a widely distributed postmine mineral in stalactites and coatings of walls or as large (up to 18 mm) pseudo-octahedra in stagnant waters; commonly in pyrite-rich areas.

Gila County: Banner district, 79 mine, sparingly as white encrustations and efflorescences in the mine workings, altering from pyrite; melanterite blankets formed on the floor of the fifth level contain short, acicular, prismatic, hairlike crystals (Keith, 1972). Globe district, 15th level of the Old Dominion mine, as the cuprian variety; 79 mine, in a crosscut on the sixth level, sparingly as the cuprian variety (Keith, 1972).

Greenlee County: Clifton-Morenci district, sparingly in the upper levels of mines (Lindgren, 1905) and locally in the Morenci open-pit mine, formed by the oxidation of sulfide minerals (Moolick and Durek, 1966).

Pima County: Sierrita Mountains, Pima district, as efflorescences on the walls of old mine workings; San Xavier West mine, associated with chalcanthite (Arnold, 1964). Silver Bell Mountains, El Tiro mine, in small amounts as the cuprian variety.

Santa Cruz County: Temporal Gulch, St. Louis mine, as the cuprian variety, formed as efflorescences on tunnel walls (Bideaux et al., 1960).

#MELILITE

Sodium calcium aluminum magnesium silicate, approximately $(Na,Ca)_2(Al,Mg)$-$(Al,Si)SiO_7$. A rock-forming mineral, typically in rocks of relatively low (undersaturated) silica content.

Navajo County: Navajo Volcanic Field, as a constituent of lamprophyre dikes (Laughlin et al., 1986).

#MELONITE

Nickel telluride, $NiTe_2$. Principally formed in hydrothermal vein deposits with other tellurides and sulfides.

Cochise County: Warren district, among the sulfide ores of the Campbell mine, with altaite in quartz (Graeme, 1993).

MERCURY

Mercury, Hg. Comparatively rare. Of secondary origin, formed by the alteration of cinnabar, with which it is commonly associated.

Coconino County: Near Lee's Ferry, in minute quantities in the Chinle Formation, associated with gold (Lawson, 1913; Lausen, 1936).

Gila County: Mazatzal Mountains, Sunflower district, Pine Mountain mine (Lausen, 1926); Ord mine, in small amounts in the Slate Creek deposits (Faick, 1958).

Maricopa County: Mazatzal Mountains (Beckman and Kerns, 1965).

Mohave County: Hualapai Mountains, Maynard district, with cerussite.

Navajo County: Snowflake, in schist with cinnabar (UA 6502).

Pinal County: About 9 miles east of Apache Junction, as fine globules in schist (Beckman and Kerns, 1965).

Yavapai County: Lower Copper Basin Wash, Kirkland placers, in appreciable quantities, probably derived from the low-grade cinnabar deposits in the area. Wagoner district, Walnut Grove, associated with cinnabar (Engineering Mining Journal, 1897).

MESOLITE

Sodium calcium aluminum silicate hydrate, $Na_2Ca_2Al_6Si_9O_{30}\cdot 8H_2O$. In cavities in volcanic rocks, associated with other zeolites.

Gila County: Banner district, Christmas mine, as fine, hairlike crystals in hydrothermally altered andesite (David Perry, pers. commun., 1967).

Graham County: Thumb Butte area, secs. 4 and 5, T. 7 S., R. 29 E., in vesicular basalt with other zeolites (William Hunt, pers. commun., 1985).

Santa Cruz County: Southwest of Patagonia, in drill core, as silky, white fibers, with calcite in veinlets that cut fresh granodiorite.

#META-ALUNOGEN

Aluminum sulfate hydrate, $Al_4(SO_4)_6 \cdot 27H_2O$. Formed in veins with pickeringite in altered andesite. Readily dehydrates to a white powder.

Pima County: Ajo district, New Cornelia mine, as crusts forming from a seep, with gypsum (William Thomas, pers. commun., 1988).

META-AUTUNITE

Calcium uranyl phosphate hydrate, $Ca(UO_2)_2(PO_4)_2 \cdot 2\text{-}6H_2O$. Closely associated with the higher hydrate, autunite. A secondary uranium mineral formed by the oxidation of other uranium minerals, notably uraninite.

Cochise County: Courtland-Gleeson district, as scaly, yellow crusts on pyrite ores.

Coconino County: Cameron district, Black Point–Murphy mine; Jackpot No. 24 mine (Austin, 1964).

Gila County: Northwestern region, Sue, Red Bluff, and Little Joe deposits, in weathered deposits in the Dripping Spring Quartzite (Granger and Raup, 1962, 1969).

METACINNABAR

Mercury sulfide, HgS. The dimorph of cinnabar. An uncommon mineral of secondary origin formed in the upper portion of cinnabar deposits.

Gila and Maricopa Counties: Mazatzal Mountains, Alder and Slate Creeks area, in small quantities with cinnabar (Lausen, 1926).

La Paz County: Dome Rock Mountains, Colonial property, as thin coatings on cinnabar.

METAHEWETTITE

Calcium vanadium oxide hydrate, $CaV_6O_{16} \cdot 9H_2O$. A secondary mineral formed as impregnations in sandstone.

Apache County: Monument Valley, Monument No. 2 mine, as one of the principal ore minerals in a channel in the DeChelly Sandstone that is filled by Shinarump Conglomerate; as an impregnation of the sandstone and a replacement of fossil plant matter; associated with tyuyamunite, carnotite, becquerelite, corvusite, hewettite, rauvite, navajoite, and uraninite (Finnell, 1957).

METANOVACEKITE

Magnesium uranyl arsenate hydrate, $Mg(UO_2)_2(AsO_4)\cdot 4\text{-}8H_2O$. A lower hydrate of novacekite. A rare secondary mineral; the Arizona locality may be only one of two known in the world.

Gila County: Cherry Creek area, Sue mine, in Dripping Spring Quartzite, as individual flakes, and as alteration rims 0.2 to 0.5 mm wide on bassetite and saleeite (Granger and Raup, 1969).

METAROSSITE

Calcium vanadium oxide hydrate, $CaV_2O_6\cdot 2H_2O$. A rare mineral found in sandstone uranium-vanadium deposits on the Colorado Plateau. Formed from the alteration of rossite, with which it is intimately associated.

Apache County: Lukachukai Mountains, as an alteration product of rossite in the Salt Wash Member of the Morrison Formation (Chenoweth, 1967). Also reported in the Monument No. 2 mine (Evensen and Gray, 1958).

METASIDERONATRITE

Sodium iron sulfate hydroxide hydrate, $Na_4Fe_2(SO_4)_4(OH)_2\cdot 3H_2O$. A rare secondary mineral associated with other secondary sulfates.

Coconino County: Cameron area, as a deep-yellow, cleavable, fibrous material from the Yazzie No. 101 mine, reportedly the first North American locality (Austin, 1957, 1964).

Metastrengite (see PHOSPHOSIDERITE)

METATORBERNITE

Copper uranyl phosphate hydrate, $Cu(UO_2)_2(PO_4)_2\cdot 8H_2O$. A secondary mineral commonly formed by dehydration of torbernite but may crystallize directly from solution; much like torbernite in mode of occurrence and association.

Apache and Navajo Counties: Monument Valley district, in the oxidized "yellow ore" of uranium-vanadium deposits in the Shinarump Conglomerate and DeChelly Sandstone, in conglomerate-filled, paleo-stream channels; associated with carnotite, tyuyamunite, metarossite, calciovolborthite, and hewettite (Evensen and Gray, 1958).

Coconino County: Cameron area, in uranium deposits in the Shinarump Conglomerate, associated with uraninite and meta-autunite (Holland et al., 1958); Huskon No. 7 mine and Riverside No. 1 claims (Austin, 1964); Arrow Head claim; southeast of Cameron, with uraninite in the River View collapse feature (Barrington and Kerr, 1963). Reported in the Breccia Pipe district, Riverview group of claims, with uranophane and torbernite (Wenrich and Sutphin, 1989).

Gila County: Northwestern region, associated with nearly all of the uranium deposits in the Dripping Spring Quartzite (Granger and Raup, 1969); Sierra Ancha Mountains, Workman Creek, in the upper Dripping Spring Quartzite, with crocoite (Robert O'Haire, pers. commun., 1972). Wilson Creek area, in Dripping Spring Quartzite (Wells, R.L., and Rambosek, 1954). Globe-Miami district, Copper Cities deposit, as small amounts in disseminated copper ore in quartz monzonite and as tiny rosettes on the walls of minute fractures along the Coronado Fault (Peterson, N.P., 1954, 1962); Melinda mine; Castle Dome mine, commonly on wavellite crusts (Peterson, N.P., 1947).

Mohave County: Hack Canyon mine (Granger and Raup, 1962).

Navajo County: Monument Valley, Monument No. 1 and Mitten No. 2 mines (Witkind, 1961; Witkind and Thaden, 1963). Ruth group of claims near Holbrook.

Pima County: Silver Bell open-pit mine, as microcrystals (ASDM x1093).

Yavapai County: Crown King area, as microcrystals (Richard Thomssen, UA x598).

METATYUYAMUNITE

Calcium uranyl vanadate hydrate, $Ca(UO_2)_2(VO_4)_2 \cdot 3\text{-}5H_2O$. A secondary mineral commonly associated with tyuyamunite in the oxidized portions of uranium-vanadium deposits. More likely than carnotite to form in limestones or calcareous sandstones.

Apache County: Carrizo Mountains, Cove Mesa, Sycamore group of claims, and King Tut mine. Monument Valley, Monument No. 2 mine, associated with tyuyamunite; forms a thick zone around the dark resinous material that is the matrix for small grains of uraninite (Rosenzweig et al., 1954).

Coconino County: Cameron area, Montezuma group of claims, in Shinarump Conglomerate; Huskon No. 12 mine (Austin, 1964). Prospect Canyon district, Ridenaur mine, with vesignieite, naumannite, bromargyrite, calciovolborthite, and tyuyamunite (Wenrich and Sutphin, 1989).

Navajo County: Holbrook district, Ruth group of claims; near Tuba City. Monument Valley, Monument No. 1 and Mitten No. 2 mines (Witkind, 1961; Witkind and Thaden, 1963).

META-URANOCIRCITE

Barium uranyl phosphate hydrate, $Ba(UO_2)_2(PO_4)_2 \cdot 6\text{-}12H_2O$. An uncommon member of the meta-autunite group; of secondary origin.

Coconino County: Cameron area, as an abundant ore mineral that forms fine-grained yellow masses, associated with fossil logs in the Petrified Forest Member of the Chinle Formation (Austin, 1964).

Gila County: Reported in uranium deposits in the Dripping Spring Quartzite (Granger, 1955).

METAVOLTINE

Potassium sodium iron sulfate hydroxide hydrate, $(K,Na,Fe)_5Fe_3(SO_4)_6(OH)_2 \cdot 9H_2O$(?). A rare mineral formed in arid climates, commonly by the oxidation of pyritic ores.

Cochise County: Warren district, 2,100-ft level of the Campbell mine, as vermicular stacks of minute, greenish-yellow, hexagonal platelets; associated with copiapite, coquimbite, voltaite, and römerite; indices of refraction show that the Na:K ratio is about 4:1 (Fabien Cesbron, pers. commun., 1975).

METAZEUNERITE

Copper uranyl arsenate hydrate, $Cu(UO_2)_2(AsO_4)_2 \cdot 8H_2O$. A secondary mineral formed in the oxidized portions of uranium deposits.

Apache County: Monument Valley, Monument No. 2 mine (Witkind and Thaden, 1963).

Coconino County: Cameron area, in minor amounts in uranium ore in the Shinarump Conglomerate, paleo-stream channels, and the sandy portions of the Chinle Formation; associated with uraninite, metatorbernite, and meta-autunite (Holland et al., 1958). Grand Canyon National Park, Horseshoe Mesa, Grandview (Last Chance) mine, as transparent, emerald-green to leek-green, tabular crystals, associated with scorodite and olivenite (X-ray data suggest that the leek-green variety is close to metazeunerite, the emerald-green variety to zeunerite); some crystals, up to 2 cm across, are among the largest known for the species (Leicht, 1971).

Gila County: Sierra Ancha Mountains, Easy deposit, where it coats limonite on fracture surfaces and is locally coated by hyalite (Granger and Raup, 1969).

Navajo County: Ruth group of claims near Holbrook.

MIARGYRITE

Silver antimony sulfide, $AgSbS_2$. Formed in low-temperature hydrothermal veins with galena and other silver minerals.

Mohave County: Cerbat Mountains, Wallapai district, as a primary mineral in minor amounts, with pyrargyrite and polybasite; with proustite in veinlets that cut galena and chalcopyrite (Thomas, B.E., 1949).

MICROCLINE

Potassium aluminum silicate, $KAlSi_3O_8$. Triclinic. A widespread rock-forming feldspar that forms under nearly the same conditions as orthoclase. Much of the potash feldspar commonly identified as orthoclase is probably microcline. The mineral is far more prevalent in the rocks of Arizona than the few localities listed below would suggest.

Cochise County: Reported in the Warren district.

Maricopa and Yavapai Counties: White Picacho district, as perthite, the most abundant mineral in the pegmatites; as crystals up to 13 ft (Jahns, 1952).

Mohave County: Cerbat Mountains, Kingman Feldspar mine, commercially mined from pegmatites since 1924 (Heinrich, 1960).

Pima County: Ajo district, south-central part of the New Cornelia orebody, as coarse crystals in the pegmatite masses (Gilluly, 1937); all of the mineral has been removed by mining. Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

MICROLITE

Sodium calcium tantalum niobium oxide hydroxide fluoride, $(Na,Ca)_2(Ta,Nb)_2O_6(OH,F)$. The tantalum end member of the pyrochlore mineral series in which there is additional, extensive ionic substitution. Typically formed in granite pegmatites. The composition of a sample can be determined only by careful mineralogical and chemical study.

Yavapai County: White Picacho district, Outpost, Midnight Owl, and Picacho View pegmatites, as tiny, olive-green to dark-brown and black crystals with sharply defined octahedral and dodecahedral faces; associated with the related species, pyrochlore (Jahns, 1952).

MIERSITE

Silver copper iodide, $(Ag,Cu)I$. A rare secondary mineral formed in the oxidized zones of base-metal deposits.

Cochise County: Warren district, Southwest mine, as small, lemon-yellow crystals, with atacamite, malachite, and cuprite (Graeme, 1993).

Pima County: South Comobabi Mountains, Cababi district, Mildren and Steppe claims, as overgrowths on iodargyrite; a product of the oxidation of sulfide ores in quartz veins that cut andesite (Williams, S.A., 1962, 1963).

MILLERITE

Nickel sulfide, NiS. Typically a low-temperature mineral formed in cavities in veins, where it is commonly associated with carbonates; also formed in geodes in limestone.

Coconino County: Orphan mine, near Grand Canyon, in cavities in barite.

MIMETITE

Lead arsenate chloride, $Pb_5(AsO_4)_3Cl$. Structurally, a member of the apatite group; an end member of the pyromorphite-mimetite series. A secondary mineral formed in the oxidized portions of lead deposits; typically associated with cerussite, plattnerite, wulfenite, smithsonite, hemimorphite, anglesite, limonite, and other oxide-zone minerals.

Cochise County: Cochise district, Empire mine, as microcrystals (Peter Megaw, UA x4620). Gallagher Vanadium property near Charleston. Warren district, Campbell mine, with wulfenite; Cole mine, with malachite in a fault zone on the 600-ft level; Shattuck mine, with cerussite.

Gila County: Banner district, 79 mine, as fine specimens, notably as brilliant-orange, orange-yellow, and bright-yellow crusts and reniform masses, some of which are stalactitic; some of the finest specimens are associated with thick, clear-orange wulfenite crystals, many of which are 0.5 in. on an edge; in some places, as small, canary-yellow crystals (Keith, 1972).

Graham County: Aravaipa district, Grand Reef mine, as microcrystals (Frank Valenzuela, UA x713).

La Paz County: Red Cloud mine, as red crystalline masses with small (1-mm), doubly terminated crystals (Edson, 1980).

Maricopa County: Near Gila Bend; east of the Alaska mine, southwest of Aguila. Painted Rock Mountains, Rowley mine near Theba, as microcrystals with a great variety of habits: as minute, perfect hexagonal crystals less than 1 mm long and as nearly perfect spherical aggregates. W.E. Wilson and Miller (1974) described the latter as an extreme example of "wheat-sheaf"-like crystal growth; the crystal aggregates are curled back upon themselves, producing the spherical shape. Colors range from red to yellow. Some crystals are color zoned: the centers are orange, and the ends are yellow. Vulture district, Domingo mine. Moon Anchor mine, as acicular yellow crystals and as pseudomorphs of galena cubes. Amazon Wash, "Broken Finger" mine, as red-fluorescing microcrystals (Arthur Roe, pers. commun.).

Mohave County: Reported in the Cerbat Mountains, Wallapai district. Buckskin Mountains, Rawhide mine, as botryoidal crusts.

Pima County: Waterman Mountains, Indiana-Arizona mine, as microcrystals with wulfenite (Francis Sousa, UA x1034). Empire district, Total Wreck and Verde Queen mines, as microcrystals with wulfenite (Francis Sousa and Brian Bond, UA x180, x2710).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as bright-orange and canary-yellow crusts and as coatings of tiny prismatic to tabular crystals, with wulfenite (Bideaux, 1980). Reported in the God's claims, as bright yellow-orange crystals and botryoidal crusts. Mineral Hill district, Reymert mine, with anglesite, cerussite, wulfenite, and vanadinite (Wilson, K.S., 1984). Table Mountain district, Table Mountain mine, as microcrystals (Kenneth Bladh, UA x526). Mineral Creek district, Ray mines, as microcrystals (UA x3494).

Santa Cruz County: Harshaw district, Hardshell mine, as microcrystals, with descloizite (Fleetwood Koutz, UA x339). Tyndall district, Glove mine, with wulfenite (UA x4672).

Yavapai County: Bradshaw Mountains, at a prospect on the Slate Creek property of Kalium Chemicals Ltd., as botryoidal crusts, with pyromorphite and mottramite (William Berridge, pers. commun., 1973).

MINIUM

Lead oxide, Pb_3O_4. A secondary mineral formed in lead deposits under extreme oxidizing conditions.

La Paz County: Silver district, Silver King mine, as microcrystals (Brian Bond, UA x3542).

Maricopa County: Big Horn Mountains, Tonopah-Belmont mine, with massicot. South of Wickenburg, at the Moon Anchor mine, Potter-Cramer property, and Rat Tail claim, with a variety of exotic secondary minerals formed by the oxidation of galena-sphalerite ores (Williams, S.A., 1968).

Mohave County: Black Mountains, Oatman district, Big Jim vein, as pulverulent material in cavities.

Pima County: South Comobabi Mountains, Cababi district, Silver-Lead and Beacon claims and Mildren mine, as coatings on wulfenite and other secondary minerals (Williams, S.A., 1962).

Pinal County: Tortilla Mountains, Florence Lead-Silver mine (Williams, S.A., and Anthony, 1970). Reef mine, Casa Grande area (UA 7324). Mammoth district, Mammoth–St. Anthony mine, as a rare powdery coating on wulfenite crystals (Bideaux, 1980).

Santa Cruz County: Patagonia Mountains, Flux mine, with cerussite (Schrader and Hill, 1915).

Yavapai County: Near Salome (UA 373, a specimen of questionable natural origin).

Yuma County: Castle Dome Mountains, Castle Dome district, with cerussite.

MIRABILITE

Sodium sulfate hydrate, $Na_2SO_4 \cdot 10H_2O$. A water-soluble mineral formed in playas, saline lakes, and clay soils of the desert. Also formed in old mine workings.

Yavapai County: Verde Valley, in salt deposits, associated with halite, glauberite, and thenardite (Silliman, 1881; Blake, W.P., 1890; Guild, 1910; Peirce, H.W., 1969; Thompson, J.R., 1983).

MIXITE

Bismuth copper arsenate hydroxide hydrate, $Bi_2Cu_{12}(AsO_4)_6(OH)_{12} \cdot 6H_2O$. A rare secondary mineral formed in some base-metal deposits.

Gila County: Banner district, Christmas mine, as spherules of delicate, twisted or matted fibers in cavities in gangue, associated with fibrous malachite; the peculiar yellow-green color of this mixite strongly resembles that of creaseyite.

Pinal County: Mammoth district, Mammoth–St.Anthony mine, as rare, pale-green, radiating sprays associated with wulfenite and mimetite on barite matrix (Bideaux, 1980). Table Mountain district, Table Mountain mine, as microcrystals (Arthur Roe, UA x4591).

Yavapai County: Cherry Creek district, as microcrystals (Brian Sage, UA x1473).

MOISSANITE

Silicon carbide, SiC. First identified as a naturally formed mineral in the Canyon Diablo meteorite. Some authorities, however, believe that the mineral is synthetic silicon carbide (carborundum), which was used to saw samples. Ferdinand Henri Moissan, who discovered moissanite in the meteorite, used no silicon carbide to prepare the sample (Kunz, 1905).

MOLYBDENITE

Molybdenum sulfide, MoS_2. The only common mineral of molybdenum; widely distributed, but in small amounts. A primary sulfide mineral formed in granitic rocks, quartz-orthoclase veins with chalcopyrite, and tin and tungsten ores. Also formed in contact metamorphic deposits. An important associated mineral in porphyry copper deposits of the Southwest.

Cochise County: Little Dragoon Mountains, Cochise district, Johnson Camp, in copper ores (Ransome, 1919; Cooper and Huff, 1951; Cooper, 1957; Cooper and Silver, 1964). Bisbee, Warren district, as rare films on pyritic ores.

Gila County: Globe-Miami district, in small quantities in ores, particularly at the Castle Dome mine (Peterson, N.P., 1947, 1962; Peterson, N.P., et al., 1946, 1951); Copper Cities deposit (Peterson, N.P., 1954). Banner district, with chalcopyrite and pyrite, locally coating the walls of veinlets in the 79 mine (Keith, 1972). Workman Creek area, in hornfels near diabase; Suckerite deposit, associated with uraninite (Granger and Raup, 1969).

Greenlee County: Clifton-Morenci district, in veins with pyrite, chalcopyrite, and sphalerite (Lindgren, 1905; Guild, 1910; Schwartz, 1947), and as thin films in fractures devoid of other sulfides (Moolick and Durek, 1966).

Maricopa County: White Picacho district, sparsely scattered in pegmatites, but locally abundant (Jahns, 1952).

Mohave County: Cerbat Mountains, Gold Basin district, O.K. mine, with galena and wolframite; Wallapai district, Mineral Park mine (Garrison, 1907; Thomas, B.E., 1949; Field, 1966); Chloride district, Samoa mine (Schrader, 1909; Blanchard and Boswell, 1930). Hualapai Mountains, Maynard district, Leviathan and American mines. Deluge Wash area, in small quantities at several properties (Frondel, J.W., and Wickman, 1970). Ithaca Peak, with pyrite in the core of a quartz monzonite stock (Eidel, 1966).

Pima County: Santa Rita Mountains, Helvetia-Rosemont district (Frondel, J.W., and Wickman, 1970), at the Leader, Ridley, and Pauline mines and in many prospects in Madera and Providencia Canyons (Guild, 1907; Schrader and Hill, 1909; Creasey and Quick, 1955); Cuprite mine, as small masses in chalcopyrite ore (Browne, 1958). Silver Bell district, at a small prospect north of the Kurtz shaft (Guild, 1910; Stewart, C.A., 1912). Baboquivari Mountains, Gold Bullion mine, in quartz veins. Pima district, Mineral Hill–Twin Buttes area (Eckel, 1930a; Guild, 1934); a primary ore mineral at the Twin Buttes open-pit mine (Stanley B. Keith, pers. commun., 1973) and the Pima mine (Himes, 1972). Ajo, in sparse amounts (Gilluly, 1937; Schwartz, 1947). Near Redington, in limestone (UA 7288). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963).

Pinal County: Galiuro Mountains, Copper Creek district, as the most important ore mineral at the Childs-Aldwinkle mine, from which 70 million lbs were produced from 1933 to 1938 (Anderson, C.A., 1969); as fine crystallized specimens (Kuhn, 1941; Fleischer, 1959). The rhenium content of the molybdenite concentrates from the Childs-Aldwinkle mine contained from 320 to 580 parts per million, among the highest known. Copper Prince mine, Old Reliable mine, and other properties, in lesser quantities (Simons, 1964). Mineral Creek district, at Ray (UA 7129). Mammoth district, San Manuel mine (Lovering et al., 1950; Schwartz, 1953); Kalamazoo orebody (Lowell, J.D., 1968).

Santa Cruz County: Patagonia Mountains, Santo Niño mine, 2.5 miles southwest of Duquesne, as large bodies of fine-grained massive material and as good crystals in quartz veins with pyrite (Blanchard and Boswell, 1930; Frondel, J.W., and Wickman, 1970); Bonanza mine at Duquesne, where small quantities were mined; Benton and Line properties (Schrader and Hill, 1915; Schrader, 1917).

Yavapai County: Copper Basin district, Copper Hill mine, Loma Prieta mine, and other properties, as extensive deposits (Johnston, W.P., and Lowell, 1961). Bradshaw Mountains, Black Hawk, Blue Bird, and Squaw Peak mines. Eureka district, in thin veins at the Bagdad mine (Lindgren, 1926; Schwartz, 1947; Anderson, C.A., 1950; Dale, 1961). White Picacho district, in pegmatites (Jahns, 1952). Crazy Basin property near Cleator, as fine single crystals up to 4 cm across, in the quartz core of a pegmatite.

#MOLYBDOFORNACITE

Lead copper arsenate-phosphate molybdate-chromate hydroxide, $Pb_2Cu[(As,P)O_4][(Mo,Cr)O_4](OH)$. Formed during severe oxidation of sulfide deposits. Related to fornacite and vauquelinite.

Maricopa County: Osborne district, Tonopah-Belmont mine, with wulfenite and pyromorphite (Allen, G.B., and Hunt, 1988).

Mohave County: Buckskin Mountains, Rawhide mine, as bladed crystals with orange mimetite.

MONAZITE

Cerium lanthanum neodymium phosphate, $(Ce,La,Nd)PO_4$. Contains a variety of rare earth and other elements, in addition to the typically preponderant cerium: e.g., lanthanum, neodymium, yttrium, thorium, uranium, calcium, and silicon. An important ore mineral of the rare earth elements and thorium. Formed as an accessory mineral in granites and pegmatites; also found in thermally metamorphosed rocks and as an abundant constituent of certain sands. Three distinct species are defined by the predominant rare earth element: monazite-(Ce), monazite-(La), and monazite-(Nd). This information, however, is not usually known for a particular sample or locality.

Graham County: Santa Teresa Mountains, as small crystals in pegmatite.

Maricopa and Yavapai Counties: White Picacho district, as a minor accessory mineral, associated with tantalum-columbium minerals in several pegmatites (Jahns, 1952).

Mohave County: Chemehuevis district, about 20 miles southeast of Topock, sparingly in stream gravels (Heineman, 1930; Overstreet, 1967). Virgin Mountains, with xenotime, in Precambrian gneiss (Young, E.J., and Sims, 1961). Aquarius Mountains, Rare Metals mine, in pegmatites, associated with sphene, chevkinite, apatite, and cronstedtite (Kauffman and Jaffe, 1946; Heinrich, 1960). Near the Nevada border, opposite Mesquite (Clark County, Nevada), in granite augen gneiss, with xenotime (Overstreet, 1967). Near Hoover Dam (H 102368).

Pima County: Two miles east of Papago Wells, as massive material (MM 1008).

Yavapai County: Black Canyon Creek, sparse in sands, with magnetite, hematite, garnet, and gold (Day and Richards, 1906). Squaw Peak district, Squaw Peak mine, as rosette-shaped aggregates in quartz-chalcopyrite veins (Roe, R.R., 1976).

#MONTEBRASITE

Lithium sodium aluminum phosphate hydroxide fluoride, $(Li,Na)Al(PO)_4$-(OH,F). Found in pegmatites as crystals, locally of large size, and as massive material. Easily mistaken for the closely related amblygonite.

Maricopa County: White Picacho district, North Morning Star mine (London, 1981); much of what has been identified as amblygonite in the district is probably montebrasite (London and Burt, 1982b).

Yavapai County: White Picacho district, common in the Independence, Lone Giant, Midnight Owl, Picacho View, and White Ridge pegmatites (London, 1981).

MONTICELLITE

Calcium magnesium silicate, $CaMgSiO_4$. An uncommon member of the olivine group.

Cochise County: Tombstone district, fourth level of the Toughnut mine, as narrow bands in a contact metamorphic zone, with calcite, thaumasite, clinozoisite, and vesuvianite (Butler, B.S., et al., 1938b).

MONTMORILLONITE

Sodium calcium aluminum magnesium silicate hydroxide hydrate, $(Na,Ca)_{0.33}$-$(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$. The most common and widespread member of the smectite group of clay minerals. The principal constituent of the bentonite clays, which result from the alteration of volcanic ash and tuffs; also formed by hydrothermal activity. Montmorillonites are characterized by high ion exchange capacities and by an ability to swell markedly when wetted.

Apache County: Sanders-Defiance Plateau area, at Cheto, Allentown, Barnwater Wash, and Ganado Mesa, in linear channels and lenselike bodies underlying the upper member of the Bidahochi Formation, derived from volcanic tuff; as a calcian variety (Kiersch and Keller, 1955b). The composition (wt %), based on a chemical analysis by J.G. Fairchild (Wells, R.C., 1937) of white material from Sanders, is as follows:

SiO_2	51.20	CaO	2.71	$H_2O(-)$	16.78
Al_2O_3	15.12	Na_2O	0.50	$H_2O(+)$	6.92
Fe_2O_3	1.41	K_2O	0.08	TiO_2	0.10
MgO	5.22	MnO	0.03	TOTAL	100.07

Monument Valley, Monument No. 2 mine, associated with uranium-vanadium ores (Witkind and Thaden, 1963).

Cochise County: Reported in an area east of Elgin. About 2 miles south of Benson. Willcox Playa, as the most abundant clay mineral (after illite) in sediments (Pipkin, 1967).

Coconino County: Near Cameron, as an abundant alteration product of mafic dike rocks associated with the Black Peak breccia pipe (Barrington and Kerr, 1961).

Colorado Plateau Region: As an abundant constituent of various sedimentary rock units, notably the Chinle Formation (Schultz, 1963), and in various units of the Morrison Formation, with illite and chlorite (Keller, 1962).

Gila County: Globe-Miami district, abundant in the host rocks of the Castle Dome and Copper Cities mines, where it formed by the hydrothermal alteration of rock-forming silicate minerals (Peterson, N.P., 1962).

Greenlee County: Morenci district, as yellowish-brown material in small amounts in the less intensely altered rock below the supergene zone, formed by hydrothermal alteration; associated with kaolinite, allophane, and beidellite (Schwartz, 1947; Moolick and Durek, 1966).

La Paz County: Near Bouse, in bentonite.

Maricopa County: Reported about 2 miles northeast of Wickenburg, in bentonites. Also reported near Phoenix. Near Carl Pleasant Dam, in poor-quality bentonites.

Mohave County: Reported in the southern part of the county and east of the Big Sandy Wash, as bentonite. Near Kingman, in altered tuff (UA 8859).

Pima County: Silver Bell area, as an alteration mineral that replaces feldspar in dacite (Kerr, 1951). Pima district, Twin Buttes mine, as a product of hydrothermal alteration (Stanley B. Keith, pers. commun., 1973).

Pinal County: Near Ray and Superior, as bentonite.

Yavapai County: Thompson Valley, Lyles deposit, between Kirkland and Yava, in W$^1/_2$ sec. 12, T. 12 N., R. 6 W., as bentonite; the clay is characterized as being intermediate between normal montmorillonite and hectorite and contains 0.3 to 0.5% Li_2O (Norton, 1965). Reported near Wagoner.

Yuma County: Reported near Wellton, in bentonite.

MONTROSEITE

Vanadium iron oxide hydroxide, (V,Fe)O(OH). An essentially unoxidized vanadium mineral formed with uraninite and sulfide minerals and believed to be of primary origin. Alters to paramontroseite, corvusite, and melanovanadite.

Apache County: Carrizo Mountains, Martin, Mesa 4$^1/_2$, and Cove mines. Reported in the Lukachukai Mountains.

#MOORHOUSEITE

Cobalt nickel manganese sulfate hydrate, $(Co,Ni,Mn)SO_4{\cdot}H_2O$. A rare, water-soluble secondary mineral. The type material was on one small specimen consisting of sulfides on a barite-siderite matrix, found near Walton, Nova Scotia, Canada.

Coconino County: Cameron district, as crusts on sandstone.

MORDENITE

Calcium sodium potassium aluminum silicate hydrate, $(Ca,Na_2,K_2)Al_2Si_{10}O_{24}{\cdot}7H_2O$. A member of the zeolite group. Formed as an alteration product of volcanic glass in tuffs; also formed in fissures and as vesicle fillings in mafic volcanic rocks.

Greenlee County: About 6 miles north of Morenci, in Tertiary volcanic tuffs (Sheppard, 1969).

La Paz County: New Water Mountains, near the Eagle Eye mine, as fine, acicular crystals (David Shannon, pers. commun., 1988).

Mohave County: Union Pass district, north side of Union Pass, in tuff and lapilli tuff in the Golden Deer volcanics (Sheppard, 1969).

Pima County: Sikort Chuapa Mountains, 15 miles northeast of Ajo, in altered tuff with clinoptilolite (Eyde, 1978).

Pinal County: Midway Station, as vesicle fillings in flow rock (Bideaux et al., 1960).

MORENOSITE

Nickel sulfate hydrate, $NiSO_4{\cdot}7H_2O$. A rare secondary mineral formed by the oxidation of nickel-bearing sulfides.

Maricopa County: Reported near Wickenburg.

MOTTRAMITE

Lead copper zinc vanadate hydroxide, $Pb(Cu,Zn)(VO_4)(OH)$. An uncommon secondary mineral formed in the oxidized portions of base-metal deposits. Commonly associated with vanadinite and cerussite.

Cochise County: Warren district, as crystals in the Higgins mine (Taber and Schaller, 1930; Schaller, 1934) and as reniform masses in the Shattuck mine (Taber and Schaller, 1930). An analysis by W.T. Schaller (Wells, R.C., 1937) of the mineral from the Higgins mine yielded the following results (wt %):

CuO	19.10	V_2O_5	21.11	Loss on Ign.	4.79
ZnO	0.00	MnO	3.06		
PbO	50.13			TOTAL	98.19

Tombstone district, Lucky Cuss and Toughnut mines, as brilliant black crystals (Guild, 1911). W.F. Hillebrand (1889b) analyzed material from the Lucky Cuss mine, which formed botryoidal incrustations up to 0.5 in. thick; his results (wt %) are as follows:

PbO	57.00	As_2O_5	1.10	CaO	1.01
CuO	11.21	P_2O_5	0.19	MgO	0.04
FeO	tr.	H_2O	2.50	K_2O	0.10
ZnO	4.19	Cl	0.07	Na_2O	0.17
V_2O_5	19.79	SiO_2	0.80	CO_2	0.82
				TOTAL	98.99

Specific gravity: 5.88

Reported in the Pat Hills. Cochise district, Texas Canyon Quartz Monzonite, in quartz-tungsten veins (Cooper and Silver, 1964). Charleston, Gallagher Vanadium property (UA 6061).

Gila County: Apache mine, as rich, black druses associated with vanadinite, in a few places as free-standing, arborescent-botryoidal forms (Wilson, W.E., 1971). Banner district, 79 mine, on the fourth level, as crystal druses encrusting wulfenite and mimetite in breccia of the Main fault zone (Keith, 1972).

Maricopa County: Painted Rock district, Rowley mine, as microcrystals (Bruce Maier, UA x3063).

Pima County: Tucson Mountains, Old Yuma mine (Guild, 1910, 1911). An analysis by F.N. Guild gave the following results (wt %):

PbO	52.26	ZnO	6.71	V_2O_5	23.02
CuO	11.64	MnO	2.16	H_2O	2.52
				TOTAL	98.31

Empire Mountains, Total Wreck mine, as microcrystalline masses and as complete pseudomorphic replacements of wulfenite crystals (H. Peter Knudsen, UA x320). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Ajo district, southwest of the New Cornelia pit, as a chromian variety formed in small quantities as crusts on weathered keratophyre (Gilluly, 1937). Pima district, Twin Buttes open-pit mine (Stanley B. Keith, pers. commun., 1973).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as crusts of small pointed crystals (Guild, 1911; Galbraith and Kuhn, 1940; Bideaux, 1980).

Santa Cruz County: J.C. Holmes claims, as microcrystals with vanadinite (Arthur Roe, UA x2942). Unspecified locality near Nogales, as "cuprodescloizite," in fibrous, reddish, chestnut-brown layers up to 0.5 in. thick, enclosed in crystallized calcite, which may, in turn, be covered by a layer of amber-colored indistinct crystals (Headden, 1903; Guild, 1911). Through analysis, W.P. Headden determined the following composition (wt %):

V_2O_5	19.014	CuO	8.506	MnO	tr.
As_2O_5	3.842	ZnO	12.450	H_2O	2.650
PbO	52.954	Fe_2O_3	0.200	Insol.	0.350
				TOTAL	99.966

Specific gravity: 6.176

Yavapai County: Bradshaw Mountains, at a prospect on the Slate Creek property of Kalium Chemicals Ltd., associated with pyromorphite and mimetite (William C. Berridge, pers. commun., 1973).

#MROSEITE

Calcium tellurium carbonate oxide, $CaTe^{4+}(CO_3)O_2$.

Cochise County: Tombstone district, T.E.I. pit, in brecciated vein quartz, mixed with massive oboyerite; associated with gold, choloalite, and an unknown copper tellurite.

MURDOCHITE

Lead copper oxide, $PbCu_2O_8$. A rare secondary mineral formed in the oxidized portion of copper-lead deposits. Associated with wulfenite, in which it may be embedded, and with hemimorphite, willemite, and quartz. The Mammoth–St. Anthony mine is the type locality (Fahey, 1955).

Cochise County: Warren district, Higgins mine (UA 7715); Southwest mine; Shattuck shaft (Graeme, 1993).

Gila County: Banner district, 79 mine, as rare tiny black crystals (up to 0.1 mm) of cubic habit, associated with plattnerite, aurichalcite, and rosasite (Keith, 1972).

Pima County: Waterman Mountains, Silver Hill mine, with plattnerite and aurichalcite (Bideaux et al., 1960).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as tiny black octahedra on the surface of and embedded within plates of wulfenite, and on the surfaces of fluorite crystals, with hemimorphite and willemite (Fahey, 1955). An analysis by J.J. Fahey gave the following results (wt %):

CuO	67.24	Fe_2O_3	0.17	Insol. in HNO_3	1.11
PbO_2	30.53	SiO_2	0.05		
				TOTAL	99.10

Specific gravity: 6.47

MUSCOVITE

Potassium aluminum silicate hydroxide, $KAl_2(AlSi_3)O_{10}(OH)_2$. An important rock-forming member of the mica group. Most abundant in schists and gneisses and in granite pegmatites, where it may form large "books." As sericite (see below), it is an abundant alteration product in the wall rocks of many mineral deposits. Also widely distributed in sediments and sedimentary rocks. An abundant and widely distributed mineral in Arizona; only a few relatively unusual occurrences are listed below.

Cochise County: Johnny Lyon Hills, at a prospect on the banks of Tres Alamos Wash, as the chromian variety fuchsite, which forms thick foliae in altered and silicified limestone. Its color is so vivid that it is likely the prospect was mistakenly opened up for copper!

La Paz County: Trigo Mountains, Eureka district, as chromian phengite, disseminated in schist and accompanied by chromite.

Maricopa County: White Picacho district, as an abundant mineral in pegmatites (Jahns, 1952). Crusher Mica quarry, as well-formed single crystals in pegmatite (Ken Phillips, pers. commun., 1989). White Tank Mountains, Caterpillar testing grounds, as crystals over 12 in. across.

Mohave County: Unspecified locality north of the Colorado River, in clear, transparent sheets up to 6 × 10 in. (Engineering Mining Journal, 1892a).

Pima County: Ko Vaya Hills, north of Sells, as the variety fuchsite (UA 4174). San Antonio Mica mine near Ajo, as large masses.

Pinal County: Willow Springs Ranch in Oracle, as pseudomorphs after tourmaline (UA 8617).

Yavapai County: Weaver Mountains, near Peeples Valley, as segregations in Yavapai Schist. Bradshaw Mountains, as segregations in a pegmatite dike that extends about 5 miles, from Middleton to Horsethief Basin. White Picacho district, as an accessory mineral in pegmatites (Jahns, 1952).

Sericite

Most, although not all, mica identified as sericite is actually muscovite. Sericite is a finely divided, shredded variety of muscovite primarily formed by hydrothermal alteration. It is common in porphyry copper deposits. Only a few representative localities are listed below.

Cochise County: Warren district, in the Sacramento Hill stock (Schwartz, 1947, 1958).

Gila County: Globe-Miami district, Castle Dome mine (Peterson, N.P., et al., 1946; Schwartz, 1947; Creasey, 1959); Copper Cities deposit (Peterson, N.P., 1954); Miami and Inspiration orebodies (Schwartz, 1947; Olmstead and Johnson, 1966).

Graham County: Gila Mountains, Lone Star district, Safford area, at and near the Safford copper deposit (Robinson, R.F., and Cook, 1966; Rose, 1970).

Greenlee County: Clifton-Morenci district (Reber, 1916; Schwartz, 1947, 1958; Creasey, 1959).

Mohave County: Cerbat Mountains, Wallapai district, associated with sulfide-bearing veins (Thomas, B.E., 1949).

Pima County: Ajo district, New Cornelia mine area (Gilluly, 1937; Schwartz, 1958; Creasey, 1959). Silver Bell area, as the most widespread alteration product (Kerr, 1951).

Pinal County: Mammoth district, San Manuel orebody (Schwartz, 1947; Creasey, (1959); Kalamazoo orebody (Lowell, J.D., 1968). Mineral Creek district, at Ray (Schwartz, 1947, 1952, 1959; Rose, 1970).

Yavapai County: Copper Basin district (Johnston, W.P., and Lowell, 1961). Big Bug district, Iron King mine (Creasey, 1952; Moxham et al., 1965). Bagdad area (Schwartz, 1947; Anderson, C.A., 1950; Creasey, 1959; Moxham et al., 1965). United Verde mine (Moxham et al., 1965).

N

NACRITE

Aluminum silicate hydroxide, $Al_4Si_4O_{10}(OH)_8$. A less common member of the kaolinite group. Dull, chalky white when pure.

Greenlee County: Steeple Rock area, northwest of Duncan, as a widespread constituent of solfatarically altered dacites and quartz latites; associated with diaspore in some places.

#NANTOKITE

Copper chloride, CuCl. Formed under oxidizing conditions at copper deposits, associated with copper, cuprite, atacamite, and hematite.

Cochise County: Bisbee, Warren district, Campbell mine, as clear, paraffinlike masses impregnating the cores of vuggy cuprite nodules; under humid conditions, it changes to paratacamite powder (Graeme, 1993).

NATROALUNITE

Sodium aluminum sulfate hydroxide, $NaAl_3(SO_4)_2(OH)_6$. A relatively rare member of the alunite group formed during alunitization, a process of solfataric action, commonly accompanied by kaolinization and silicification.

La Paz County: Sugarloaf Butte near Quartzsite (Omori and Kerr, 1963; UA 9348).

NATROJAROSITE

Sodium iron sulfate hydroxide, $NaFe_3(SO_4)_2(OH)_6$. Isostructural with jarosite. Formed, with other sulfates, as an oxidation product of pyrite.

Gila County: Reported in the Globe area, exact locality unknown.

Mohave County: Georgia Sunset claim, 4 miles south of Kingman, as compact to earthy, golden-brown to yellow masses made up of tabular crystals. An analysis reported in E.V. Shannon and Gonyer (1927) gave the following results (wt %):

Fe_2O_3	48.23	K_2O	2.28	$(NH_4)_2O$	0.00
Al_2O_3	0.09	Na_2O	4.28	SO_3	33.71
FeO	0.58	Ag_2O	0.00	H_2O	10.76
CaO	0.05	PbO	tr.	Insol.	0.22
MgO	0.05			TOTAL	100.25

NATROLITE

Sodium aluminum silicate hydrate, $Na_2Al_2Si_3O_{10} \cdot 2H_2O$. A member of the zeolite group.

Graham County: Aravaipa district, Grand Reef mine, with linarite (Jones, R.W., 1980).

Maricopa Country: One mile south of Horseshoe Dam, in a road cut and in boulders along the Verde River, abundant in basalt with crystals up to 1 cm long in radiating hemispheres (Shannon, D.M., 1983b).

Mohave County: On U.S. Highway 93, near mile marker 446, 7 miles southeast of Hoover Dam, in a kaersutite-camptonite dike (Bideaux et al., 1960).

Yavapai County: Near Hillside mine; in vesicular basalt about 10 miles south of Bagdad, secs. 14 and 15, T. 13 N., R. 8 W. (William Hunt, pers. commun., 1984).

#NAUMANNITE

Beta silver selenide, β-Ag_2Se. An uncommon mineral associated with sulfides and other selenium minerals in hydrothermal mineral deposits.

Coconino County: Prospect Canyon district, Ridenaur mine, with vesignieite, bromargyrite, tyuyamunite, metatyuyamunite, and calciovolborthite (Wenrich and Sutphin, 1989).

La Paz County: Near Quartzsite, as small beads within massive djurleite in quartz veins.

NAVAJOITE

Vanadium oxide hydrate, $V_2O_5 \cdot 3H_2O$. An uncommon secondary mineral formed as impregnations of sandstone, associated with oxidized vanadium-uranium minerals. The Monument No. 2 mine is the type locality.

Apache County: Monument Valley, Monument No. 2 mine, as dark-brown, silky to fibrous, minute columns normal to fracture surfaces in channel fillings in Shinarump Conglomerate, with a host of other secondary uranium and vanadium minerals (Weeks et al., 1954, 1955; Finnell, 1957; Ross, M., 1959; Witkind and Thaden, 1963; Young, R.G., 1964). An analysis by Sherwood (Weeks et al., 1954) gave these results (wt %):

V_2O_5	71.68	V_2O_4	3.08	Fe_2O_3	3.58
CaO	0.22	SiO_2	1.20	H_2O	20.30
				TOTAL	100.06

Specific gravity: 2.56

NEKOITE

Calcium silicate hydrate, $CaSi_2O_5 \cdot 2H_2O$. A dimorph of okenite. First described from the Crestmore quarry in Riverside, California.

Graham County: Aravaipa district, Iron Cap mine, near Landsman's Camp, in contact-metamorphosed limestone as white, radiating fibers, filling fractures in quartz-epidote hornfels.

#NEKRASOVITE

Copper vanadium tin arsenic antimony sulfide, $Cu_{26}V_2(Sn,As,Sb)_6S_{32}$. Formed in ore aggregates within propylitic andesites and dacites.

Cochise County: Warren district, Campbell orebody, as blebs up to 0.7 mm in quartz, with pyrite and calcite (Graeme, 1993).

#NELTNERITE

Calcium manganese silicate, $CaMn^{3+}_6SiO_{12}$. A member of the braunite mineral group. Formed in veins and lenses as a secondary mineral associated with braunite, marokite, and crednerite.

Cochise County: White Tail Deer mine, as small, 1-mm, oval crystals embedded in braunite II or at the contact between braunite II cores and braunite rims. Associated minerals are hübnerite, coronadite, and tilasite.

NEOTOCITE

Manganese magnesium iron silicate hydroxide, $(Mn,Mg,Fe)_4(SiO_2)_3(OH)_{10}$(?). Of uncertain composition. A poorly defined species that appears to form partly through alteration of manganese-bearing silicate minerals.

Graham County: Aravaipa district, in drusy cavities associated with johannsenite, which has replaced limestone containing galena, sphalerite, chalcopyrite, quartz, and calcite (Simons and Munson, 1963). Black Hole deposit.

Pima County: Ajo district, New Cornelia mine, as black dendrites (Thomas, W.J., and Gibbs, 1983).

NEPHELINE

Sodium potassium aluminum silicate, $(Na,K)AlSiO_4$. A feldspathoid mineral. Commonly formed in alkaline igneous rocks and similar rocks thought to be of metasomatic origin.

Coconino County: Cameron area, Black Peak, as small anhedral crystals filling interstices in the augite matrix of mafic dike rocks associated with a breccia pipe (Barrington and Kerr, 1961); as anhedral crystals between blades of augite in the monchiquite Tuba dike (Barrington and Kerr, 1962).

Pima County: Sierrita Mountains, Gunsight Mountain, sparse in a pulaskite dike (Bideaux et al., 1960). Esperanza mine, in nepheline syenite encountered in an exploratory drill hole (Schmidt, H.A., et al., 1959).

#NEYITE

Lead copper silver bismuth sulfide, $Pb_7(Cu,Ag)_2Bi_6S_{17}$. In hydrothermal quartz veins.

Maricopa County: Cortez prospect, as minute beads in vein quartz, with bismuthinite and eichbergite.

Niccolite (see NICKELINE)

NICKELINE

Nickel arsenide, NiAs. An uncommon mineral of primary origin, found in significant quantities at only a few localities. Typically associated with cobalt and silver-arsenic minerals and with primary silver.

Coconino County: Typically formed with rammelsbergite and pararammelsbergite as an early formed primary phase in breccia pipes mined for uranium (Wenrich and Sutphin, 1988).

Yavapai County: Monte Cristo mine, with chloanthite and silver (Bastin, 1922).

#NICKEL-SKUTTERUDITE (Chloanthite)

Nickel arsenide, $NiAs_{2-3}$. Formed in a manner similar to skutterudite (see also this mineral description for substitutional relationships).

Maricopa County: Wickenburg Mountains, Monte Cristo mine, with silver (Bastin, 1922).

#NICKEL-ZIPPEITE

Nickel uranyl sulfate hydroxide hydrate, $Ni_2(UO_2)_6(SO_4)_3(OH)_{10} \cdot 16H_2O$. Probably a secondary mineral partly formed under oxidizing conditions from primary uranium minerals and sulfides.

Yavapai County: Hillside mine, in very small amounts, associated with other minerals of the zippeite group, especially zippeite proper, sodium-zippeite, and probably cobalt-zippeite, as well as schröckingerite, johannite, bayleyite, and gypsum (Frondel, C., et al., 1976).

NITER

Potassium nitrate, KNO_3. A product of evaporation; formed from guano or by bacterial action upon other animal remains. Found in caves or old mine workings in small amounts.

Coconino County: Walnut Canyon, as a thin, white covering on limestone shelves in ancient cliff dwellings (Guild, 1910).

Graham County: Peloncillo Mountains, in caves.

Pinal County: Galiuro Mountains, Aravaipa Canyon, as thin crusts and in cracks in rock below caves.

NITRATINE

Sodium nitrate, $NaNO_3$. A water-soluble mineral formed in arid environments as coatings and efflorescences on rocks and soil.

Mohave County: Rawhide Mountains, 3 miles south of Artillery Peak.

Pinal County: Superstition Mountains (UA 7838). Gila River Indian Reservation, as a minor constituent of sodium nitrate- and sodium chloride-bearing crusts in salt flats of the Santa Cruz Wash (Wilson, E.D., 1969).

NITROCALCITE

Calcium nitrate hydrate, $Ca(NO_3)_2 \cdot 4H_2O$. A water-soluble mineral formed as efflorescences in limestone caverns. Locally, the nitrate is derived from guano.

Gila and Pinal Counties: Along the Gila River, 2 miles above Winkelman, in fissures up to 6 to 8 in. wide in Mississippian limestone.

Pinal County: Casa Grande area (UA 7837).

#NOLANITE

Vanadium iron titanium oxide hydroxide, $(V^{3+},Fe^{2+},Fe^{3+},Ti)_{10}O_{14}(OH)_2$. Associated with other vanadium oxides in an assemblage of hydrothermal origin. Bisbee is the third locality discovered in the world.

Cochise County: Warren district, Campbell orebody (Graeme, 1993).

NONTRONITE

Sodium iron aluminum silicate hydroxide hydrate, $Na_{0.33}Fe_2^{3+}(Al,Si)_4O_{10}(OH)_2 \cdot nH_2O$. An iron-rich end member of the montmorillonite (smectite) group of clay minerals. A secondary mineral of uncertain origin, known to form in hydrothermally altered copper deposits. "Morencite" has been shown to be identical with nontronite.

Gila County: Globe-Miami district, Miami orebody, abundant as pseudomorphs after plagioclase phenocrysts, associated with sericite, kaolinite, and hydromuscovite (Schwartz, 1947). Workman Creek area, associated with sulfide minerals in Dripping Spring Quartzite (Granger and Raup, 1969).

Graham County: Stanley district, Friend mine.

Greenlee County: Clifton-Morenci district, as silky seams in limy shale in the Arizona Central mine (Schwartz, 1947, 1958) and on the periphery of the Morenci orebody (Moolick and Durek, 1966).

Pima County: Santa Rita Mountains, Helvetia-Rosemont district, Pauline mine, in metamorphosed wall rock (Schrader and Hill, 1915). Ajo district, uncommon as a secondary mineral (Gilluly, 1937). Pima district, Twin Buttes open-pit mine, in the supergene zone in collapsed breccias (Stanley B. Keith, pers. commun., 1973).

Pinal County: Mineral Creek district, Ray deposit, in hydrothermally altered quartz monzonite with sericite, hydromuscovite, and quartz (Schwartz, 1952). Mammoth district, impregnating younger sediments on Copper Creek, where it debouches from the box canyon (Herbert E. Hawkes, pers. commun., 1973).

Yavapai County: Black Hills, United Verde mine, with limonite in gossans.

#NORDSTRÖMITE

Lead copper bismuth sulfide selenide, $Pb_3CuBi_7(S_{10}Se_4)$. Of hydrothermal origin.

Cochise County: Northeast side of the Johnny Lyon Hills, in vein quartz.

#NSUTITE

Gamma manganese oxide, γ-MnO_2; more specifically, manganese oxide hydroxide, $Mn^{2+}_x Mn^{4+}_{1-x} O_{2-2x}(OH)_{2x}$, with the value of x being small. A fairly widespread manganese ore mineral.

Santa Cruz County: Hardshell mine, with several other manganese oxide minerals (Koutz, 1984).

Yuma County: Kofa district, King of Arizona mine, No. 5 vein, with groutite (Hankins, 1984).

NUKUNDAMITE

Copper iron sulfide, $(Cu,Fe)_4S_4$. Commonly a primary mineral of hypogene origin. Also formed as an alteration product of primary chalcopyrite.

Pinal County: Superior area, as polygonal orange grains that resemble stannoidite, in bornite; reported by Ben Leonard, U.S. Geological Survey (John S. White, Jr., pers. commun., 1981).

O

OBOYERITE

Hydrogen lead tellurite tellurate hydrate, $H_6Pb_6(TeO_3)_3(TeO_6)_2{\cdot}2H_2O$. An extremely rare mineral formed by oxidation of other tellurium minerals. The mine dump at the Grand Central mine is the type locality.

Cochise County: Tombstone district, in the dumps of the Grand Central mine, associated with many tellurium oxysalt minerals; as tiny, milk-white spherules perched on clear, botryoidal opal which, in turn, coats jarosite filling voids left in altered shale by the removal of galena. A chemical analysis by Marjorie Duggan (Williams, S.A., 1979) gave the following results (wt %):

PbO	58.0	CaO	0.3	TeO_2	22.1
TeO_3	16.2	H_2O	4.2	TOTAL	100.8

OFFRETITE

Potassium calcium aluminum silicate hydrate, $(K,Ca)_3Al_5Si_{13}O_{36}\cdot 14H_2O$. An uncommon mineral of the zeolite group, found in amygdaloidal cavities in basaltic flow rocks, associated with other zeolites.

Greenlee County: East side of the San Francisco River, about 1 mile north of Clifton, as tiny, elongate, prismatic crystals in amygdules in basalt flows exposed in a road cut (William Hunt and Dan Caudle, pers. commun., 1976).

Yavapai County: South side of the Santa Maria River, between U.S. Highway 93 and State Highway 96, in a basalt flow (William Hunt, pers. commun., 1985).

#OKENITE

Calcium silicate hydrate, $Ca_{10}Si_{18}O_{46}.18H_2O$. Formed as amygdule fillings in eruptive volcanic rocks.

Maricopa County: Near Horseshoe Dam, as bladed, fibrous, white microcrystals that line vug walls, associated with zeolites (Shannon, D.M., 1983b).

OLIVENITE

Copper arsenate hydroxide, $Cu_2AsO_4(OH)$. A secondary mineral formed in the oxidized zones of base-metal mineral deposits, where it is associated with other secondary lead and copper minerals.

Cochise County: Tombstone district (UA 6439, 8240).

Coconino County: Grand Canyon National Park, Horseshoe Mesa, Grandview (Last Chance) mine, as short, olive-green, prismatic crystals and lighter colored acicular groups, on altered metazeunerite (Leicht, 1971).

Gila County: Banner district, 79 mine, as clusters of tiny green crystals on sphalerite and galena, associated with brochantite, siderite, chalcanthite, and anglesite (Keith, 1972; Thomas Trebisky, pers. commun., 1972).

Graham County: Aravaipa district, Grand Reef mine, as acicular green tufts on azurite (Jones, R.W., 1980).

Pima County: Ajo district, New Cornelia mine, as small crystals with ajoite (Thomas, W.J., and Gibbs, 1983).

Pinal County: Galiuro Mountains, Copper Creek district, Old Reliable mine, as small olive-green crystals. Pioneer district, Magma mine, in the outcrop at the No. 1 glory hole, as small crystals with dioptase.

Yavapai County: Copper Mountain, Old Robertson claims near Mayer, with clinoclase (Robert O'Haire, pers. commun., 1972). Bagdad mine, as microcrystals on chrysocolla (William Hunt, pers. commun., 1985).

Olivine

Magnesium iron silicate, $(Mg,Fe)_2SiO_4$. A group term that includes the end members forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4). An abundant rock-forming group of minerals characteristic of mafic igneous rocks. The occurrences listed below cannot be more specifically identified because their chemical compositions are not known well enough to label them as forsterite or fayalite (see also these mineral descriptions) or because they are compositionally in between these end members.

Apache County: Buell Park, 10 miles north of Fort Defiance, and Garnet Ridge, as clear, green to brown, gem-quality material (Gregory, 1916).

Cochise County: Tombstone district, in the contact zone at Comstock Hill; Lucky Cuss mine, as an important constituent of basalt (Butler, B.S., et al., 1938b). Reported in the Warren district.

Coconino County: San Francisco Mountains, in basalts (Gregory, 1917).

Gila County: San Carlos Indian Reservation, near Peridot and Tolklai, in basaltic rocks, volcanic bombs, and stream gravels (H 89313); a cut stone from this locality weighed 25.75 carats. An analysis (by S.S. Goldich) of material from Rice Station School at Tolklai (S 86128) gave the following results (wt %):

SiO_2	40.90	Fe_2O_3	0.59	NiO	0.30
TiO_2	0.05	FeO	8.24	MgO	49.78
Al_2O_3	0.22	MnO	0.12	CaO	0.05
Cr_2O_3	0.02	$H_2O(-)$	0.01	TOTAL	100.28

Near Globe, as granular masses of roughly ellipsoidal shape, associated with larger crystals of magnetite and spinel as well as grains of albite, diopside, hornblende, and biotite; believed to be volcanic bombs (Lausen, 1927a). Sierra Ancha, abundant in a differentiated diabase sill complex (Smith, D., 1970). A microprobe analysis gave the following results (wt %):

SiO_2	36.6	MnO	0.39	CaO	0.07
TiO_2	0.05	MgO	35.6	NiO	0.11
FeO	26.0			TOTAL	98.8

Mohave County: Cerbat Mountains, in Quaternary basalts (Thomas, B.E., 1953).

Pinal County: As an accessory mineral in diabase sills that intrude rocks of the Apache Group in this and adjacent counties. Dripping Spring Mountains, with augite and iddingsite in Tertiary basalts. Galiuro Mountains, in the contact zone between granodiorite and Cretaceous sedimentary rocks.

Santa Cruz County: Santa Rita and Patagonia Mountains, sparingly in gabbro, diabase, and andesites.

Yavapai County: Big Bug district, Iron King mine, as phenocrysts in porphyritic basalt flows associated with mineralized volcanic breccias, with augite (Creasey, 1952).

#OMPHACITE

Calcium sodium magnesium iron aluminum silicate, $(Ca,Na)(Mg,Fe,Al)Si_2O_6$. A member of the pyroxene group of rock-forming silicate minerals, whose presence indicates high-pressure origins.

Apache County: Garnet Ridge, associated with garnet and lawsonite in eclogite inclusions in kimberlite pipes (Watson, K.D., and Morton, 1969).

Onyx (see QUARTZ)

#Opal (see CRISTOBALITE)

ORPIMENT

Arsenic sulfide, As_2S_3. Of secondary origin. Formed by the alteration of other arsenic-bearing minerals. Typically associated with realgar, but less common.

Pinal County: In 1915 several pounds of orpiment and realgar were discovered at an unidentified locality near the junction of the Gila River and Hackberry Wash.

ORTHOCLASE

Potassium aluminum silicate, $KAlSi_3O_8$. Monoclinic. An important rock-forming alkali feldspar. An abundant constituent of felsic igneous rocks and detrital sedimentary rocks derived from them. Also formed by the action of hydrothermal solutions on wall rocks of mineral deposits. Widely distributed in the felsic igneous rocks of the state. Phenocrysts up to several inches long have been found in some granites in Arizona.

Cochise County: Texas Canyon stock, as phenocrysts up to several inches long and as abundant, excellent examples of Carlsbad twins.

Maricopa County: Bradshaw Mountains, Cave Creek district, in pipes up to 175 ft in diameter in granite.

Mohave County: Cerbat and Hualapai Mountains, mined from the pegmatites (Wilson, E.D., 1944). Reported near Hackberry, as thick veins.

Pima County: Ajo district, New Cornelia orebody, as crystals up to several inches across, as part of a massive replacement of quartz monzonite (Gilluly, 1937). Silver Bell area, as a late-stage alteration mineral (Kerr, 1951).

Pinal County: Crystal Pass near Ray, as small euhedra, commonly twinned after the Carlsbad and other laws. Northern Santa Catalina Mountains, as Carlsbad twins (UA 4034, 4035). Reported near Kearny, as twinned crystals. Copper Creek district, Childs-Aldwinkle mine, as crystals up to 6 in. long, in a pegmatite zone at the base of a breccia pipe (Kuhn, 1941).

Yavapai County: Bradshaw Mountains, near the old townsite of Middletown on the Crown King Road, as relatively pure material.

OSARIZAWAITE

Lead copper aluminum sulfate hydroxide, $PbCuAl_2(SO_4)_2(OH)_6$. An uncommon mineral formed in the oxidized zone of some base-metal veins.

Cochise County: Bisbee, Warren district, as massive, pistachio-green material in goethite gossans at several localities; particularly common at the Shattuck mine.

Pima County: Helvetia district, Omega mine, as microcrystalline yellow-green crusts (David Shannon, UA x4351). Waterman district, Silver Hill mine, as attractive, blue, massive to microcrystalline material (Stolberg, 1988; Hal Frazier, UA x2146).

Yavapai County: Fat Jack mine, with stolzite, cerussite, pyromorphite, and mottramite (Modreski and Scovil, 1990; Scovil and Wagner, 1991).

P

PALYGORSKITE (Attapulgite)

Magnesium aluminum silicate hydroxide hydrate, $(Mg,Al)_2Si_4O_{10}(OH)\cdot 4H_2O$. Commonly classified as a clay mineral because of its finely divided habit in soils. Also formed by hydrothermal activity. A variety consisting of intertwined fibers is termed *mountain leather.*

Colorado Plateau: In certain zones of the Petrified Forest and Owl Rock Members of the Chinle Formation (Schultz, 1963).

Gila County: Globe Hills district, Black Copper pit, Inspiration Consolidated Copper Co., along foliation in gouge near the dacite hanging wall of the Keystone fault system, as irregular, white to pale-lavender, slickensided seams up to 0.5 in. thick that apparently cement gouge fragments (Bladh, K.W., 1973). Apache mine (Brian Bond, UA x3325).

Pima County: Ajo district, New Cornelia mine (Thomas, W.J., and Gibbs, 1983). Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

Pinal County: Mammoth–St. Anthony mine, in some fault gouges (Bideaux, 1980).

Santa Cruz County: Washington Camp–Duquesne districts, South Empire and Silver Bill mine areas, as tough, matted, fibrous masses on fault surfaces (Lehman, 1978).

PAPAGOITE

Calcium copper aluminum silicate hydroxide, $CaCuAlSi_2O_6(OH)_3$. A rare mineral known only from the New Cornelia mine at Ajo, and from Messina, Transvaal, South Africa. The Ajo occurrence is the type locality.

Pima County: Ajo district, New Cornelia mine, as elongated, somewhat flattened, cerulean-blue crystals in narrow veinlets and in veneers on slip surfaces in altered granodiorite porphyry, associated with aurichalcite, shattuckite, ajoite, barite, and iron oxides (Hutton and Vlisidis, 1960; Guillebert and Le Bihan, 1965; UA 168; NHM 1959,192).

#PARAGONITE

Sodium aluminum silicate hydroxide, $NaAl_2(Si_3Al)O_{10}(OH)_2$. A muscovitelike member of the mica group that contains sodium rather than potassium as the alkalication.

Yavapai County: Governors Peak quadrangle, in schist (Shafiqullah et al., 1980).

PARAKHINITE

Copper lead tellurate hydroxide, $Cu_3PbTeO_4(OH)_6$. Dimorphous with khinite. An extremely rare secondary mineral formed by oxidation of other tellurium minerals in acid waters. Like khinite, known only from Tombstone, the type locality.

Cochise County: Tombstone district, in the dumps of the Old Guard mine, as thin crystalline films on fractures in quartz gangue, and as deep-green, tabular, hexagonal euhedral crystals up to 0.5 mm in vugs. Chemical analysis by Marjorie Duggan (Williams, S.A., 1978) gave the following results (wt %):

CuO	32.8	PbO	31.9	TeO_3	25.7
H_2O	7.8			TOTAL	98.2
Density: 6.69					

PARALAURIONITE

Lead chloride hydroxide, PbCl(OH). The monoclinic dimorph of laurionite. A rare secondary mineral known from only a few localities in the world. Formed in the oxidized zones of lead-copper deposits.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, Collins vein, as small, slender, isolated, yellowish-white crystals in cavities with cerussite, and as coarser crystal aggregates with leadhillite and diaboleite; characterized by extremely good cleavage and some flexibility; many crystals are bent (Fahey et al., 1950; Palache, 1950; Bideaux, 1980). An analysis by F.A. Gonyer gave the following results (wt %):

Pb	77.75	O	6.00	Cl	12.84
H_2O	3.51			TOTAL	100.10

PARAMELACONITE

Copper oxide, $Cu^{2+}_{1-2x}Cu^{1+}_{2x}O_{1-x}$. A rare secondary mineral. Only two localities are known: the Copper Queen mine in Bisbee, which is the type locality, and the Algomah mine in Michigan.

Cochise County: Bisbee, Warren district, Copper Queen mine, in a matrix of goethite, associated with cuprite, copper, tenorite, malachite, and connellite, as unusually large crystals with the following forms: {001}, {101}, and {100} (Koenig, G.A., 1891; Frondel, C., 1941; O'Keefe and Bovin, 1978).

PARAMONTROSEITE

Vanadium oxide, VO_2. A rare secondary mineral formed by the oxidation of montroseite.

Apache County: Monument Valley, Monument No. 2 mine, as shiny black crystals up to 0.5 mm (Evensen and Gray, 1958; Witkind and Thaden, 1963; Young, R.G., 1964).

#PARARAMMELSBERGITE

Nickel arsenide, $NiAs_2$. Dimorphous with rammelsbergite. Formed in nickel- and cobalt-bearing hydrothermal veins.

Coconino County: In breccia pipes mined for uranium; may be associated with its dimorph rammelsbergite and nickeline (Wenrich and Sutphin, 1988).

PARATACAMITE

Copper hydroxide chloride, $Cu_2(OH)_3Cl$. The rhombohedral dimorph of atacamite. A secondary mineral found at numerous localities.

Cochise County: Warren district, Holbrook and Cole mines, where it is associated with cuprite, malachite, and azurite, but is rare; Southwest mine, as crystals up to 1.5 cm long, probably the finest examples of the species (Graeme, 1993).

Pima County: South Comobabi Mountains, Cababi district, Mildren mine, as fibrous and granular masses embaying linarite and as pseudomorphs after atacamite in quartz veins cutting andesite (Williams, S.A., 1962, 1963).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, with cerussite, boleite, and diaboleite (Bideaux, 1980; UA 5154).

PARATELLURITE

Tellurium oxide, TeO_2. A fairly rare oxide mineral formed in acid waters from tellurides or tellurium. Easily mistaken for anglesite in appearance.

Cochise County: Bisbee, Warren district, in the ores of the Campbell mine (Graeme, 1993). Tombstone, Joe mine, in numerous samples of partly oxidized pyritic telluride ore, as crystals up to 3 mm long in cavities, with anglesite, rodalquilarite, and emmonsite.

#PARGASITE

Sodium calcium magnesium iron aluminum silicate hydroxide, $NaCa_2(Mg,Fe)_4$-$Al(Si_6Al_2)O_{22}(OH)_2$. A member of the amphibole group of rock-forming silicate minerals.

Cochise County: Geronimo Volcanic Field, associated with inclusions (Kempton, 1983).

Gila County: San Carlos Apache Reservation, associated with ultramafic inclusions (Frey and Prinz, 1978).

#PARISITE

Calcium cerium neodymium lanthanum carbonate fluoride, $Ca(Ce,Nd,La)_2$-$(CO_3)_3F_2$. Used here as a group name. The relative amounts of the rare earth elements may be unknown; thus, the suffix -(Ce) or -(Nd) cannot always be assigned to local species. A fairly widespread mineral formed in several geological environments: pegmatites, certain high-sodium granites, and veinlets in shales.

Mohave County: Gold Basin–Lost Basin district, in an unnamed prospect, as small crystals in miarolitic cavities in small leucosyenite intrusive bodies, with fluorite and gold (Blacet, 1969).

PARNAUITE

Copper arsenate sulfate hydroxide hydrate, $Cu_9(AsO_4)_2(SO_4)(OH)_{10}\cdot 7H_2O$. A rare secondary mineral formed by oxidation of primary copper-bearing ores at low temperatures.

Coconino County: Grandview district, Grandview mine on the Grand Canyon's South Rim, as a rare member of an extensive suite of secondary sulfates, arsenates, and carbonates formed by the oxidation of primary copper ores. The mineral, designated as "unknown no. 6" in Leicht's (1971) description of the Grandview mine, was subsequently identified by William Wise (pers. commun., 1980).

PARSONSITE

Lead uranyl phosphate hydrate, $Pb_2(UO_2)(PO_4)_2\cdot 2H_2O$. A rare secondary mineral known only from a few localities.

Cochise County: Huachuca Mountains, as pale-yellow crusts on quartz in a small lead prospect.

#PARTZITE

Copper antimony oxide hydroxide, $Cu_2Sb_2(O,OH)_7$(?). A secondary mineral formed by the oxidation of antimony-bearing sulfides.

Cochise County: Johnny Lyon Hills, along the banks of the Tres Alamos Wash, as an abundant, chalky-green mixture pseudomorphous after tetrahedrite, associated with bindheimite, lewisite, and stibiconite.

PASCOITE

Calcium vanadium oxide hydrate, $Ca_2V_6O_{17}\cdot 11H_2O$. A water-soluble secondary mineral formed under surficial oxidizing conditions. Locally associated with carnotite.

Apache County: Monument Valley, Monument No. 2 mine, as water-soluble coatings on the mine walls (Witkind and Thaden, 1963). Lukachukai Mountains, Mesa No. 1, No. 5, and No. 6 mines (Chenoweth, 1967). Carrizo Mountains, Zona No. 1 claim.

PAULKERRITE

Potassium titanium magnesium manganese iron aluminum phosphate hydroxide hydrate, $KTi(Mg,Mn)_2(Fe,Mg,Al,Ti)_2(PO_4)_4(OH)_3\cdot H_2O$. A rare mineral formed in granitic pegmatites as small, yellow-brown to nearly colorless, minute vitreous crystals. The 7U7 Ranch is the type and only known locality.

Yavapai County: 7U7 Ranch near Hillside, associated with altered triplite and other secondary phosphate minerals (Peacor et al., 1984).

PEARCEITE

Silver arsenic sulfide, $Ag_{16}As_2S_{11}$. An uncommon mineral formed under low to moderate temperatures in veins, typically associated with lead and silver sulfosalts, galena, and acanthite.

Cochise County: Warren district, Campbell shaft (Graeme, 1993; S 100455).

Mohave County: Cerbat Mountains, reported in small amounts from some of the high-grade silver ores; Chloride district, Distaff mine (Bastin, 1925).

Santa Cruz County: Trench mine, 500-ft level; World's Fair mine (Kartchner, 1944).

#PECORAITE

Nickel silicate hydroxide, $Ni_3Si_2O_5(OH)_4$. Originally described from an Australian meteorite.

Cochise County: Dragoon Mountains, at the ghost town of Barrett Camp, in crystalline dolomite, as bright-green, microcrystalline material that apparently replaced another mineral, which, in turn, had replaced rock fragments of possible fossil hash; the dolomite, despite its degree of crystallinity, exudes a pronounced fetid odor when cut or broken.

#PECTOLITE

Sodium calcium silicate hydroxide, $NaCaSi_3O_8(OH)$. A widespread mineral formed in a variety of environments: in cavities in basaltic rocks, commonly with zeolites, and in metamorphosed rocks high in calcium.

Navajo County: Navajo Volcanic Field, in lamprophyre dike rocks (Laughlin et al., 1986).

#PEKOITE

Lead copper bismuth sulfide selenide, $PbCuBi_{11}(S,Se)_{18}$. At the type locality in Australia, formed in magnetite-bearing pipes of hydrothermal origin that cut felsic sediments and volcanic rocks; the pipes are probably hydrothermal replacements associated with volcanism.

Cochise County: Dos Cabezas Mountains, near the Comstock mine, as slender prisms up to 8 mm long in vein quartz, associated with pyrite and bismutite; the pekoite is corroded by gladite along crystal margins.

Penninite (a variety of CLINOCHLORE)

Magnesium iron aluminum silicate hydroxide, $(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)_8$. An important member of the chlorite group, formed during thermal metamorphism and by hydrothermal processes. Extremely common, despite the few localities noted below.

Cochise County: Warren district, north of the Dividend Fault, as small, scaly crystals interlayered with sericite in altered Bolsa Quartzite; also common as a matrix of breccia dikes exposed in the upper reaches of Brewery Gulch.

Pima County: East side of the Tortolita Mountains, as large crystals pseudomorphous after hornblende in abundant syenodiorite dikes. Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

PENTLANDITE

Iron nickel sulfide, $(Fe,Ni)_9S_8$. A primary mineral commonly associated with pyrrhotite; in places, thought to be a product of basic magmatic segregation. An important nickel ore.

Mohave County: Reported near Littlefield, in mafic dikes with pyrrhotite and chalcopyrite.

#PERICLASE

Magnesium oxide, MgO. A high-temperature, metamorphic mineral found in dolomitic marbles.

Cochise County: Tombstone district.

Mohave County: Oatman district, about 3 miles northwest of Oatman, as corroded relicts in marble, with brucite.

PERITE

Lead bismuth oxide chloride, $PbBiO_2Cl$. A rare secondary mineral that was known only from Långban, Sweden, until it was found in several localities in the western United States.

Cochise County: About 8 miles northeast of Benson, as bright-yellow, scaly masses in vugs in contorted quartz veins that cut epidote-plagioclase gneiss, associated with minor amounts of chrysocolla, pyromorphite, and vauquelinite.

PEROVSKITE

Calcium titanium oxide, $CaTiO_3$. Widespread as an accessory mineral in alkaline and mafic igneous rocks and as a mineral of deuteric origin.

Pima County: Sierrita Mountains, Gunsight Mountain, as polysynthetically twinned cores of sphene crystals in a pulaskite dike (Bideaux et al., 1960).

Petrified (Fossil) Wood (see QUARTZ)

#PETZITE

Silver gold telluride, Ag_3AuTe_2. Commonly formed in vein deposits associated with other tellurides.

Cochise County: Bisbee, Warren district, Campbell mine, in the massive sulfide orebody (Criddle et al., 1983).

PHARMACOSIDERITE

Iron arsenate hydroxide hydrate, $Fe_3(AsO_4)_2(OH)_3 \cdot 5H_2O$. A widespread but uncommon mineral formed from hydrothermal solutions, as well as from alteration of arsenopyrite and other primary arsenic minerals.

Cochise County: Warren district (Richard Graeme, pers. commun., 1971; UA 10086).

Santa Cruz County: Santa Rita Mountains, Tyndall district, St. Louis mine, Temporal Gulch, on barite, with azurite, formed by the alteration of tennantite (Bideaux et al., 1960).

PHILLIPSITE

Potassium sodium calcium aluminum silicate hydrate, $(K_2,Na_2,Ca)Al_2Si_4O_{12}\cdot 4.5H_2O$. A member of the zeolite group.

Gila County: North side of Roosevelt Lake, in an altered volcanic ash.

Greenlee County: About 5 miles south of Hannagan Meadow, along road cuts on U.S. Highway 666, as limpid, clear fourlings with heulandite in vesicles in basalt.

La Paz County: Harquahala Mountains, as microcrystals (Brian Bond, UA x3311).

Maricopa County: In altered tuff about 2.25 miles south of Horseshoe Dam (Eyde, 1978), and in basalt about 1 mile south of the dam (Shannon, D.M., 1983b).

Mohave County: East of Big Sandy Wash, east half of T. 16 N., R. 13 W., in Pliocene tuff with analcime, chabazite, erionite, and clinoptilolite (Ross, C.S., 1928, 1941).

Navajo County: Wood Chop Mesa, as twinned fiveling crystals (A. Hampson, UA x4523).

Pima County: Ajo district, Well No. 1 of Phelps Dodge Corp. (William Thomas, pers. commun., 1988).

Pinal County: In a railway cut 1 mile north of Mammoth, with chabazite, heulandite, and calcite on celadonite (Thomssen, 1983). Nugget Fracture property, as microcrystals (David Shannon, UA x4346).

Yavapai County: Cottonwood Basin, in an altered tuff bed, with mordenite (Eyde, 1978). James Stewert [*sic*] Co. lithium claims, 9 miles west of Kirkland, in altered tuff (Eyde, 1978). At two localities in the Verde Valley, in altered tuffs (Eyde, 1978).

PHLOGOPITE

Potassium iron magnesium aluminum silicate fluoride hydroxide, $K(Fe,Mg)_3(AlSi_3)O_{10}(F,OH)_2$. A member of the mica group. Commonly formed in metamorphosed limestones and dolomites and in ultramafic igneous rocks.

Gila County: Northwestern region, associated with the uranium ores in the Dripping Spring Quartzite; Little Joe, Lucky Boy, Bix Six, and Last Chance properties (Granger and Raup, 1969). Banner district, Christmas mine, associated with talc and tremolite adjacent to anhydrite-sulfide veinlets in diopside hornfels, forming most of the footwall of the lower Martin orebody; also in skarn rocks and some of the hornfels (David Perry, pers. commun., 1967).

Pima County: Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

Pinal County: Lakeshore mine, in metadolomites, with forsterite and chondrodite.

Santa Cruz County: Washington Camp–Duquesne district, Simplot mine, as a product of the alteration of volcanic rocks (Lehman, 1978).

PHOENICOCHROITE

Lead oxide chromate, $Pb_2O(CrO_4)$. A rare secondary mineral associated with crocoite, vauquelinite, and cerussite in oxidized galena-bearing veins.

Maricopa County: Collateral, Chromate, Blue Jay, and Phoenix claims, east of the present location of Trilby Wash. In 1881, Benjamin Silliman noted the presence of phoenicochroite, vauquelinite, and crocoite, and the probable presence of "jossaite," volborthite, descloizite, and "chileite" from the "Vulture region." South of Wickenburg, at several localities, including the Moon Anchor mine, Potter-Cramer property, and Pack Rat claim, as dark, cochineal-red, cleavable and polycrystalline masses formed by the oxidation of lead-zinc ores and associated with wickenburgite, willemite, mimetite, hemihedrite, and vauquelinite (Williams, S.A., 1968; Williams, S.A., et al., 1970; Williams, S.A., and Anthony, 1970). An analysis by George Roseveare gave the following results (wt %):

PbO	80.88	CrO_3	18.08	TOTAL	98.96

Specific gravity: 7.01

Yavapai County: Near the confluence of Amazon Wash and the Hassayampa River, from several unnamed properties, with mimetite, hemihedrite, and descloizite (William Hunt, pers. commun., 1985).

PHOSGENITE

Lead carbonate chloride, $Pb_2(CO_3)Cl_2$. A rare secondary mineral formed by the oxidation of galena and other lead minerals. Commonly associated with cerussite and anglesite.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, 400-ft level of the Collins vein, as slender, prismatic crystals with diaboleite, paralaurionite, boleite, and cerussite (Palache, 1941b; Fahey et al., 1950; Bideaux, 1980; H 104522).

PHOSPHOSIDERITE

Iron phosphate hydrate, $FePO_4 \cdot 2H_2O$. A dimorph of strengite. A rare mineral found in pegmatites with other phosphate minerals.

Yavapai County: Eureka district, 7U7 Ranch, with bermanite in seams in triplite, associated with leucophosphite and hureaulite (Leavens, 1967).

PHOSPHURANYLITE

Calcium uranyl phosphate hydroxide hydrate, $Ca(UO_2)_4(PO_4)_2(OH)_4 \cdot 7H_2O$. A secondary mineral commonly associated with torbernite and other uranium minerals.

Coconino County: Cameron district, Huskon No. 17 mine, where it replaces part of a fossilized log; Jack Daniels No. 1 mine (Austin, 1964; Finch, 1967).

PICKERINGITE

Magnesium aluminum sulfate hydrate, $MgAl_2(SO_4)_4 \cdot 22H_2O$. Formed by weathering. Found in the gossans of oxidized pyrite-bearing bodies with other hydrated secondary sulfates.

Cochise County: Reported as abundant in an unspecified locality about 30 miles east of Douglas. Warren district, Shattuck shaft (Richard Graeme, pers. commun., 1991).

Gila County: Pueblo Canyon, Ancient deposit, in Mescal Limestone; near the Rock Canyon deposit, as efflorescences identified only as members of the pickeringite-halotrichite group (Granger and Raup, 1969).

PIEMONTITE

Calcium aluminum manganese iron silicate hydroxide, $Ca_2(Al,Mn^{3+},Fe^{3+})_3(SiO_4)_3(OH)$. A member of the epidote group, formed in low-grade metamorphic rocks and by hydrothermal activity. The variety withamite is a low-manganese piemontite.

Cochise County: Pat Hills, north of Pearce, as small rosettes of minute crystals in andesite (Lausen, 1927b).

Maricopa County: Southwestern slope of Squaw Peak in Phoenix, as acicular to bladed crystals up to 3 mm long in quartz muscovite schist (Thorpe, 1980).

Pima County: Tucson Mountains, Tucson Mountain Park, in rhyolite and adjacent sandstone (Guild, 1935). Santa Rita Mountains, near Madera Canyon (Guild, 1935). Northern Comobabi Mountains, with epidote and manganaxinite, as vesicle fillings in andesite flow boulders (Bideaux et al., 1960). About 6 miles from Vail (UA 2256).

Pinal County: Near Casa Grande (UA 2218).

Yavapai County: Northwest of Prescott, in the Government Canyon and Prescott granodiorites, as small veinlets and disseminated grains (Krieger, 1965).

PIGEONITE

Magnesium iron calcium silicate, $(Mg,Fe^{2+},Ca)(Mg,Fe^{2+})Si_2O_6$. A member of the pyroxene group. A rock-forming mineral largely confined to quickly cooled, mafic flow rocks.

Cochise County: Tombstone district, Lucky Boy mine, as dark-green grains with vesuvianite in the contact silicate zone (Butler, B.S., et al., 1938b).

#PINALITE

Lead tungstate chloride, $Pb_3WO_5Cl_2$. An exotic secondary minerals formed by late oxidation processes. The Mammoth–St. Anthony mine is the type and only known locality.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, typically as isolated crystals and as divergent sprays in irregular cavities that are pseudomorphic molds of an uncertain precursor, perhaps calcite; in some places, enclosed by chromian leadhillite (Dunn et al., 1989).

PINTADOITE

Calcium vanadium oxide hydrate, $Ca_2V_2O_7{\cdot}9H_2O$. A secondary mineral formed as water-soluble efflorescences.

Apache County: Lukachukai Mountains, Mesa No. 5 and No. 6 properties, in the Salt Wash Member of the Morrison Formation.

Pisanite (cuproan MELANTERITE)

Pitchblende (see URANINITE)

PLAGIOCLASE

Sodium calcium aluminum silicate. The plagioclase feldspars are a group of silicate minerals that form a substitutional series. The sodic and calcic end members, $NaAlSi_3O_8$ and $CaAl_2Si_2O_8$, are albite and anorthite, respectively. Throughout the series, Na and Ca substitute freely for one another; the electrical charge in the structures is maintained by concomitant substitution between Al and Si. Names for minerals within the series are somewhat arbitrary; in order of increasing calcium content, they are oligoclase, andesine, labradorite, and bytownite. Potassium content is typically lower than 10%.

The plagioclase feldspars are the most abundant minerals in the upper portion of the Earth's crust. They are contained in most igneous rocks and pegmatites and are common in many metamorphic rocks, such as the gneisses and schists of Arizona. After quartz, they are the most abundant minerals in sandstones. Only a few localities of these common rock-formers can be listed below. The reader is referred to R.T. Moore and Wilson (1965) for additional references.

Cochise, Graham, and Pima Counties: As abundant, exceptional, andesine-labradorite phenocrysts up to 2 in. long, in intrusive and flow porphyritic rocks, locally termed *turkey-track porphyry,* at several localities within 75 miles of Tucson, including the following: Twin Buttes quadrangle, in the lower part of the Helmet fanglomerate; Dragoon quadrangle, on the east side of the Steele Hills and at the southern tip of the Winchester Mountains; Galiuro Mountains; Cienega Gap area, in the Pantano Formation; Graham Mountains–Fisher Hills area; Dos Cabezas Mountains; Tucson Mountains, on the southwest side of Sentinel Peak ("A" Mountain); San Xavier Indian Reservation, at Black Mountain; Mineta Ridge area, on the east flank of the Rincon Mountains (Cooper, 1961; Mielke, 1964; Percious, 1968).

Cochise County: Tombstone district, Lucky Cuss mine, as bytownite, with vesuvianite in metamorphosed shaly limestones.

Coconino County: Canyon Diablo area, as high albite in the Canyon Diablo octahedrite meteorite, associated with kosmochlor, roedderite, richterite, and chromite (Olsen and Fuchs, 1968).

Pima County: Sierrita Mountains, west of Helmet Peak, as coarse, perthitic oligoclase in pegmatite dikes.

Pinal County: Galiuro Mountains, as coarse, fresh andesine crystals in the Copper Creek granodiorite; Copper Creek, as coarse, fresh albite crystals in metasomatized granodiorite.

PLANCHEITE

Copper silicate hydroxide hydrate, $Cu_8Si_8O_{22}(OH)_4 \cdot H_2O$. A rare secondary mineral formed in the oxidized portions of copper deposits.

La Paz County: Eagle Eye mine, in quartz (David Shannon, pers. commun., 1990).

Maricopa County: Bighorn district, about 20 miles south of Aguila, as deep-blue fibrous veinlets and masses in quartzite, associated with chrysocolla and "copper pitch" (Montoya, 1967).

Mohave County: Bradshaw Mountains, Whipsaw mine (H 90834).

Pima County: Ajo district, New Cornelia mine, as massive material in the first oxide zone (Thomas, W.J., and Gibbs, 1983).

Pinal County: Galiuro Mountains, Table Mountain mine near Klondyke, as blue crystalline grains and as masses disseminated in compact green conichalcite. Tortolita Mountains, Azurite mine, with "bisbeeite" and shattuckite (Bideaux et al., 1960). Mammoth district, San Manuel mine, as blue tablets in chrysocolla (Thomas, L.A., 1966; UA 5390, 6461); Mammoth–St. Anthony mine, as veinlets and as coatings on chrysocolla (Bideaux, 1980). Silver Reef Mountains, Nugget Fraction mine, with brochantite (David Shannon, pers. commun., 1988).

PLATINUM

Platinum, Pt. A rare mineral mostly restricted to ultramafic rocks, their metamorphic equivalents, and placers derived from them. The localities listed below have not been recently verified.

Maricopa County: Reported in the Santo Domingo placers, along the Gila River, opposite the old Riverside Stage station.

Yavapai County: Reported in black sands near Columbia and Prescott (Guild, 1910).

PLATTNERITE

Lead oxide, PbO_2. Tetragonal. An uncommon mineral formed in lead deposits by extreme oxidation. Associated with cerussite, smithsonite, pyromorphite, wulfenite, and other oxidized minerals.

Cochise County: Warren district, with murdochite and malachite on goethite (Bideaux et al., 1960; Graeme, 1993). Turquoise district, Silver Bill, Defiance, and Tom Scott mines, with wulfenite (Bideaux et al., 1960).

Gila County: Banner district, 79 mine, as tiny needlelike crystals up to 1.5 mm long, associated with aurichalcite, rosasite, and in a few places, murdochite (Keith, 1972).

La Paz County: Silver district, Red Cloud mine, as minute black needles with vanadinite (Edson, 1980).

Pima County: Tucson Mountains, Old Yuma mine, as tiny crystals on vanadinite (Bideaux et al., 1960). Waterman Mountains, Silver Hill mine, with murdochite, malachite, and aurichalcite (Bideaux et al., 1960). Empire Mountains, Total Wreck mine, with hemimorphite on limonite (Bideaux et al., 1960); Lone Mountain mine (UA 6364); Chief mine (Scott Richardson, UA x1510). Gunsight district, Gunsight mine (Scott Richardson, UA x2676).

Santa Cruz County: Tyndall district, Cottonwood Canyon, Glove mine, as crystals on wulfenite. Hilton mine, as microcrystals (Gene Wright, UA x4498).

Pleonaste (ferroan SPINEL)

PLUMBOGUMMITE

Lead aluminum phosphate hydroxide hydrate, $PbAl_3(PO_4)_2(OH)_5{\cdot}H_2O$. A secondary mineral formed by oxidation of lead ores.

Gila County: Coronado Fault area, Copper Cities deposit, with chalcopyrite in quartz (H 106829; specimen collected by A.R. Still).

PLUMBOJAROSITE

Lead iron sulfate hydroxide, $PbFe_6(SO_4)_4(OH)_6$. A member of the alunite group. Less common than jarosite, to which it is similar in origin and mode of occurrence.

Cochise County: Tombstone district, abundant in the brown oxide ore of the Holderness "roll"; Empire mine, as material that assayed 58.92 oz in silver; Toughnut mine, as material that assayed up to 200 oz in silver (Butler, B.S., et al., 1938b). Warren district, Southwest and Shattuck mines, abundant in lead ore adjacent to quartz breccia (Graeme, 1993).

Gila County: Banner district, 79 mine, as ocherous brown, massive material in the surface and near-surface workings (Keith, 1972).

Graham County: Aravaipa district, Dogwater mine (Simons, F.S., 1964).

Mohave County: Cerbat Mountains, Tennessee-Schuylkill mine. Wallapai district, as a secondary mineral (Thomas, B.E., 1949).

Pima County: Empire Mountains, Hilton mines, as earthy masses. Pima district, Twin Buttes mine (Stanley B. Keith, pers. commun., 1972).

Yavapai County: Humbug mine, Castle Hot Springs area.

PLUMBONACRITE

Lead carbonate hydroxide oxide, $Pb_{10}(CO_3)_6(OH)_6O$(?). An inadequately characterized mineral, long confused with hydrocerussite and probably formed under similar conditions during oxidation of lead-rich sulfide ores.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, 1,000-ft level of the Collins vein, on a specimen collected by S.C. Creasey (S 71), as small, pearly-white scales, associated with anglesite and linarite on galena; a = 9.072, c = 24.55 Å.

#PLUMBOTSUMITE

Lead silicate hydroxide, $Pb_5Si_4O_8(OH)_{10}$. Formed on alamosite and incrusted, in turn, by melanotekite at the type locality, Tsumeb, Namibia.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as massive white material intergrown with wulfenite (Pete J. Dunn, pers. commun., 1988).

POLLUCITE

Cesium sodium aluminum silicate hydrate, $(Cs,Na)_2Al_2Si_4O_{12}\cdot H_2O$. A member of the zeolite group. A rare mineral formed in granite pegmatites.

Maricopa County: White Picacho district, Independence mine, a reported but unconfirmed locality.

POLYBASITE

Silver copper antimony sulfide, $(Ag,Cu)_{16}Sb_2S_{11}$. Found in silver veins formed at low to moderate temperatures. Associated with other silver sulfosalts.

Mohave County: Cerbat Mountains, common in the silver ores of several mining districts (Bastin, 1925; Thomas, B.E., 1949).

Pinal County: Pioneer district, Silver King mine, as fine specimens (Guild, 1910).

Santa Cruz County: Patagonia Mountains, Tyndall district, Ivanhoe mine, near Squaw Gulch, with stromeyerite, proustite, and silver (Engineering Mining Journal, 1912).

Yavapai County: Bradshaw Mountains, Hassayampa district, Davis mine, with proustite (Lindgren, 1926). Tip Top mine, with pyrargyrite and tetrahedrite in quartz veins (Kortemeir, C.P., 1984).

Yuma County: Kofa Mountains, King of Arizona district, King of Arizona mine (Hankins, 1984).

POLYCRASE

Yttrium calcium cerium uranium thorium titanium niobium tantalum oxide, $(Y,Ca,Ce,U,Th)(Ti,Nb,Ta)_2O_6$. A member of the euxenite-polycrase series. A rare mineral formed in granite pegmatites.

Maricopa County: South of Buckeye, in a pegmatite dike with kasolite (Robert O'Haire, pers. commun., 1972).

POLYHALITE

Potassium calcium magnesium sulfate hydrate, $K_2Ca_2Mg(SO_4)_4{\cdot}2H_2O$. Primarily formed as a precipitate from oceanic waters. Widely distributed and commonly associated with halite and anhydrite.

Apache and Navajo Counties: East-central Arizona, encountered in drill holes that delineated a northeast-trending potash zone underlying an area of about 300 square miles, in Permian evaporites (Peirce, H.W., 1969); the log of a hole drilled in sec. 24, T. 18 N., R. 24 E., also listed carnallite, sylvite, halite, anhydrite, and gypsum (H. Wesley Peirce, pers. commun., 1972).

#POLYLITHIONITE

Potassium lithium aluminum silicate fluoride hydroxide, $KLi_2AlSi_4O_{10}(F,OH)_2$. Found in nepheline syenites associated with microcline, natrolite, and other minerals.

Graham County: Near Landsman Camp, in axinite- and babingtonite-rich metamorphosed limestone.

POSNJAKITE

Copper sulfate hydroxide hydrate, $Cu_4(SO_4)(OH)_6{\cdot}H_2O$. A rare secondary mineral formed under acidic oxidizing conditions by the alteration of copper sulfides.

La Paz County: A specimen in the Natural History Museum in London (NHM 1972,201) is labeled as coming from Bouse (Peter G. Embrey, pers. commun., 1973).

Pima County: Ajo district, New Cornelia mine, with gypsum, associated with partially altered pyrite (Hidemichi Hori, pers. commun., 1984).

Yavapai County: Prospect in the Turret Peak quadrangle, sec. 30, T. 13 N., R. 5 E., as a powder-blue film on chalcopyrite.

POWELLITE

Calcium molybdate, $CaMoO_4$. Commonly contains tungsten. An uncommon secondary mineral found in tungsten ores.

Cochise County: Cochise district near Johnson, as pseudomorphs after molybdenite (Cooper and Silver, 1964). Reported in the Warren district; one verified locality is the Bisbee Queen shaft east of Warren.

Gila County: Globe-Miami district, Inspiration mine, as crusts of tiny crystals in a seam adjacent to veins containing molybdenite and lindgrenite; thought to be a product of late hydrothermal solutions, which attacked molybdenite (Fredrick E. Pough, pers. commun.).

Maricopa County: Near Morristown, on the upper Santo Domingo Wash, with scheelite. White Picacho district, as a rare mineral in pegmatites (Jahns, 1952). Vulture Mountains, Flying Saucer group, with scheelite as disseminations in granitic rocks (Dale, 1959).

Mohave County: Reported in the Cerbat Mountains.

Pima County: Helvetia district, disseminated with scheelite in the contact zone near the Black Horse shaft (Dale et al., 1960). Pima district, Twin Buttes mine (Stanley B. Keith, pers. commun., 1973; Kuck, 1978); Senator Morgan mine, with scheelite in quartz veins (Dale et al., 1960). Eastern flank of the Santa Catalina Mountains, north of Redington Pass, at the Korn Kob mine, as reaction rims around molybdenite (Wilson, J.R., 1977).

Pinal County: Near Antelope Peak, Gold Circle district, Upshaw Tungsten mines group, with wolframite and scheelite in quartz veins (Dale, 1959).

Yavapai County: White Picacho district, as a rare mineral in pegmatites (Jahns, 1952).

PREHNITE

Calcium aluminum silicate hydroxide, $Ca_2Al_2Si_3O_{10}(OH)_2$. Primarily formed in cavities and in veins in mafic lavas, where it is commonly associated with zeolite minerals. Also formed in veins in granitic rocks and in contact-metamorphosed limestones.

Cochise County: One mile northwest of Portal, in vesicles in basalt with celestite, pyrite, and pumpellyite. Central Dragoon Mountains, Middlemarch Canyon, Middle Pass district, Middlemarch mine, as sparse veinlets in garnet-wollastonite schist (Sousa, 1980).

Gila County: Coolidge Dam, as large white crystalline masses (Les Presmyk, pers. commun., 1988).

Pima County: Santa Rita Mountains, Mt. Fagan, as crystalline masses with copper, epidote, and quartz in andesite (Bideaux et al., 1960).

Santa Cruz County: Two miles south of the Cerro Colorado mine, on the road to Arivaca (Robert O'Haire, pers. commun., 1972).

PROSOPITE

Calcium aluminum fluoride hydroxide, $CaAl_2(F,OH)_8$. An uncommon mineral found in greisen in tin veins, associated with other fluorine-bearing minerals; also in pegmatites.

Graham County: Grand Reef mine, as light-green masses (George Godas, pers. commun., 1988).

La Paz County: At a copper prospect about 10 miles north of Bouse, in hematite veins in andesite with chrysocolla, malachite, and tenorite, as lovely, complex, limpid-sea-green crystals up to 6 mm long in voids in hematite gangue.

PROUSTITE

Silver arsenic sulfide, Ag_3AsS_3. A late-stage mineral formed in hydrothermal veins at low temperatures with other silver sulfosalts.

Cochise County: Pearce Hills, Commonwealth mine, associated with tetrahedrite and silver halides.

Maricopa County: Wickenburg Mountains, Monte Cristo mine, with silver and acanthite (Bastin, 1922).

Mohave County: Cerbat Mountains, Chloride district, Minnesota-Connor, Distaff, and Merrimac mines (Bastin, 1925). Mineral Park district, Gold Star mine; Cerbat district, Paymaster mine (Thomas, B.E., 1949). Cupel mine, Stockton Hill area, in relatively large quantities (Schrader, 1907).

Pinal County: Pioneer district, Belmont mine, as minute blebs in galena.

Santa Cruz County: Nogales district, Mount Benedict area, with gold in quartz monzonite (Schrader, 1917). Tyndall district, Ivanhoe mine, with stromeyerite, polybasite, and silver (Engineering Mining Journal, 1912).

Yavapai County: Bradshaw Mountains, Hassayampa district, Davis and Catoctin mines, with polybasite. Turkey Creek district, near the Thunderbolt mine, with silver and chlorargyrite in a vein. Tip Top district, Tip Top mine, with silver and chlorargyrite.

PSEUDOBOLEITE

Lead copper chloride hydroxide, $Pb_{31}Cu_{24}Cl_{62}(OH)_{48}$. A rare secondary mineral formed in small amounts in oxidized lead-copper deposits.

Pima County: Banner mine, Daisy shaft, with connellite, gerhardtite, and atacamite in cuprite (Williams, S.A., 1961).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as overgrowths on boleite, associated with other secondary lead minerals (Palache, 1941b; Bideaux, 1980).

PSEUDOBROOKITE

Iron titanium oxide, Fe_2TiO_5. An uncommon mineral formed in volcanic rocks by pneumatolytic or fumarolic action.

Pima County: Near Ajo, Well No. 1 of Phelps Dodge Corp. (William Thomas, pers. commun., 1988).

Pinal County: Near Saddle Mountain, Winkelman area, as a few needlelike crystals, with topaz, spessartine, and bixbyite, in rhyolite (White, 1992).

#PSEUDOGRANDREEFITE

Lead sulfate fluoride, $Pb_6SO_4F_{10}$. Associated with galena and fluorite, from which it is thought to have formed by interaction with supergene fluids. The Grand Reef mine is the type, and at the time of this writing, only known locality.

Graham County: Aravaipa district, Grand Reef mine, as colorless, tabular crystals and as a subparallel crystal aggregate, in a quartz-lined vug, associated with galena, fluorite, and anglesite (Kampf et al., 1989).

PSEUDOMALACHITE

Copper phosphate hydroxide hydrate, $Cu_5(PO_4)_2(OH)_4{\cdot}H_2O$. A rare secondary mineral found in the oxidized zone of copper deposits with other oxidized copper minerals.

Gila County: Globe-Miami district, Castle Dome mine, as small, dark, emerald-green crystals.

Graham County: Safford area, Lone Star district, as prismatic crystals, many of which are almost hairlike, in metasomatized volcanic rocks, associated with malachite, brochantite, antlerite, carbonate-apatite, chrysocolla, jarosite, lepidocrocite, and sulfide minerals (Hutton, 1959b).

La Paz County: Harquahala Mountains, Harquahala mine, as clusters of sharp, dark-green crystals in vugs, partially coated by chrysocolla(?) (John S. White, Jr., pers. commun., 1972). Cunningham Pass near Wenden, at the Critic mine.

Pima County: East end of the South Comobabi Mountains, as lovely green crystals with slightly curved faces, up to 3 mm long, and as films on the walls of fractures in severely deformed quartz monzonite, associated with libethenite. Southern side of Saginaw Hill, about 7 miles southwest of Tucson, associated with other oxidized minerals, including cornetite, brochantite, malachite, libethenite, atacamite, and chrysocolla, in fractures in chert (Khin, 1970). Silver Bell mine, Oxide pit, as microcrystals (Kenneth Bladh, UA, x3720).

Pinal County: Galiuro Mountains, Bunker Hill district, Copper Creek, with botryoidal malachite on quartz crystals, some of which are Japan twins (William and Mildred Schupp, pers. commun.). Silver Bell mine (Joseph Urban, pers. commun.). Sacaton Hill, found in drill core.

Psilomelane (including ROMANECHITE)

As used here, psilomelane is a general term for massive, undifferentiated, hard manganese oxides whose compositions approximate to barium manganese oxide hydroxide (Fleischer and Mandarino, 1991). Romanechite is a distinct mineral species having the composition $(Ba,H_2O)(Mn^{4+},Mn^{3+})_5O_{10}$. It is highly probable that the species is contained among the manganese oxides at many of the localities listed below. Of secondary origin, formed under surface conditions from the alteration of manganous carbonates or silicates and associated with materials of similar origin such as pyrolusite, goethite, limonite, and wad (see also these mineral descriptions).

Cochise County: Tombstone district, as the most abundant manganese oxide mined in the ore deposits (Rasor, 1939; Romslo and Ravitz, 1947; Hewett and Fleischer, 1960). Warren district, Higgins mine, with pyrolusite and braunite (Palache and Shannon, 1920; Taber and Schaller, 1930).

Coconino County: Aubrey Cliffs, with braunite at the Adams-Woodie prospect and with other manganese oxides cementing rock fragments in veins that cut and partly replace Kaibab Limestone; associated with braunite, pyrolusite, and cryptomelane (Potter and Havens, 1949; Hewett et al., 1963). Long Valley district, as numerous, small, irregular, disconnected, lenticular masses in Kaibab Limestone, with pyrolusite (secs. 19, 20, 29, and 30, T. 14 N., R. 10 E.); Denison, Shoup, Blue Ridge, and Lost Apache claims (Farnham and Stewart, 1958). Heber district, in a small deposit in parts of secs. 17, 18, 19, and 20, T. 11 N., R. 15 E.; Johnson and Hayden deposit, NW1/4 sec. 2, T. 26 N., R. 7 W., in a steeply dipping fracture or brecciated zone in Kaibab Limestone (Farnham and Stewart, 1958).

Gila County: About 6 miles north of Roosevelt Lake, in sec. 29, T. 5 N., R. 13 E., in Apache group rocks (Hewett and Fleischer, 1960; Hewett et al., 1963). Globe-Miami district, where, with manganite and pyrolusite, it forms the bulk of the gangue in the manganese-zinc-lead-silver deposits (Peterson, N.P., 1962). Banner district, 79 mine, as a common supergene mineral in replacement deposits in limestone and rhyolite porphyry (Kiersch, 1949). Apache and Accord manganese deposits, Medicine Butte area, with wad, as fracture fillings and cement in Cenozoic conglomerate (Moore, R.T., 1968). Sierra Ancha Mountains, Sierra Ancha district, Armer Wash (Sunset) mine, as fine-grained mammillary material in breccia zones in quartzite of the Apache group; contains 0.02% thallium, approximately 12% BaO, and 0.2% K_2O (Crittenden et al., 1962).

Greenlee County: Ash Peak district, Fourth of July mine, as mammillary layers on fluorite in veins in andesite porphyry (Hewett and Fleischer, 1960; Hewett et al., 1963; Hewett, 1964). Pyrolusite claims, 12 miles southeast of Morenci, with pyrolusite and manganite (Potter et al., 1946).

La Paz County: Artillery district, Kaiserdoom claims, in sec. 22, T. 11 N., R. 11 W., in bedded manganese oxides underlying a bed of volcanic ash in the Artillery Formation, with associated soft manganite (Hewett et al., 1963); Spring mine, 40 miles west of Congress Junction, as irregular nodular fragments cemented by clay (Long et al., 1948); Doyle-Smith claims, 15 miles from Artillery Peak (Ipsen and Gibbs, 1952).

Maricopa County: Black Vulture mine, 32 miles south of Wickenburg, with pyrolusite as replacements in limestone (Long et al., 1948). Bighorn district, Black Queen and Black Nugget mines, with pyrolusite and manganite in small fissure veins in volcanic flows and breccia (Sandell and Holmes, 1948; Farnham and Stewart, 1958).

Mohave County: Artillery Mountains, Black Jack, Price, and Priceless veins and Maggie Canyon bedded deposit, in numerous veinlets and fractures in Tertiary volcanic rocks, associated with cryptomelane, hollandite, coronadite, pyrolusite, ramsdellite, and lithiophorite (Hewett and Fleischer, 1960; Mouat, 1962). Black Warrior mine, 6 miles northeast of Alamo Crossing, with pyrolusite (Long et al., 1948). Arizona Manganese claims, 30 miles north of Parker Dam (Havens et al., 1947).

Navajo County: Sonsela Buttes area, filling pore spaces between pebbles or fragments in sandstones and conglomerates, with pyrolusite (Mayo, 1955b).

Pima County: Reported near Tucson, but the exact locality is unknown (Palache et al., 1944). An analysis by C. Milton (Wells, R.C., 1937) on material from the Tucson Mountains(?) gave the following results (wt %):

Na_2O	0.42	P_2O_5	0.05	MnO	6.70
SiO_2	0.90	K_2O	0.11	BaO	14.40
Al_2O_3	0.55	$H_2O(-)$	0.49	CuO	0.25
Fe_2O_3	3.27	$H_2O(+)$	3.78	PbO	0.32
MgO	tr.	TiO_2	tr.	Insol.	8.35
CaO	0.05	MnO_2	59.65	TOTAL	99.29

Specific gravity: 4.21

Northern end of the Coyote Mountains, as massive hard coatings up to 3 in. thick on porphyritic rocks (Blake, W.P., 1910a).

Pinal County: Cochise group of claims, as fine-grained mammillary material, in veins and breccia zones in Gila(?) Conglomerate; contains less than 0.01% thallium and about 12% BaO (Crittenden et al., 1962). Copper Creek district, Blue Bird mine (Kuhn, 1951). Mammoth district, in a vein with barite and calcite on the west side of Tucson Wash (Schwartz, 1953). Riverside district, Almino and Cochise mines, cementing fragments in breccia zones (Hewett and Fleischer, 1960; Hewett et al., 1963). Geronimo claims, 8 miles west of Winkelman, with manganite cementing brecciated zones of conglomerate (Dean et al., 1952); Benningfield property, 11.5 miles south of Winkelman, with pyrolusite, as nodules and lenses replacing limestone in capping over an igneous dike (Dean et al., 1952); North Star group and Orson Branch claim near Winkelman (Dean et al., 1952). Pioneer district, Domeroy property, 4 miles north of Superior, with pyrolusite and hetaerolite (Dean et al., 1952).

Santa Cruz County: Tyndall district, Cottonwood Wash, Glove mine (Olson, H.J., 1966). Patagonia district, Mowry mine, in replacement deposits in limestone, with pyrolusite and hematite (Schrader, 1917).

Yavapai County: Castle Creek district, Black Rock deposit, with pyrolusite in Precambrian granite gneiss (Fleischer and Richmond, 1943; Hewett and Fleischer, 1960; Hewett et al., 1963). Burmeister mine, near Sycamore Creek above its junction with the Agua Fria River, with cryptomelane and other manganese oxides interlayered with volcanic ash, clastic sediments, and a basalt flow (Hewett and Fleischer, 1960; Hewett et al., 1963). Big Bug district, 13 miles from Mayer, at the confluence of Big Bug and Sycamore Creeks, as nodules and irregular veins, with minor amounts of pyrolusite (Engineering Mining Journal, 1918).

Yuma County: Sheep Tanks district, Sheep Tank mine, southwest of Salome (Romslo and Ravitz, 1947). Kofa district, North Star mine, in the North Star vein, with bixbyite, and in the No. 2 vein, with bixbyite, todorokite, groutite, and manganite (Hankins, 1984).

PUMPELLYITE (a group name)

Calcium aluminum iron magnesium manganese chromium silicate hydroxide hydrate, $Ca_2XY_2(SiO_4)(Si_2O_7)(OH)_2 \cdot 2H_2O$, where X = Al, Fe^{2+}, Fe^{3+}, Mg, Mn^{2+}; Y = Al, Fe^{3+}, Cr^{3+}, Mn^{3+}. Associated with prehnite and zeolites in vesicles in volcanic rocks. (None of the Arizona localities has been assigned a specific mineral species, of which six are currently recognized.)

Cochise County: About 1 mile northwest of Portal, in vesicles in basalt with prehnite, celestite, and adularia; as amygdule fillings up to 1 in. across, in radiating fibrous masses. Reported in the Warren district.

Gila County: Aztec Creek, Workman Creek Falls, as amygdule fillings in a 34-m-thick basalt flow, with quartz, chlorite, pyrite, and chalcopyrite (Heidecker, 1978).

Pima County: Santa Rita Mountains, Mt. Fagan, with thomsonite, pennine, prehnite, epidote, and copper in andesite (Bideaux et al., 1960). Chicago mine near Sells, with epidote and delessite as amygdules in altered andesite.

PURPURITE

Manganese iron phosphate, $(Mn^{3+},Fe^{3+})PO_4$. A rare mineral formed in granite pegmatites as an alteration product of triphylite and lithiophilite; also associated with sicklerite.

Yavapai County: White Picacho district, as tiny needles and plates forming crusts and cavity fillings, associated with strengite (Jahns, 1952).

PYRARGYRITE

Silver antimony sulfide, Ag_3SbS_3. An important ore of silver formed in veins and commonly associated with galena, tetrahedrite, pyrite, and other silver-bearing sulfosalt minerals as a product of late-stage mineralization.

Mohave County: Cerbat Mountains, mined in the Chloride, Mineral Park, Cerbat, and Stockton Hill districts (Thomas, B.E., 1949).

Pinal County: Vekol mine, near Casa Grande, as massive material in quartz (AM 24969). Galiuro Mountains, Saddle Mountain district, Little Treasure mine.

Santa Cruz County: Patagonia Mountains, Harshaw district, Alta mine, with embolite and fluorite. Palmetto district, Sonoita mine (Schrader, 1917).

Yavapai County: Bradshaw Mountains, Hassayampa district, Tillie Starbuck and Davis mines; Black Canyon district, Thunderbolt mine. Tip Top district, Tip Top mine (Kortemeir, C.P., 1984). Reported in the Tiger district (Lindgren, 1926).

PYRITE

Iron sulfide, FeS_2. The most common of all sulfide minerals, pyrite forms under a wide range of conditions. In Arizona it is typically an abundant associate of most metallic mineral deposits. The localities noted here are only representative of a very widespread mineral.

Apache and Navajo Counties: Monument Valley, in the uranium-vanadium deposits, in vein fillings and as cement in sandstone (Joralemon, 1952; Rosenzweig et al., 1954; Coleman and Delavaux, 1957; Jensen, 1958).

Cochise County: Warren district, Copper Queen and other mines, in large, massive bodies (Ransome, 1904; Mitchell, 1920; Trischka et al., 1929; Schwartz and Park, 1932; Bain, 1952; Bryant, 1968).

Coconino County: South Rim of the Grand Canyon, Orphan mine, associated with copper-uranium-lead ores in Coconino Sandstone (Isachsen et al., 1955). Cameron area, commonly associated with uranium minerals in sedimentary rocks;

Alyce Tolino mine, where it is cobalt bearing (Rosenzweig et al., 1954; Hamilton, P., and Kerr, 1959).

Gila County: Banner district, 79 mine, as a massive body containing some highly modified crystals (Keith, 1972); Christmas mine (Ross, C.P., 1925b; Peterson, N.P., and Swanson, 1956; Perry, D.V., 1969). Globe-Miami district, Copper Cities deposit (Peterson, N.P., 1954). Castle Dome mine (Peterson, N.P., 1947). Miami and Inspiration mines (Schwartz, 1947). Old Dominion mine (Ransome, 1903a).

Graham County: Lone Star district, as the primary sulfide mineral in the Safford porphyry copper deposit (Robinson, R.F., and Cook, 1966).

Greenlee County: Clifton-Morenci district, Hudson and Fairplay veins, as large crystals (Lindgren, 1905; Reber, 1916; Schwartz, 1947, 1958; Creasey, 1959).

La Paz County: Dome Rock Mountains, Don Welsh prospect, as crystals more than 2.5 cm in diameter.

Mohave County: Cerbat Mountains, Wallapai district, widespread in a belt of sulfide-bearing fissure-vein deposits (Thomas, B.E., 1949; Field, 1966). Ithaca Peak, with chalcopyrite, galena, sphalerite, and molybdenite in quartz monzonite porphyry (Eidel, 1966).

Pima County: Tucson Mountains, Arizona-Tucson mine, as crystals up to 0.25 in. in diameter, with remarkably abundant crystal faces (Ayres, 1924). Ajo district, New Cornelia mine, particularly abundant in dioritic border facies; also in the Concentrator Volcanics (Gilluly, 1937), as a few fine crystal groups. Pima district, Twin Buttes mine, with other primary sulfide minerals (Stanley B. Keith, pers. commun., 1973). Santa Rita Mountains, in most of the mines and prospects (Schrader and Hill, 1915). Sierrita Mountains, abundant in and near the mining districts. Silver Bell district (Kerr, 1951).

Pinal County: Pioneer district, Belmont mine, as large crystals; the Magma mine is probably Arizona's premier pyrite locality, having yielded thousands of fine, complex, single crystals and groups (Short et al., 1943; Mills and Eyrich, 1966; Barnes and Hay, 1983). Ray district, Iron Cap mine, as perfect pyritohedral crystals up to 1 in. in diameter, in soft clay gangue (Ransome, 1919; Schwartz, 1947; Clarke, O.M., 1953; Rose, 1970). Galiuro Mountains, Childs-Aldwinkle mine, as excellent crystals (Kuhn, 1941). Mammoth district, San Manuel mine, as the most abundant sulfide mineral (Schwartz, 1947, 1949, 1958; Lovering, 1948; Creasey, 1959); Kalamazoo orebody (Lowell, J.D., 1968).

Santa Cruz County: Patagonia Mountains, Three R mine, as striated and twinned crystals up to 8 in. across and as large crystal aggregates; Santo Niño mine, as large crystal groups near the molybdenite bodies (Schrader and Hill, 1915; Schrader, 1917; Frondel, J.W., and Wickman, 1970). Duquesne, as a very large crystal (UA 5693). Patagonia district, Four Metals mine, as striated crystals 2 cm on an edge (James Bleess, pers. commun., 1972).

Yavapai County: United Verde mine, as one of the largest pyritic orebodies in the world (Fearing, 1926; Lausen, 1928; Schwartz, 1938; Anderson, C.A., and

Creasey, 1958; Moxham et al., 1965); other properties in the Jerome-Bradshaw Mountains area (Lindgren, 1926). Box Canyon district, Mistake mine, as radiating acicular crystals and replacing ramsdellite (Wilkinson et al., 1983).

PYROLUSITE

Manganese oxide, MnO_2. A member of the rutile structural group. A common manganese mineral formed under oxidizing conditions. Typically associated with other manganese minerals such as manganite (from which it forms by alteration), hausmannite, braunite, and psilomelane, as well as limonite, hematite, and goethite. Widely distributed in small amounts throughout Arizona.

Cochise County: Tombstone district, in commercial quantities at the Oregon-Prompter, Lucky Cuss, Telephone, and Bunker Hill mines (Butler, B.S., et al., 1938b; Rasor, 1939; Romslo and Ravitz, 1947; Havens et al., 1954; Hewett and Fleischer, 1960). Warren district, Higgins mine, with psilomelane and braunite (Palache and Shannon, 1920). Texas Canyon area, as acicular crystals in vugs in the quartz-hübnerite veins that cut the Texas Canyon Quartz Monzonite (Cooper and Silver, 1964). Near Bowie, as microcrystals of the variety polianite (William Kurtz, UA x4139).

Gila County: Globe-Miami district, with manganite and psilomelane, as the bulk of the gangue in the manganese-zinc-lead-silver deposits (Peterson, N.P., 1962). Globe district, as the variety polianite (UA 7756). East of Ripsey Wash near Kelvin, in sec. 14, T. 3 N., R. 13 E.; as fibrous material, pseudomorphous after manganite (Robert O'Haire, pers. commun., 1972). Banner district, 79 mine, as numerous dendritic forms coating fractures in near-surface limestones (Keith, 1972).

Greenlee County: Clifton-Morenci district, in black, sooty masses with iron oxides in metamorphosed limestones (Lindgren, 1905; Guild, 1910).

La Paz County: Dobbins claims, 6 miles east of Bouse; at a locality 2.5 miles west of Bouse. Reported in the Silver district (Wilson, E.D., 1933). Trigo Mountains, as microcrystals (Robert Mudra, UA x185).

Maricopa County: Bighorn Mountains, Aguila district, with manganite or wad. White Picacho district, as crusts on lithium phosphate minerals in pegmatites (Jahns, 1952). Black Vulture mine, 32 miles south of Wickenburg, as replacements in limestone (Long et al., 1948).

Mohave County: Rawhide Mountains, Artillery Peak, in large deposits with wad (Head, 1941; Lasky and Webber, 1944, 1949). Reported in veins 4 miles south of Hoover Dam. Little Chemehuevi Valley, Arizona Manganese claims, in veins and shear zones with wad (Havens et al., 1947). Near the Colorado River, 18 miles north of Parker Dam. Artillery Mountains, Black Jack, Price, and Priceless veins and Plancha bedded deposit, associated with a variety of oxidized manganese minerals (Mouat, 1962). Black Warrior mine, 6 miles northeast of Alamo Crossing, with psilomelane (Long et al., 1948).

Navajo County: Sonsela Buttes area, filling voids between pebbles or rock fragments in sandstone and conglomerate, with pyrolusite, and as nodules (Mayo, 1955b).

Pima County: Tucson Mountains, in quartz (UA 4486). Stovall mine, near Alamo Crossing, as good-quality crystals (H 108492). Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

Pinal County: Pioneer district, in the outcrops of the Magma vein. Near Winkelman, at several claims (Dean et al., 1952). Black Hills, as microcrystals (William Kurtz, UA x4175).

Santa Cruz County: Patagonia Mountains, Mowry mine, with wad. Hardshell, North Mowry, Hermosa, and Black Eagle mines (Schrader and Hill, 1915; Schrader, 1917). Tyndall district, Cottonwood Canyon, Glove mine (Olson, H.J., 1966). Harshaw district, Salvador mine (Romslo and Ravitz, 1947).

Yavapai County: Northern Aguila district. In ores of the Bradshaw Mountains. Castle Creek, 23 miles northeast of Morristown (Hewett and Fleischer, 1960; Hewett et al., 1963). Burmeister property, 12 miles southeast of Mayer on the Agua Fria River, with manganite and minor amounts of psilomelane (Long et al., 1948). White Picacho district, as thick crusts coating lithium phosphate minerals in pegmatites (Jahns, 1952). Castle Creek district, north of Castle Hot Springs, in Precambrian granite gneiss, with psilomelane (Hewett and Fleischer, 1960; Hewett et al., 1963). Big Bug district, 13 miles from Mayer, in minor amounts with psilomelane in nodules and stratified veins (Engineering Mining Journal, 1918).

Yuma County: Kofa district, King of Arizona mine, with todorokite, groutite, chalcophanite, and aurorite (Hankins, 1984).

PYROMORPHITE

Lead phosphate chloride, $Pb_5(PO_4)_3Cl$. A member of the apatite group. An uncommon mineral formed in the oxidized portion of lead deposits. Typically associated with cerussite, limonite, smithsonite, anglesite, malachite, wulfenite, vanadinite, and other oxidized minerals.

Cochise County: Tombstone district, as small crystals associated with wulfenite (Butler, B.S., et al., 1938b). Warren district (Graeme, 1993). About 8 miles northeast of Benson, in quartz veins that cut gneiss, in minor amounts with chrysocolla, vauquelinite, and perite (Phelps Dodge Corp., pers. commun., 1972). Huachuca Mountains (UA 6254).

Gila County: Banner district, 79 mine, sparingly as clear-yellow, needlelike crystals on chrysocolla; crystal forms include $\{01\bar{1}\bar{1}\}$, $\{20\bar{2}1\}$, $\{40\bar{4}1\}$, $\{10\bar{1}1\}$, and $\{0001\}$.

Graham County: Golondrina property, in pyroclastic rocks, associated with chalcopyrite, chalcocite, and malachite; contains as much as 0.6% uranium (Granger and Raup, 1962).

La Paz County: Iber-Plomosa mine near Bouse.

Maricopa County: White Picacho district, in pegmatites (Jahns, 1952). Rowley mine, as small green crystals, up to 6 mm long.

Pima County: Cerro Colorado Mountains, Cerro Colorado mine. South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Waterman Mountains, Indiana-Arizona mine, as small, green to brown crystals.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as olive-green crystals on mottramite, with vanadinite (Peterson, N.P., 1938a,b). Slate Mountains, Jackrabbit mine, coating fault breccia and in vugs in silicified limestone (Hammer, 1961).

Santa Cruz County: Harshaw district, Trench mine, as incrustations; Hardshell mine, as good, yellow-green crystals (MM L589). Patagonia district, Javalina prospect (Schrader and Hill, 1915; Schrader, 1917). Pajarito district, Sunset mine group, as microcrystals (Francis Sousa, UA x4611).

Yavapai County: Bradshaw Mountains, at a prospect on the Slate Creek property of Kalium Chemicals Ltd., as tiny, transparent, light-green, barrel-shaped prismatic crystals, associated with plentiful mottramite and with botryoidal crusts of mimetite (William C. Berridge, pers. commun., 1973); Fat Jack mine, as green crusts.

Yuma County: Castle Dome Mountains, Castle Dome district, in old mine workings, associated with wulfenite and grades into vanadinite (Blake, W.P., 1881b; Wilson, E.D., 1933).

PYROPE

Magnesium aluminum silicate, $Mg_3Al_2(SiO_4)_3$. A member of the garnet group. Typically formed in ultramafic rocks; found in blocks in mafic volcanic agglomerates.

Apache County: Navajo Indian Reservation, Garnet Ridge, as gem-quality pebbles (Williams, H., 1936). Buell Park, near Fort Defiance, in alluvium and agglomerate and as inclusions in igneous rock (Gregory, 1917; Gavasci and Kerr, 1968; Switzer, 1977).

PYROPHYLLITE

Aluminum silicate hydroxide, $Al_2Si_4O_{10}(OH)_2$. An uncommon metamorphic mineral typically formed by hydrothermal alteration of feldspar. Commonly associated with quartz and kyanite. Closely resembles talc.

Cochise County: Warren district, at Warren, with barite (UA 5978); common in the Sacramento stock, Lavender pit.

Gila County: South of Christopher Mountain, in Gordon Canyon, in a weathered zone in rhyolite beneath Mazatzal Quartzite (Donald L. Livingston, pers. commun., 1972).

La Paz County: Reported near Bouse. Big Bertha Extension mine, as well-crystallized, pale-green tufts and sprays, on quartz and hematite (H 124764). Three miles southwest of Quartzsite, with dumortierite, andalusite, and kyanite (Wilson, E.D., 1929).

Mohave County: Williams River near Alamo, Cactus Queen mine. Reported in large quantities southeast of Yucca.

Pima County: At a locality 50 miles southwest of Ajo (UA 8865).

Yuma County: Near Alamo Springs, 27 miles southeast of Quartzsite. Dome Rock Mountains, Sugarloaf Peak area, where 200 to 250 ft of pyrophyllite were encountered in a drill hole (James D. Loghry, pers. commun., 1989).

PYROXENE

A group name for minerals with the general composition, calcium iron magnesium aluminum silicate, $(Ca,Fe,Mg,Al)SiO_3$. Includes a variety of species that differ in chemistry and, to some extent, in structural features. Individual species, where recognized, are listed individually. Common in igneous rocks, some of which consist almost entirely of pyroxene. Abundant in dark-colored volcanic rocks. Some species are typically formed in the contact metamorphic environment.

PYRRHOTITE

Iron sulfide, $Fe_{1-x}S$. The hexagonal, iron-deficient modification of iron sulfide. Formed as a high-temperature, early-stage mineral in veins and as a primary mineral in some igneous rocks, pegmatites, and contact metamorphic deposits.

Cochise County: Cochise district, Johnson Camp, sparse in a drill core taken near the Mammoth mine (Cooper and Silver, 1964).

Gila County: Christmas mine, common in the pyrrhotite-chalcopyrite zone of the lower Martin orebody (Knoerr and Eigo, 1963; Perry, D.V., 1969; McCurry, 1971). Northwestern region, Workman Creek area, and Brush, Sorrel Horse, and Citation deposits in the Cherry Creek area, as a common disseminated constituent in hornfels and related metamorphic rocks (Granger and Raup, 1969).

Greenlee County: Clifton-Morenci district, northern Morenci open-pit mine, in an extensive contact metamorphic assemblage (Moolick and Durek, 1966).

Maricopa County: White Picacho district, scattered in pegmatites, especially the coarse-grained interior portions (Jahns, 1952).

Mohave County: Near Littlefield, in mafic dikes with chalcopyrite and pentlandite. Copper World mine near Yucca, with sphalerite, chalcopyrite, and löllingite (Rasor, 1946). Hualapai Mountains, Antler mine, coated by covellite (Romslo, 1948).

Navajo County: As troilite in stones of the Holbrook meteorite.

Pima County: Santa Rita Mountains, Helvetia district, with pyrite (Schrader and

Hill, 1915); Busterville mine, as blebs in sphalerite. Sierrita Mountains, Pima district, in chalcopyrite ores; Twin Buttes mine, as a primary mineral (Stanley B. Keith, pers. commun., 1973).

Santa Cruz County: Patagonia district, Duquesne and Washington Camp, in contact zones in Paleozoic limestones (Schrader, 1917).

Yavapai County: Bradshaw Mountains, with gold ores; Black Canyon district, Rainbow deposit near Turkey Creek station, in massive form (Lindgren, 1926). White Picacho district, in pegmatites (Jahns, 1952).

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QUARTZ

Silicon oxide, SiO_2. Low or alpha quartz. By far the most abundant of the polymorphic forms of silica and, following the feldspar minerals, the most widespread and abundant mineral of the Earth's crust. Formed in igneous, metamorphic, and sedimentary rocks; hydrothermal veins; and metasomatic and hot-spring deposits.

Cochise County: Little Dragoon Mountains, Cochise district, Johnson Camp area, as well-formed crystals, some of which are large. Huachuca Mountains, at Hamburg, as clear crystals twinned after the Japan law (Frondel, C., 1962; H 83142; UA 9692); Jack Wakefield mine, as beautiful, clear groups of crystals similar to those found at Hot Springs, Arkansas (S 15034). Russellville, with inclusions of tiny, yellow, octahedral crystals of scheelite grown on phantoms within the quartz (S 105926). Courtland (UA 8989).

Gila County: Mazatzal Mountains, Four Peaks, as amethyst crystals lining vugs in Mazatzal Quartzite; superb gem-quality material was produced from the area. Globe-Miami district, Old Dominion mine, where crystals colored blue by associated chrysocolla line cavities in oxidized ores; some quartz is brilliant red from included, finely divided hematite. Green Valley district, as clear crystals up to 1 in. long at the Oxbow mine. San Carlos Indian Reservation, as tiger-eye (silicified chrysotile).

Graham County: Galiuro Mountains, Crystal Peak (UA 4424); Table Mountain, as twinned crystals up to 1 in. long (H 106631; UA 9521); Stanley Butte, abundant as slender, tapering crystals several inches long, in places associated with and including andradite (S 12847). Aravaipa district, as good-quality crystals in the veins of the Tenstrike group.

Maricopa County: North of Scottsdale, in a quarry about 7 miles northeast of Curry's Corner. Mazatzal Mountains, Four Peaks, as gem-quality amethyst crystals of a rich, red-violet color that rival the best Siberian material; exceptional smoky quartz crystals have been produced from a claim owned by the Maricopa Mining Corp. (Lowell, J., and Rybicki, 1976; UA 5722). Near Lake Pleasant, as pseudomorphs (UA 223).

La Paz County: As large crystals in pegmatite in Precambrian granites over considerable areas. Near Crystal Park, near Quartzsite, as a chatoyant variety from which gem-quality cat's-eye has been produced (Frondel, C., 1962; H 104852).

Mohave County: Black Mountains, Oatman district, Moss mine, as locally abundant rose quartz; San Francisco (Oatman and Katherine) district, as amethystine bands in colorless quartz of gold veins (Roedder et al., 1963). Good-quality specimens of rose quartz are reported from a locality 40 miles northeast of Kingman. Cerbat Mountains, McConnico district, northeast of Boulder Spring, as amethystine crystals in Precambrian granite; a crystal from this locality was reportedly sold to Tiffany's (Guild, 1910). Kingman Feldspar mine, in pegmatite, produced as a by-product of feldspar mining (Heinrich, 1960).

Pima County: Tucson Mountains, near Sentinel Peak ("A" Mountain), as geodes in basalt flows (UA 6353); Contzen Pass area, with manganese oxide dendrites (UA 6324); unspecified mine dump, as crystals with copious chrysocolla inclusions. Arivaca, as scepter crystals (UA 9361). Ajo district, New Cornelia mine, associated with cuprite and copper and including shattuckite (UA 3431).

Pinal County: Galiuro Mountains, Bunker Hill district, Copper Creek Canyon, at the western end of the Aldwinkle and Longstreet claims, as Japan twins and as individuals up to 2 in. long in a soft limonite matrix; smaller specimens are typically flattened on the prism, and the tips of crystals have smaller crystals perched upon them. Some crystals show markedly flattened terminations that resemble the basal pinacoid. Red and green tourmaline is commonly enclosed in quartz crystals (William and Mildred Schupp, pers. commun., 1969; Gary M. Edson, pers. commun., 1972; UA 691, 3182). Pioneer district, in geodes in perlite (UA 1813). Sacaton Mountains, Gila River Indian Reservation, as extensive outcrops of white vein quartz (Wilson, E.D., 1969). Locality about 3 miles southwest of Pinal, as hollow, thin-walled crystals in sandstone (Kunz, 1887).

Santa Cruz County: Patagonia Mountains, Duquesne, Holland mine, as slender, tapering crystals up to 12 in. long, some of which form Japan twins; the individual crystals of one specimen are about 7 in. from tip to tip. These twins and slender crystals formed in a pocket with calcite, drusy siderite, and chlorite (UA 1096, 4459). This locality has probably produced the finest Japan twins in the United States. Near Duquesne, as amethyst in pegmatite. Belmont and Lead King properties, as a body 100 ft wide containing crystals up to 2 ft long (Schrader and Hill, 1915). In geodes at Temporal Gulch (UA 9352). Sierra de Tordillo, Parker Canyon district.

Yavapai County: Bradshaw Mountains, Hassayampa district, Cash mine, as clear crystals lining open veins, accompanied by crystals of adularia, calcite, and sulfide ore minerals. Bagdad area, along the creek above the open-pit mine, as Japan twins up to 2 in. long, commonly stained with iron oxides. Near Hillside, as fernlike growths (H 106631). Date Creek, near Congress Junction, as amethyst scepters on milky quartz crystals up to 2 in. long, loose in the soil (ASDM, Hill collection).

Near Mayer, as Japan twins (Robert Mudra, UA x646). About 6 miles east of Mayer, on a mine dump at the Yankee Boy mine, as one group of multiply twinned crystals consisting of a central, doubly terminated crystal about 5 mm long, to which are twinned (after the Japan law) two shorter individual crystals; other, smaller, simpler twins have also been collected (collection of Mrs. Donald C. Sonnenberg; Bideaux, 1970). Fat Jack mine, near Crown King, as smoky crystals having many scepters, amethyst, phantoms, and crystals exhibiting a variety of forms (Scovil and Wagner, 1991).

Agate

A term applied to chalcedony in which thin layers are typically accentuated by color differences. All gradations exist between chalcedony and agate, however, and many varieties of variegated and clouded agate have been given popular and commercial names. Moss agate is a variety in which manganese oxides form patterns.

Coconino and Mohave Counties: As nodules and geodes in the Kaibab Limestone (Guild, 1910).

Greenlee County: Peloncillo Mountains, near the Willow Spring Ranch (Dimick, 1957).

Maricopa County: Agua Fria River area, as plume agate and green and white fortification agate. In an area of several miles from Gila Bend to the north (Richards, 1956a).

Pima County: Tucson Mountains, near Sentinel Peak ("A" Mountain), as abundant geodes of blue and white agate in the basaltic rocks (Guild, 1905). North of Pantano, as rare carnelian and blue-and-white-banded fortification agate.

Yavapai County: Near Morgan City and Slow Springs Washes, as spherulitic nodules in lava. On the Agua Fria River, west of New River Station, as plume agate and mottled material (Richards, 1956a). A few miles north of Castle Hot Springs, as excellent gray, blue, pink, and violet material (Richards, 1956a).

Chalcedony

Cryptocrystalline quartz with fibrous microtexture formed as transparent to translucent crusts and coatings and as mammillary, botryoidal, nodular, and irregular masses; exhibits greasy or waxy luster. Commonly shows banding parallel to a free surface or to the surface upon which it was deposited. Formed under low-temperature conditions by hydrothermal and weathering processes. Several variety names are applied to chalcedonic silica based mainly on color and textural characteristics.

Apache and Navajo Counties: Several localities, as the principal constituent of petrified wood (see Petrified [Fossil] Wood).

Gila County: Globe-Miami district, colored blue or green from included chrysocolla or malachite.

Graham County: Duncan area, as an unusual and attractive type, locally termed *fire agate,* which exhibits a play of colors like that of fire opal.

Greenlee County: Clifton-Morenci district, in limestone; also loose at Shannon Mountain.

La Paz County: Chocolate Mountains, as excellent specimens. Locality east of Parker, near milepost 87 of the Santa Fe Railway.

Maricopa County: South of Aguila (AM 31736). Saddle Mountain, as *fire agate.*

Pinal County: Galiuro Mountains, in the pass between Little and Big Table Top Mountains, abundant as chalcedonic roses up to 12 in., and as other forms.

Santa Cruz County: Grosvenor Hills, near the old village of Santa Cruz, Canelo Hills. Santa Rita Mountains, Cottonwood Canyon, Glove mine, as pseudomorphs after calcite and as casts of hemimorphite crystals (Olson, H.J., 1966; UA 700, 9367).

Yavapai County: Near Morgan City and Slow Spring Washes, as spherulitic nodules in lavas; much of the chalcedony is fluorescent. Agua Fria River, 14 miles from Mayer, in opalite (UA 1660). Saddle Mountain, about 30 miles northwest of Hassayampa, as abundant roses weathered from volcanic rocks (Rogers, W., 1958).

Yuma County: Kofa Mountains, 20 miles southeast of Quartzsite, lining geodes in rhyolite (Walker, L.W., 1957); west of the Kofa Mountains and north of the Castle Dome Mountains, about 26 miles south of Quartzsite, in geodes (Weight, 1949).

Chert and Flint

The only difference between these materials is color. Most cherts are fairly light in color and may be grayish-white, gray, yellowish, reddish, or brownish; flint is commonly darker, grays and black being typical colors. Both are principally composed of fine-grained, fibrous chalcedony and typically form in sedimentary rocks, especially limestones, in which they may be of primary or secondary origin. Very large beds of chert have formed in some limestones; the smaller bodies of chert assume a great variety of shapes.

Cochise and Pima Counties: As abundant chert in some beds of Permian limestones, which are widely distributed in southeastern Arizona; also abundant in one bed of the Earp Formation, as small, reddish, jellybean-like bodies.

Coconino and Mohave Counties: As abundant chert in the Permian Kaibab Limestone.

Chrysoprase

Chalcedony colored green by inclusions of nickel silicate (Frondel, C., 1962). Other green or greenish-blue chalcedonies, e.g., those from the Live Oak and Keystone mines in the Globe-Miami district (Guild, 1910), are not chrysoprase because they are colored by chrysocolla.

Mohave County: Reported on the western slopes of the River Mountains, Weaver district.

Petrified (Fossil) Wood

Fossil wood, replaced pseudomorphously by cryptocrystalline quartz, largely chalcedony and jasper, the red, brown, or yellow variety. As silica carried in underground waters replaced the wood, even the most minute details of the original woody structures were commonly preserved.

Apache and Navajo Counties: Petrified Forest National Monument is world-renowned for the abundance and quality of fossil wood in the Petrified Forest Member of the Chinle Formation, which extends over many square miles. Tree logs, trunks, limbs, and fragments are preserved, typically in beautiful colors. Near Nazlini Canyon, north of Ganado, and at numerous other localities (Gregory, 1917).

Coconino, Mohave, and Yuma Counties: Abundant along the banks of the Colorado River (Guild, 1910; Wilson, E.D., and Butler, 1930).

Pima County: Tucson Mountains area, where it is common in the Cretaceous Amole Formation (Donald L. Bryant, pers. commun., 1972). South of the Empire Mountains, in Cretaceous red beds.

Santa Cruz County: Santa Rita Mountains, Adobe Canyon, in Cretaceous red beds.

QUEITITE

Lead zinc silicate sulfate, $Pb_4Zn_2(SiO_4)(Si_2O_7)(SO_4)$. A rare secondary mineral formed in the oxide zone of lead- and zinc-bearing deposits. Initially discovered at Tsumeb, Namibia.

Cochise County: Tombstone district, Lucky Cuss mine, as a chalky-white calcian variety that replaces alamosite and forms masses of spherulitic nodules.

QUETZALCOATLITE

Copper zinc tellurite hydroxide, $Cu_4Zn_8(TeO_3)_3(OH)_{18}$.

Cochise County: Tombstone district, Old Guard mine, in one tiny specimen, as small nodules of coarsely granular, bright-blue crystals cemented with gold; the pockets may form a core to masses of dugganite rimmed with khinite (Williams, S.A., 1978).

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#RALSTONITE

Sodium magnesium aluminum fluoride hydroxide hydrate, $Na_xMg_xAl_{2-x}(F,OH)_6\cdot H_2O$. An uncommon mineral associated with thomsenolite in cryolite in Green-land and with pachnolite and thomsenolite in altered rhyolite near Pikes Peak, Colorado.

Cochise County: Bisbee, Warren district, Southwest mine; one specimen was found by Richard Graeme in a void, associated with later paratacamite (Graeme, 1993).

#RAMEAUITE

Potassium calcium uranium oxide hydrate, $K_2CaU_6O_{20}{\cdot}9H_2O$. A secondary uranium mineral associated with uraninite and other oxidized uranium minerals.

Coconino County: South Rim of the Grand Canyon, among the ores of the Orphan mine.

#RAMMELSBERGITE

Nickel arsenide, $NiAs_2$. Formed at moderate temperatures in hydrothermal veins, with other nickel and cobalt minerals.

Coconino County: South Rim of the Grand Canyon, Orphan mine (Gornitz, 1986).

RAMSDELLITE

Gamma manganese oxide, γ-MnO_2. An orthorhombic polymorph of pyrolusite. Formed in veins and bedded manganese deposits with a variety of other oxidized manganese minerals.

Maricopa County: Black Rock mine, in hypogene veins in Precambrian crystalline gneisses (Hewett, 1964).

Mohave County: Artillery Mountains, Black Jack, Price, and Priceless veins, in veinlets along fractures and joints, as small tabular to blocky crystals, with hollandite, psilomelane, cryptomelane, coronadite, pyrolusite, and lithiophorite; Plancha bedded manganese deposit (Mouat, 1962; UA 9404).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as pseudomorphs after groutite microcrystals (Bideaux, 1980); Malpais Hill, as pseudomorphs (Thomssen, 1983).

Yavapai County: Locality east of Octave and northeast of Wickenburg, as masses of equant to tabular crystals up to about 5 mm long (UA 10086). Mistake mine, as crystals up to 1 cm long (Wilkinson et al., 1983).

#RANCIEITE

Calcium manganese oxide hydrate, $(Ca,Mn^{2+})Mn^{4+}_4O_9{\cdot}3H_2O$. A rare mineral formed in the oxidized zone of mineral deposits, associated with limonite.

Cochise County: On the mine dumps at Courtland, in crystalline form on goethite (Hidemichi Hori, pers. commun., 1986).

Pima County: Ajo district, Well No. 1 of the Phelps Dodge Corp., in vugs in volcanic rock with zeolites (William Thomas, pers. commun., 1988; William Hunt, UA x3209).

RANSOMITE

Copper iron sulfate hydrate, $CuFe_2(SO_4)_4 \cdot 6H_2O$. A rare mineral originally found at Jerome, where it formed as a result of a mine fire.

Cochise County: Warren district, Cole and Campbell mines, as a postmine mineral associated with voltaite and römerite in warm (oxidizing) parts of pyritic ores.

Yavapai County: Black Hills, United Verde mine (the type locality), as crusts and small tufts of crystals formed by the burning of pyritic ore (Lausen, 1928; Wood, 1970). A chemical analysis by T.F. Buehrer gave the following results (wt %):

H_2O	18.82	Fe_2O_3	22.57	CuO	11.29
SO_3	46.30	Al_2O_3	1.52	TOTAL	100.50

Specific gravity: 2.63

RAUVITE

Calcium uranyl vanadium oxide hydrate, $Ca(UO_2)_2V_{10}O_{28} \cdot 16H_2O$. A secondary mineral found in masses, as crusts and coatings, and as interstitial matter in sandstone, with other oxidized uranium-vanadium minerals, in Colorado Plateau–type deposits.

Apache County: Monument Valley, Monument No. 2 mine (Weeks et al., 1955; Finnell, 1957; Witkind and Thaden, 1963).

Navajo County: Monument Valley, Monument No. 1 mine and the adjoining Mitten No. 2 mine (Witkind, 1961; Witkind and Thaden, 1963).

REALGAR

Arsenic sulfide, AsS. Formed as a minor constituent in some gold, silver, and lead veins with orpiment, stibnite, and other arsenic minerals. Also formed by volcanic fumarolic action and some hot springs. Typically associated with orpiment, to which it readily alters.

Pinal County: In 1915 several pounds of realgar and orpiment were discovered at an unspecified locality near the junction of the Gila River and Hackberry Wash.

Yavapai County: Bradshaw Mountains, near Castle Hot Springs.

#REEVESITE

Nickel iron carbonate hydroxide hydrate, $Ni_6Fe_2(CO_3)(OH)_{16}\cdot 4H_2O$. Originally found in a weathered Australian meteorite and subsequently in certain nickel ores of South Africa.

Cochise County: Dragoon Mountains, in the ghost town of Barrett Camp, in veins in crystalline dolomite, as greenish-yellow microcrystalline material that appears to be the product of leaching or dissolution of pecoraite; associated with earthy goethite.

RHODOCHROSITE

Manganese carbonate, $MnCO_3$. A member of the calcite group. A common gangue mineral in sulfide mineral deposits formed under a wide range of temperatures. Also a secondary mineral in iron and manganese oxide deposits.

Apache County: Springerville–St. Johns area, as nodules of iron oxide and rhodochrosite formed in small amounts in the Chinle Formation. In the northwestern part of Antelope Valley, these nodules weather out of the uppermost shale unit of the Chinle Formation and cover the shale slope (Sirrine, 1958).

Cochise County: Tombstone district, Lucky Cuss mine, as small grains in oxidized alabandite ore (Hewett and Rove, 1930; Butler, B.S., et al, 1938b; Rasor, 1939). Warren district, Higgins mine, replacing dolomitic limestone, in drusy cavities in alabandite (Hewett and Rove, 1930; Hewett and Fleischer, 1960). Chiricahua Mountains, Humboldt mine, with rhodonite, calcite, and quartz, associated with alabandite in lenses in a fissure vein that cuts limestone (Hewett and Rove, 1930).

Coconino County: In breccia pipes being mined for uranium (Wenrich and Sutphin, 1988).

Gila County: Banner district, London Range shaft. Globe-Miami district, Ramboz (Silver Glance) deposit, with manganoan ankerite, the principal hypogene gangue mineral (Hewett and Fleischer, 1960; Peterson, N.P., 1962; Hewett et al., 1963).

Pima County: Rincon Mountains, with pyrolusite (UA 7554). Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

Pinal County: Superior district, Magma mine, as massive material and as rare small crystals in the South vein (Barnes and Hay, 1983).

Santa Cruz County: Patagonia Mountains, Trench mine, associated with alabandite, sphalerite, and galena (Schrader and Hill, 1915; Schrader, 1917; Hewett and Rove, 1930). Santa Rita Mountains, Cottonwood Canyon, Glove mine, with manganese oxide minerals (Olson, H.J., 1966).

Yuma County: Sheep Tanks district, Sheep Tanks mine, Booth Bonanza deposit, as brown veins in black-banded calcite veins (Cousins, 1972).

RHODONITE

Manganese iron magnesium silicate, $(Mn,Fe,Mg)SiO_3$. A member of the pyroxenoid group. Commonly formed through hydrothermal processes. Found in many manganese orebodies and pegmatites. Also formed in contact metamorphic deposits through the alteration of rhodochrosite.

Cochise County: Chiricahua Mountains, Humboldt mine, with rhodochrosite and alabandite in lenses in a fissure vein in limestone (Hewett and Rove, 1930).

Pima County: Unspecified locality in the Twin Buttes area (UA 4496); Twin Buttes mine (William Hefferon, pers. commun.). Reported near Sasabe (Lee Hammonds, pers. commun., 1974).

Santa Cruz County: South-central Patagonia Mountains, in quartz gangue in veins cutting Tertiary volcanic rocks (Schrader, 1917).

Yuma County: Kofa Mountains, King of Arizona district, with galena, pyrite, and fluorite in veins in the Eichelberger exotic breccia (Hankins, 1984).

#RHODOSTANNITE

Copper iron tin sulfide, $Cu_2FeSn_3S_8$. Formed as a replacement (alteration product) of stannite.

Cochise County: Bisbee, Warren district, Campbell mine, as a component of the sulfide ores (Graeme, 1993).

RHOMBOCLASE

Hydrogen iron sulfate hydrate, $HFe(SO_4)_2{\cdot}4H_2O$. A secondary mineral formed from the oxidation of pyrite as an incrustation on mine walls. Associated with chalcanthite, römerite, and epsomite.

Cochise County: Warren district, Copper Queen mine, in porous crusts with römerite (Merwin and Posnjak, 1937).

Pinal County: Superior district, Magma mine, 1,000-ft level, with voltaite and szomolnokite.

RICHTERITE

Sodium potassium calcium magnesium manganese silicate hydroxide, $(Na,K,Ca)_3$-$(Mg,Mn)_5Si_8O_{22}(OH)_2$. A member of the amphibole group. Formed in igneous and contact-metamorphosed rocks.

Coconino County: Canyon Diablo area, associated with krinovite, roedderite, high albite, kosmochlor, and chromite in the Canyon Diablo octahedrite meteorite (Olsen and Fuchs, 1968).

RICKARDITE

Copper telluride, Cu_4Te_3. A rare, late-formed mineral found in veins with pyrite, tellurium, and other tellurides.

Cochise County: Warren district, 1,400-ft level of the Junction mine, as small purple fragments in a sample of sulfide pulp; the identification was based on the characteristic purple-red color and a positive qualitative test for tellurium (Crawford, 1930); Campbell shaft (Graeme, 1993). Tombstone district, Little Joe shaft, where it replaces empressite as patches of purple platelets in adularia gangue.

RIEBECKITE

Sodium iron silicate hydroxide, $Na_2Fe^{2+}_3Fe^{3+}_2Si_8O_{22}(OH)_2$. Formed in granitic igneous rocks and low-grade regionally metamorphosed schists.

Coconino County: Southern San Francisco Mountains, at several places around Fremont Peak, in a blue to blue-gray, fine-grained rhyolite with sanidine phenocrysts (Updyke, 1977).

Pima County: Northern Sierrita Mountains and southern Roskruge Mountains, as the asbestiform variety, crocidolite (Robert O'Haire, pers. commun., 1972; UA 3065, 9212).

#ROALDITE

Iron nitride, Fe_4N. Formed as platelets in kamacite in iron meteorites.

Coconino County: Meteor Crater near Winslow, in the Canyon Diablo iron meteorite (E.R.D. Scott, pers. commun., 1988).

ROBERTSITE

Calcium manganese phosphate hydrate, $Ca_2Mn_3(PO_4)_3 \cdot H_2O$. A rare mineral previously reported only in certain pegmatites near Custer, South Dakota, where it is associated with other dark-colored, late-stage, iron and manganese phosphate minerals.

Yavapai County: White Picacho district, in pegmatites (material collected by Joseph E. Urban).

Rock Salt (see HALITE)

RODALQUILARITE

Hydrogen iron tellurite chloride, $H_3Fe_2(TeO_3)_4Cl$. The exact composition is in doubt. A very rare mineral; the Tombstone locality is one of only three known in the world.

Cochise County: Tombstone district, where it was first found by R.W. Thomssen at the Joe mine; common as highly perfect, 1-mm crystals and as cleavage plates up to 2.5 cm across, with a distinctive oil-green to pistachio-green color inclining toward a bright cadmium yellow; formed on fractures in silicified and opalized pyritic shales, with emmonsite (to which it alters), sonoraite, and a variety of other tellurides and tellurites.

The mineral that W.F. Hillebrand (1885) described as emmonsite from Tombstone (the type locality) was probably rodalquilarite. The physical description, optics, and chemical analysis are close to those of rodalquilarite. The emmonsite type locality should therefore be changed to Cripple Creek, Colorado.

ROEDDERITE

Sodium potassium magnesium iron silicate, $(Na,K)_2(Mg,Fe)_5Si_{12}O_{30}$. Formed in iron meteorites and the Eifel district, Germany.

Coconino County: Canyon Diablo area, with krinovite in graphite nodules in the Canyon Diablo octahedrite meteorite; also associated with richterite, high albite, kosmochlor, and chromite (Olsen and Fuchs, 1968).

ROMANECHITE (see Psilomelane)

RÖMERITE

Iron sulfate hydrate, $Fe^{2+}Fe^{3+}_2(SO_4)_4{\cdot}14H_2O$. A secondary mineral commonly formed by the alteration of pyrite. Typically associated with copiapite and other secondary sulfates. The louderbackite of Lausen (1928) was subsequently shown to be this species (Pearl, 1950).

Cochise County: Warren district, Copper Queen mine, in porous crusts (Merwin and Posnjak, 1937).

Yavapai County: Black Hills, United Verde mine, as thin crusts on pyrite formed under fumerolic conditions as a result of burning pyritic ores (Lausen, 1928; Wood, 1970). An analysis by T.F. Buehrer on the original "louderbackite" type material (H 90534) gave the following results (wt %):

H_2O	31.33	Fe_2O_3	20.84	FeO	7.01
SO_3	39.34	Al_2O_3	2.55	Na_2O	0.88
				TOTAL	101.95

Specific gravity: 2.19

ROSASITE

Copper zinc carbonate hydroxide, $(Cu,Zn)_2(CO_3)(OH)_2$. A secondary mineral found with aurichalcite, brochantite, malachite, and other secondary minerals in the oxidized portions of copper-zinc-lead deposits.

Cochise County: Tombstone district, Toughnut and Empire mines, as bright-green mammillary spherules in siliceous linings of vugs and between hemimorphite crystals (Butler, B.S., et al., 1938b). Turquoise district, Gleeson Ridge, with smithsonite and manganese oxides; Silver Bill and Mystery Tunnel mines, as large specimens of botryoidal crusts, with smithsonite, aurichalcite, and hemimorphite on manganese oxides (Knudsen, 1983). Warren district, common in gossans in underground workings, as small, dense spherules of radiating blue-green fibers in vugs, with calcite, aurichalcite, and hemimorphite.

Gila County: Banner district, 79 mine, in the oxidized portion as "deep blue-green velvety mats or warty crusts encrusting manganese oxides and smithsonite. Some of the mats are associated with aurichalcite, smithsonite, wulfenite, calcite, malachite, and mimetite"; formed contemporaneously with aurichalcite (Keith, 1972).

Maricopa County: Osborn district, Tonopah-Belmont mine, as balls of acicular crystals up to 4 mm in diameter (Allen, G.B., and Hunt, 1988).

Pima County: Waterman Mountains, Silver Hill mine (UA 6937, 5537). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Pima district, San Xavier West mine, intergrown with flat bladed calcite (Arnold, 1964). Empire district, Chief mine, as microcrystals with hemimorphite (Francis Sousa, UA x524).

Pinal County: Copper Creek, as microcrystals (William Kurtz, UA x4254).

Santa Cruz County: Santa Rita Mountains, Cottonwood Canyon, Glove mine (Olson, H.J., 1966).

ROSCOELITE

Potassium vanadium aluminum magnesium silicate hydroxide, $K(V,Al,Mg)_3(Al,Si)_3O_{10}(OH)_2$. A rare vanadian member of the mica group.

Apache County: Monument Valley, Monument No. 2 mine, with many other uranium-vanadium minerals (Gruner and Gardiner, 1952).

Cochise County: Warren district, Campbell orebody (Graeme, 1993).

Navajo County: Monument Valley, Mitten No. 2 mine (Witkind and Thaden, 1963); Monument No. 1 mine (Holland et al., 1958).

ROSSITE

Calcium vanadium oxide hydrate, $CaV_2O_6 \cdot 4H_2O$. A rare mineral associated with the oxidized uranium-vanadium deposits of the Colorado Plateau. Intimately associated with metarossite, to which it alters.

Apache County: Lukachukai Mountains, reported in the Mesa No. 1 mine.

ROZENITE

Iron sulfate hydrate, $FeSO_4 \cdot 4H_2O$. A secondary sulfate commonly formed as a postmine efflorescence.

Cochise County: Bisbee, Warren district, Copper Queen mine, as a powdery white efflorescence on specimens of coquimbite, copiapite, and other minerals in postmine sulfate assemblages (Fabien Cesbron, pers. commun., 1979).

#RUCKLIDGEITE

Bismuth lead telluride, $(Bi,Pb)_3Te_4$. Of hydrothermal origin. Associated with gold, arsenopyrite, boulangerite, calaverite, and other hydrothermal minerals.

Cochise County: Bisbee, Warren district, Campbell orebody, replacing granular pyrite in the massive sulfide ores (Graeme, 1993).

RUIZITE

Calcium manganese silicate hydroxide hydrate, $CaMnSi_2O_6(OH)\cdot 2H_2O$. Formed during retrograde metamorphism and oxidation of a contact metamorphic calc-silicate assemblage developed in limestones. The Christmas mine is the type locality.

Gila County: Banner district, Christmas mine, as orange spherules of radial acicular crystals, in veinlets and on fracture surfaces in metamorphosed limestone that contain wollastonite, grossular, diopside, and vesuvianite; associated with junitoite, kinoite, apophyllite, smectite, xonotlite, and sepiolite. An analysis (Williams, S.A., and Duggan, 1977) gave the following results (wt %):

CaO	20.57	SiO_2	39.14	H_2O	16.00
Mn_2O_3	23.42			TOTAL	99.13

RUTILE

Titanium oxide, TiO_2. Widespread as an accessory mineral in granitic igneous rocks. Also common in metamorphic rocks, as a product of the alteration of other titanium-bearing silicates, and as a detrital mineral in sands and sedimentary rocks.

Apache County: Monument Valley area, Garnet Ridge, as mineral fragments in a breccia dike that pierces the sedimentary rocks; common as needlelike crystals in garnet (Gavasci and Kerr, 1968).

Cochise County: Warren district, northwest of Bisbee, as an accessory mineral in granite; Sacramento Hill, in a hydrothermally altered granite porphyry, as clusters of tiny crystals in pseudomorphs after biotite (Schwartz, 1947).

Gila and Pinal Counties: As an accessory mineral in the Madera Diorite, Pinal Schist, and Solitude and Ruin Granites (Peterson, N.P., 1962). Globe-Miami district, Miami orebody, as a product of hydrothermal alteration of granite porphyry, and near the orebody, in schist (Schwartz, 1947, 1958); Castle Dome mine, as a product of the clay mineral phase of alteration, recrystallized from sphene and ilmenite (Peterson, N.P., et al., 1946; Schwartz, 1947).

Greenlee County: Morenci district, as clusters replacing ferromagnesian minerals in an intensely altered porphyry copper orebody, associated with a suite of hydrothermal alteration minerals (Reber, 1916; Schwartz, 1947, 1958).

La Paz County: Eastern Dome Rock Mountains, 3 miles southwest of Quartzsite, as small grains scattered throughout Precambrian schist and as well-formed crystals in fractures in quartz veins (Wilson, E.D., 1929); also in kyanite-rich rocks.

Mohave County: Cerbat Mountains, Wallapai district, in a hydrothermally altered, disseminated sulfide deposit in a porphyritic intrusive, as sagenite webs and in clusters of crystals; also replacing sphene (Thomas, B.E., 1949).

Pima County: Ajo district, as stumpy crystals that are an alteration product of biotite (Schwartz, 1958; Hutton and Vlisidis, 1960). Silver Bell area, as small, acicular crystals associated with quartz and as small grains and prismatic crystals (Kerr, 1951). Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

Pinal County: Mineral Creek district, Ray area, formed in hydrothermally altered quartz monzonite porphyry, in pseudomorphs after biotite, with chlorite, sericite, and hydromica (Schwartz, 1952). Mammoth district, San Manuel mine, in hydrothermally altered monzonite and quartz monzonite porphyries, associated with chlorite pseudomorphs after biotite (Schwartz, 1947, 1949, 1958); found in the propylitic, potassium silicate, and argillic phases of alteration (Creasey, 1959). Sacaton Mountains, sec. 12, T. 5 S., R. 5 E., as small irregular masses in felsite, with corundum and quartz (Wilson, E.D., 1969). Bunker Hill district, Childs-Aldwinkle mine, as small single crystals, associated with molybdenite, quartz, and orthoclase crystals.

Santa Cruz County: Patagonia Mountains, Santo Niño mine at Duquesne, as slender crystals and reticulated masses up to several inches in altering granite (J.H. Courtright, pers. commun.). Washington Camp district, as microcrystals (H. Peter Knudsen, UA x274).

Yavapai County: Black Hills, United Verde mine, as well-developed crystals. Bradshaw Mountains, Black Canyon district, Howard copper property, with tourmaline in the gangue. Eureka district, Bagdad, as stubby crystals or granular aggregates derived from sphene and biotite in an altered quartz monzonite stock, associated with quartz and orthoclase and in a few places, with sericite (Anderson, C.A., 1950).

S

SABUGALITE

Hydrogen aluminum uranyl phosphate hydrate, $HAl(UO_2)_4(PO_4)_4 \cdot 16H_2O$. A rare secondary mineral formed in vein-type uranium deposits as an alteration product of uraninite and in Colorado Plateau–type deposits.

Apache County: Black Mesa Basin, Black Water mine.

Coconino County: Cameron district, O'Jaco, Huskon No. 5, and Arrow Head Nos. 1, 3, and 7 claims (Holland et al., 1958).

SALEEITE

Magnesium uranyl phosphate hydrate, $Mg(UO_2)_2(PO_4)_2 \cdot 8H_2O$. A secondary mineral of the autunite group associated with oxidized uranium deposits.

Gila County: Cherry Creek area, Sue mine, where it is intimately associated with bassetite (Granger and Raup, 1969). North-central region, in weathered deposits in sandstone in the Dripping Spring Quartzite (Granger and Raup, 1962).

Salmonsite (a mixture of HUREAULITE and JAHNSITE)

SAMARSKITE

Yttrium cerium uranium calcium lead niobium tantalum titanium tin oxide, $(Y,Ce,U,Ca,Pb)(Nb,Ta,Ti,Sn)_2O_6$. Generally formed in granite pegmatites in small amounts with other rare earth minerals such as monazite. The lighter rare earth elements tend to enter the monazite structure, whereas the heavier elements enter the samarskite structure; thus, the two minerals are commonly found in the same pegmatite.

Mohave County: Aquarius Mountains, in granite pegmatites with allanite. Reported northeast of Kingman.

Pima County: Sierrita Mountains, New Year's Eve mine, as shiny black crystals.

Yavapai County: Black Hills, reported near Jerome.

SANIDINE

Potassium sodium aluminum silicate, $(K,Na)AlSi_3O_8$. A member of the alkali feldspar group that may be described as a structurally disordered orthoclase. Typically found in rocks formed at elevated temperatures. A constituent of alkali and felsic volcanic rocks such as rhyolites and trachytes, as transparent, glassy crystals. The mineral is undoubtedly much more common in the state than suggested by the few localities noted below.

Cochise County: Chiricahua National Monument, in the groundmass and as phenocrysts in welded rhyolite tuffs, associated with quartz and magnetite (Enlows, 1955). Reported in the Warren district. Peloncillo Mountains, Cottonwood Canyon, common as phenocrysts, some showing a blue play of colors, in rhyolites.

Pima County: Northern Sierrita Mountains, Gunsight Mountain, as a barian variety, in a pulaskite dike (Bideaux et al., 1960). Batamote Mountains near Ajo, as clear, round phenocrysts in rhyolite welded tuffs.

#SANTAFEITE

Sodium manganese calcium strontium vanadium arsenic oxide hydrate, Na_2Mn_3-$(Mn,Ca,Sr)_6(V,As)_6O_{28} \cdot H_2O$. Formed as a secondary coating on joint surfaces in limestone.

Navajo County: Monument Valley, in the dumps of the Monument No. 1 mine, as massive veinlets that cut sandstone in one large chunk of ore.

SAPONITE

Calcium sodium magnesium iron aluminum silicate hydroxide hydrate, $(Ca_{0.5}$,-$Na)_{0.33}(Mg,Fe)_3(Si,Al)_4O_{10}(OH)_2 \cdot 4H_2O$. A member of the smectite (montmorillonite) group.

Cochise County: Tombstone district, Toughnut mine (H 106306).

Maricopa County: Tonopah-Belmont mine, south of Wickenburg, as smears along fractures in vein quartz; 1 mile south of Horseshoe Dam, with zeolites (Shannon, D.M., 1983b).

Pima County: Unspecified locality near Pantano (UA 6486).

Santa Cruz County: Flux mine, in the open pit (David Shannon, pers. commun., 1988).

SAPPHIRINE

Magnesium aluminum silicate, $Mg_{7\text{-}8}Al_{16\text{-}18}Si_{3\text{-}4}O_{40}$. A relatively rare mineral formed in metamorphic rocks high in alumina and low in silica.

La Paz County: About 3 miles southwest of Quartzsite, as sparse, irregular grains in schist, tentatively identified by optical means (Wilson, E.D., 1929).

SAUCONITE

Sodium zinc aluminum silicate hydroxide hydrate, $Na_{0.33}Zn_3(Si,Al)_4O_{10}(OH)_2$-$\cdot 4H_2O$. A member of the smectite (montmorillonite) group.

Cochise County: Gleeson district, Defiance–Silver Bill mines, mixed with fraipontite (Foord et al., 1983).

Gila County: Globe-Miami district, Castle Dome area, as purplish, waxy lumps in manganiferous material. Banner district, 79 mine, associated with chrysocolla and hemimorphite in a stope system above the 470-ft level (Keith, 1972).

Pinal County: Pioneer district, Magma mine, as soft, waxy, gougelike material from near the lower limit of oxidation, associated with coronadite. A partial analysis gave the following results (wt %):

Zn	14.6	Al_2O_3	22.0
SiO_2	33.6	H_2O	14.9

Scapolite (a group name)

A complex silicate chloride fluoride hydroxide carbonate sulfate of sodium, calcium, potassium, and aluminum. The scapolite group can broadly be expressed by the formula $(Na,Ca,K)_4Al_3(Al,Si)_3Si_6O_{24}(Cl,F,OH,CO_3,SO_4)$. The two end members are sodium-rich marialite and calcium-rich meionite. The exact composition of the mineral at most of the localities noted below is unknown. Mainly confined to regionally or contact-metamorphosed rocks such as schists, gneisses, and crystalline limestones. Where these rocks are calcareous, the mineral is probably meionite.

Cochise County: Dragoon Mountains, at the northern end of Stronghold Canyon, as short, curved, fibrous masses of marialite that replace vesuvianite (Rushing, 1978).

Gila County: Reported in the Diamond Butte quadrangle, in metamorphosed Precambrian rocks (Gastil, 1958).

Yavapai County: Bradshaw Mountains, Black Canyon district, 6 miles south of Cleator, in Yavapai Schist.

SCAWTITE

Calcium silicate carbonate hydrate, $Ca_7Si_6O_{18}(CO_3)\cdot 2H_2O$. A rare late-stage mineral associated with calcium-rich tactites.

Gila County: Banner district, Christmas mine, as tiny euhedral prisms projecting into vugs in grossular-diopside tactites.

SCHEELITE

Calcium tungstate, $CaWO_4$. A widespread mineral, commonly an important ore of tungsten. Typically formed in high-temperature environments: granite pegmatites, contact metamorphic deposits formed in limestone, and quartz-rich high-temperature veins. Commonly associated with wolframite. Widely distributed in small amounts in Arizona.

Cochise County: About 4 miles north of Dragoon, in small quantities in quartz veins that cut granite (Guild, 1910). Cochise district, Johnson Camp area, near the Republic mine, as crystals embedded in quartz crystals (Romslo, 1949; Cooper, 1957; Baker, A., 1960; Cooper and Huff, 1951; Cooper and Silver, 1964). Cohen Tungsten mine, 10 miles east of Willcox, as light-brown crystals weighing up to 15 lb, and as smaller crystals embedded in gray, doubly terminated, quartz crystals. Eastern slope of the Whetstone Mountains, in quartz veins and as replacements in granite (Guild, 1910; Dale et al., 1960). Huachuca Mountains, Reef mine, in a quartz vein associated with chalcopyrite, sphalerite, hübnerite, fluorite, galena, pyrite, and stolzite (Palache, 1941a); James, Harper, and other properties (Wilson, E.D., 1941; Dale et al., 1960). Swisshelm Mountains (Dale, 1959). Chiricahua Mountains, Paradise area, in quartz veins in silicified limestones (Dale et al., 1960).

Gila County: Globe-Miami district, on the lower east slope of Day Peaks, Lost Gulch area, as sparse, isolated crystals with stolzite, in a mineralized zone in a fault that cuts diabase (Faick and Hildebrand, 1958).

Graham County: Southwest of the Graham Mountains, SE1/4 sec. 35, and SW1/4 sec. 36, T. 8 S., R. 22 E., with tourmaline from the Black Beauty group (Dale, 1959).

La Paz County: Trigo Mountains, Silver district, Gold Reef claims, in a sheared quartz vein (Wilson, E.D., 1941). Little Harquahala Mountains (Dale, 1959). Ellsworth district, Colorado mine, as large, crude crystals and masses over 5 cm, with wolframite (MM K128-135); Jewel Ann group, as masses up to 2.5 cm in quartz (MM L710-711). Granite Wash Mountains, Three Musketeers mine, in sec. 24, T. 6 N., R. 15 W., as crystals up to 4 in. across, in white quartz; the crystals show brilliant blue-white fluorescence (David Shannon, pers. commun., 1971). Placer near Quartzsite (H 97745). Dome Rock and Plomosa Mountains, in a few localities (Dale, 1959).

Maricopa County: Mazatzal Mountains, northwest of Four Peaks. Near Morristown, on the upper Santo Domingo Wash, with powellite. Cave Creek district, at an unspecified locality, with cuprotungstite and ferberite (Schaller, 1932). Northwest of Morristown, in several properties (Dale, 1959). Vulture Mountains, Flying Saucer group of claims, in sec. 12, T. 6 N., R. 6 W., with powellite as disseminations in granitic rocks (Dale, 1959).

Mohave County: Hualapai Mountains, Boriana (Hobbs, 1944; Dale, 1961), Telluride Chief, and other properties, with wolframite in quartz veins. Aquarius Mountains, Boner Canyon, sparingly at the Williams mine (Hobbs, 1944; Dale, 1961). Cottonwood and Greenwood areas, in small amounts with wolframite (Dale, 1961). Mohave Mountains, Dutch Flat (Wilson, E.D., 1941).

Pima County: Las Guijas Mountains (Dale et al., 1960). Santa Rita Mountains, Helvetia district (Schrader and Hill, 1915). Sierrita Mountains, Pima district, Twin Buttes mine, in contact zones (Stanley B. Keith, pers. commun., 1973). Gunsight Hills (Wilson, E.D., 1941; Dale et al., 1960). Eastern part of the Tohono O'odham (Papago) Indian Reservation, about 50 miles west of Tucson, on several claims (Dale et al., 1960). Santa Catalina Mountains, near Marble and Piety Peaks (Dale et al., 1960). San Luis Mountains, southwest of Arivaca, in quartz veins in the Easter prospect (Dale et al., 1960).

Pinal County: Campo Bonito area, Maudina and other properties (Guild, 1910). Northwest of Mammoth, Tarr, and Antelope Peak areas (Wilson, E.D., 1941).

Santa Cruz County: San Cayetano district, near Calabasas, with wolframite (Dale et al., 1960). Patagonia Mountains, 4 miles south of Duquesne, with molybdenite (Schrader and Hill, 1915; Wilson, E.D., 1941). Nogales district, Reagan Camp, with wolframite (Schrader, 1917).

Yavapai County: Bradshaw Mountains, Tip Top district (Dale, 1961). Hassayampa district. Wickenburg Mountains, White Picacho district (Jahns, 1952), upper Santo Domingo and Little Santo Domingo Washes, disseminated in garnet-epidote schist. Silver Mountain area (Wilson, E.D., 1941).

Yuma County: Kofa and Gila Mountains (Dale, 1959).

SCHIEFFELINITE

Lead tellurate sulfate hydrate, $Pb_8(TeO_4)_5(SO_4)_3 \cdot 8H_2O$ or $Pb(Te,S)O_4 \cdot H_2O$. A secondary mineral formed from other tellurium minerals under conditions of severe oxidation. Tombstone is the type locality.

Cochise County: Tombstone district, on the dumps of the Joe shaft, as clusters of intergrown, colorless or milk-white scales, with individuals up to 1 mm, in a large chunk of shattered quartz vein; tellurides have been converted to rodalquilarite, several unknown tellurites or tellurates, girdite, and schieffelinite. An analysis by Marjorie Duggan (Williams, S.A., 1980a) gave the following results (wt %):

PbO	58.2	TeO_3	28.6
H_2O	4.7	SO_3	6.8
		TOTAL	98.3

Specific gravity 4.98

SCHOEPITE

Uranium oxide hydrate, $UO_3 \cdot 2H_2O$. A secondary mineral commonly associated with uraninite, from which it may form by alteration.

Apache County: Monument Valley, Monument No. 2 mine, as a surficial alteration product of uraninite, with becquerelite and small amounts of fourmarierite (Frondel, C., 1956).

Coconino County: Cameron area, Black Point–Murphy mine, sparsely distributed in Pleistocene gravels (Austin, 1964).

Yavapai County: Abe Lincoln mine, northeast of Wickenburg, as the principal secondary uranium mineral, formed as a coating on pyrite grains (Raup, 1954; Granger and Raup, 1962).

SCHORL (see Tourmaline)

SCHREIBERSITE

Iron nickel phosphide, $(Fe,Ni)_3P$. Formed in many of the metallic meteorites found in the state.

SCHRÖCKINGERITE

Sodium calcium uranyl carbonate sulfate fluoride hydrate, $NaCa_3(UO_2)(CO_3)_3(SO_4)F \cdot 10H_2O$. Formed as a late secondary mineral with other oxidized uranium minerals; also formed as a postmine mineral.

Coconino County: Cameron area, Jack Daniels No. 1 mine, coating fractures in sandstone, possibly of postmine origin; Foley Bros. No. 5 mine (Austin, 1964).

Yavapai County: Hillside mine, as 1/8-in.-thick coatings on gypsum, with andersonite, bayleyite, and swartzite; johannite and pitchblende are reported in the same mine (Axelrod et al., 1951).

#SCHUBNELITE

Iron vanadate hydrate, $FeVO_4 \cdot H_2O$. Formed with other vanadium and uranium minerals under oxidizing conditions.

Apache County: Monument No. 2 mine, in Triassic fossilized wood; identified by Howard T. Evans, Jr. (Haynes, 1991).

SCOLECITE

Calcium aluminum silicate hydrate, $CaAl_2Si_3O_{10} \cdot H_2O$. A member of the zeolite group. Formed as seams and amygdule fillings in mafic volcanic rocks; less commonly, of hydrothermal origin in metamorphic rocks.

Graham County: Black Point, about 4 miles below Geronimo on the Gila River, as highly fluorescent amygdule fillings up to 0.5 in. in diameter in basalt.

Pinal County: Copper Creek district, as well-formed prisms up to 1 in. long, in brecciated zones in the Copper Creek Granodiorite, with calcite.

SCORODITE

Iron arsenate hydrate, $FeAsO_4 \cdot 2H_2O$. A relatively common mineral formed under oxidizing conditions in gossans associated with arsenic-bearing minerals. Typically the first mineral to replace arsenopyrite. Rarely formed as a primary hydrothermal mineral.

Coconino County: Grand Canyon National Park, Horseshoe Mesa, Grandview (Last Chance) mine, as light-brown to gray mammillary masses with radiating internal structure, associated with metazeunerite and olivenite (Leicht, 1971; John S. White, Jr., pers. commun.).

Mohave County: Cerbat Mountains, Wallapai district, as a common secondary mineral; Mollie Gibson mine (Thomas, B.E., 1949).

Yavapai County: Mazatzal Wilderness Area, Stingy Lady mine, as stains and coatings on arsenopyrite (Wrucke et al., 1983).

#SCORZALITE

Iron magnesium aluminum phosphate hydroxide, $(Fe^{2+},Mg)Al_2(PO_4)_2(OH)_2$. Formed in granite pegmatites associated with other phosphate minerals.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites (London, 1981).

SELENIUM

Selenium, Se. A rare secondary mineral. First recognized as a mineral at Jerome.

Yavapai County: Verde district, United Verde mine in Jerome, as a coating of needlelike crystals on rock above the burning pyrite orebody; crystals are up to 2 cm long and are bounded by first- and second-order rhombohedrons (Palache, 1934; H 92678, 92679). An analysis by F.A. Gonyer showed that the mineral contained no tellurium and only a trace of sulfur.

SENGIERITE

Copper uranyl vanadate hydrate, $Cu(UO_2)_2(VO_4)_2 \cdot 8\text{-}10H_2O$. A rare secondary mineral. The locality noted below was the first one discovered in the United States.

Cochise County: Bisbee, Warren district, Cole mine, originally found in 1935 in one isolated pocket, associated with malachite, chalcocite, covellite, and chlorargyrite; later found to be more widely distributed in the mine; it "occurred in one of a series of five sulfide-oxide veins which extended from the 800 level to the 1300 level of the Cole Shaft" (Hutton, 1957).

SEPIOLITE (Meerschaum)

Magnesium silicate hydroxide hydrate, $Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$. Formed by the alteration of magnesian rocks and generally associated with serpentine or magnesite. A component of certain clays; found in some hydrothermal veins. A compact variety is the meerschaum used in industry.

Greenlee County: Clifton area (UA 8847).

Maricopa County: Locality 42 miles north of Phoenix and 2 miles east of State Highway 69.

Pima County: Pima district, San Xavier West mine (UA 4164).

Yavapai County: In the basin of the Santa Maria River, west of the McCord Mountains, as crystalline, fibrous material (Kauffman, 1943). An analysis by A.J. Kauffman gave the following results (wt %):

SiO_2	54.83	CaO	0.55	K_2O	0.03
Al_2O_3	0.28	MgO	24.51	$H_2O(-)$	8.18
Fe_2O_3	0.45	Na_2O	0.35	$H_2O(+)$	10.74
				TOTAL	99.92

Sericite (see MUSCOVITE)

Serpentine (Kaolinite-Serpentine mineral group)

Magnesium silicate hydroxide, $Mg_3Si_2O_5(OH)_4$. Small amounts of ferric iron and aluminum commonly substitute for magnesium. Serpentine specimens typically consist of mixtures of the polymorphs of clinochrysotile, orthochrysotile, lizardite, parachrysotile, and antigorite (Nagy and Faust, 1956). The fibrous habit of "chrysotile" is due to the rolled-up tube nature of its kaolinitelike sheet structure. The nomenclature of the serpentine minerals is further complicated by stacking polymorphism. Serpentine is of secondary origin, derived from the alteration of non-aluminous magnesian silicates, particularly olivine, amphibole, or pyroxene. In places, it is formed as large masses derived from peridotite or other mafic igneous rocks. A common product of contact metamorphism of magnesian limestones, it is also found in hydrothermal veins. The most notable serpentine mineral in Arizona is "chrysotile," although its exact composition may be unknown. "Chrysotile" has been extensively mined as asbestos. Antigorite is also abundant as a major constituent of the nonasbestiform serpentine rock associated with the asbestos ore.

Extensive lists of asbestos localities are included in Funnell and Wolfe (1964) and in Bulletins 126 and 180, published by the Arizona Bureau of Mines (currently the Arizona Geological Survey).

Apache County: Garnet Ridge, abundant in a boulder, pseudomorphous after an orthopyroxene; related to a breccia dike that pierces sedimentary rocks (Gavasci and Kerr, 1968).

Cochise County: Tombstone district, Lucky Cuss mine, in altered limestone (Butler, B.S., et al., 1938b). Chiricahua Mountains, as chrysotile, with contact metamorphic ores. Dos Cabezas Mountains, in metamorphosed limestones (Guild, 1910). Little Dragoon Mountains, Johnson Camp area, Moore orebody, as a retrograde product of higher temperature metamorphism of forsterite, tremolite, and diopside (Cooper and Huff, 1951; Cooper and Silver, 1964).

Coconino County: Grand Canyon region, Bass and Hance properties, where the Precambrian Bass Limestone has been altered adjacent to diabase sills (Selfridge, 1936); cross-fiber asbestos is locally up to 4 in. long, but is commonly shorter (Funnell and Wolfe, 1964).

Gila County: The most extensive and commercially important deposits of chrysotile in Arizona are north and northeast of Globe along the Salt River near Chrysotile and along Cherry and Ash Creeks (Engineering Mining Journal, 1915; Melhase, 1925; Stewart, L.A., and Haury, 1947; Stewart, L.A., 1956). The deposits originated through metamorphic action of diabase intrusives upon Precambrian Mescal Limestone. The composition (wt %) of some typical specimens is as follows:

R.E. Zimmerman

(1)

MgO	42.05	Al_2O_3	1.27	$H_2O(+)$	14.31
SiO_2	41.56	FeO	0.64	TOTAL	99.83

(2)

MgO	41.85	Al_2O_3	0.91	CaO	0.07
SiO_2	41.35	FeO	0.69	$H_2O(+)$	13.34
				TOTAL	98.21

George T. Faust (Nagy and Faust, 1956)

MgO	41.44	Al_2O_3	0.52	$H_2O(+)$	14.04
SiO_2	42.02	FeO	0.11	$H_2O(-)$	1.64
Fe_2O_3	0.19	MnO	0.03	TOTAL	99.99

Pinal and Mescal Mountains and Pinto Creek region. Sierra Ancha Mountains, at the head of Pocket Creek (Bateman, 1923; Sampson, 1924). Banner district, Christmas mine, replacing dolomite and forsterite in the orebodies (Perry, D.V., 1969). San Carlos Indian Reservation, Emsco and Bear mines (Bromfield, C.S., and Schride, 1956). Globe district, Old Dominion mine, in Mescal Limestone near diabase sills.

Greenlee County: Clifton-Morenci district, northern part of the Morenci open-pit area, locally formed with other calc-silicate minerals in an extensive contact metamorphic assemblage (Moolick and Durek, 1966); on the ridge just west of Morenci, at the Thompson mine, as green-banded material associated with magnetite (Lindgren, 1905; Reber, 1916; Creasey, 1959).

Pima County: Pima district, Twin Buttes open-pit mine, in metamorphic rocks (Stanley B. Keith, pers. commun., 1973).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as aggregated masses of shining white balls of antigorite that form a matrix for wulfenite and descloizite (Bideaux, 1980). Hewett Wash area (Stewart, L.A., 1956).

Yavapai County: Copper Basin district, as an alteration product in ores in breccia pipes (Johnston, W.P., and Lowell, 1961).

#SERPIERITE

Calcium copper zinc sulfate hydroxide hydrate, $Ca(Cu,Zn)_4(SO_4)_2(OH)_6{\cdot}3H_2O$. A rare secondary mineral.

Cochise County: Middle Pass district, San Juan mine, as microcrystals (Bruce Maier, UA x3086).

Gila County: Brick or D.H. claims, northeast of Hayden, with ktenasite (William Hunt, UA x3715).

SHATTUCKITE

Copper silicate hydroxide, $Cu_5(SiO_3)_4(OH)_2$. A secondary mineral formed as an alteration of other secondary copper minerals. First described from Bisbee by Schaller (1915).

Cochise County: Warren district, Shattuck mine, as pseudomorphs after malachite and as small blue spherules; associated with "bisbeeite" which replaces it (Schaller, 1915). The composition (wt %), based on analyses by W.T. Schaller (Wells, R.C., 1937) is as follows:

(1) Analysis of mineral from heavy-liquid separation

SiO_2	39.68	H_2O	5.94	FeO	0.16
CaO	0.05	CuO	54.80	ZnO	tr.
				TOTAL	100.63

(2) Analysis of deep-blue spherules

SiO_2	37.91	H_2O	5.83	FeO	0.43
CaO	—	CuO	55.51	ZnO	—
				TOTAL	99.68

Greenlee County: Clifton-Morenci district, in Gila Conglomerate (UA 1036).

Maricopa County: South of Wickenburg, at several localities, including the Moon Anchor mine and Potter-Cramer property, associated with several oxidized minerals (Williams, S.A., 1968).

Mohave County: Small prospect near Artillery Peak, in oxidized ores with drusy quartz, alamosite, and luddenite (Williams, S.A., 1982).

Pima County: Ajo district, in veins at the New Cornelia open-pit mine (Schaller and Vlisidis, 1958; Newberg, 1964; Mrose and Vlisidis, 1966; Vlisidis and Schaller, 1967; Evans, H.T., and Mrose, 1977). An analysis by Vlisidis and Schaller (1967) gave these results (wt %):

SiO_2	36.06	CaO	0.01	MnO	0.03
CuO	59.39	MgO	0.02	$H_2O(+)$	2.62
FeO	0.19			TOTAL	98.32

Specific gravity (corrected): 4.09. An analysis by H.B. Wiik (Sun, 1961) on Ajo material gave these results (wt %):

SiO_2	35.90	CaO	0.00	CO_2	0.00
CuO	55.27	TiO_2	0.00	$H_2O(+)$	6.31
Fe_2O_3	0.31	Al_2O_3	0.79	$H_2O(-)$	0.08
				TOTAL	98.66

Unspecified locality in the Tortolita Mountains (probably the Azurite mine). Santa Catalina Mountains, Molino Basin, with flecks of gold on chrysocolla-stained quartz.

Pinal County: Mammoth district, San Manuel mine, as veinlets in chrysocolla. Poston Butte porphyry copper deposit. Slate Mountains, Roadside mine, associated with fornacite and cerussite in mine dumps.

SHERWOODITE

Calcium vanadium oxide hydrate, $Ca_3V_8O_{22}{\cdot}15H_2O$. A secondary oxidation product of lower-valence vanadium minerals, commonly associated with selenium, metatyuyamunite, and melanovanadite.

Apache County: Joleo mine (AEC mineral collection).

SICKLERITE

Lithium manganese iron phosphate, $(Li,Mn,Fe)PO_4$. A rare secondary mineral formed by the alteration of lithiophilite and triphylite in pegmatites.

Yavapai County: White Picacho district, as thin discontinuous rims on lithiophilite and triphylite (Jahns, 1952).

SIDERITE

Iron carbonate, $FeCO_3$. A member of the calcite group. Typically found in bedded sedimentary rocks, where it may be an important ore mineral. Also commonly formed as a hydrothermal vein mineral.

Cochise County: Warren district, where boxwork siderites have proved to be a useful guide to ore deposits (Trischka et al., 1929); Campbell mine, as fine granular, dark-brown, stalactitic material, coated by small iridescent crystals.

Gila County: Dripping Spring Mountains, Banner district, McHur prospect, with wulfenite and vanadinite.

Greenlee County: Clifton-Morenci district, as a weathering product found in massive form in highly mineralized limestone (Reber, 1916).

La Paz County: Harquahala Mountains (UA 7586). Dome Rock Mountains, in cinnabar veins with tourmaline. Harcuvar Mountains, Cunningham Pass area, as nearly jet-black cleavable material with chalcopyrite.

Mohave County: Cerbat Mountains, Wallapai and Gold Basin districts, as a common gangue mineral (Thomas, B.E., 1949). Antler mine, as large botryoidal masses, some with an iridescent coating.

Pima County: Santa Rita Mountains, Old Baldy district, Iron Mask mine, with magnetite and schorl. Empire Mountains, Hilton mines (Schrader and Hill, 1915). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Silver Bell district, as small crystals (Stewart, C.A., 1912).

Pinal County: Mammoth district, San Manuel mine (UA 8836).

Santa Cruz County: Tyndall district, Cottonwood Canyon, Glove mine, replacing limestone (Olson, H.J., 1966). Patagonia Mountains, Duquesne district, Mowry mine; Harshaw district, Flux mine (Schrader, 1917).

Yavapai County: Bradshaw Mountains, Lynx Creek, in veins with chlorite and tourmaline; Turkey Creek district, Gold Note group; Peck district, Peck and Swastika mines, associated with silver and bromargyrite. Near Yarnell, as large crystalline nodules. Stonewall Jackson mine near Prescott, as gangue associated with silver, chlorargyrite, and chalcanthite (Guild, 1917). Black Hills, at the Shea, Brindle Pup, and Mingus Mountain mines, in quartz veins with sulfides (Lindgren, 1926).

#SIDEROTIL

Iron sulfate hydrate, $Fe(SO_4)\cdot 5H_2O$. Formed as a product of the dehydration of melanterite.

Cochise County: Reported from the Bisbee area, Warren district (Graeme, 1981).

Coconino County: In breccia pipes mined for uranium (Wenrich and Sutphin, 1988).

#SIEGENITE

Nickel cobalt sulfide, $(Ni,Co)_3S_4$. Found in hydrothermal veins, associated with other copper, nickel, and iron sulfides.

Coconino County: Orphan mine, on the South Rim of the Grand Canyon; Hack mine.

SILLIMANITE

Aluminum silicate, Al_2SiO_5. Characteristically formed in high-grade, thermally metamorphosed, argillaceous rocks. Commonly associated with andalusite or cordierite.

Cochise County: Cochise district, about 2 miles southwest of Adams Peak, as acicular porphyroblasts up to 1 cm long in hornfels shale near the Texas Canyon stock (Cooper and Silver, 1964).

Coconino County: Grand Canyon, abundant in the Inner Gorge 0.5 mile downstream from Monument Creek (Campbell, 1936).

Gila and Pinal Counties: Pinal Ranch quadrangle, in Pinal Schist near post-Cambrian granite contacts (Peterson, N.P., 1962).

La Paz County: Near the eastern margins of the Dome Rock Mountains, 3 miles southwest of Quartzsite, in Precambrian schists, associated with dumortierite, kyanite, and andalusite (Wilson, E.D., 1929).

Mohave County: Hualapai Mountains, Maynard district, in quartz veins that cut schist. Cerbat Mountains, principally as the variety fibrolite in elongate masses of interlacing needles intergrown with biotite, garnet, quartz, and feldspar in migmatite (Thomas, B.E., 1953).

Pinal County: Gila Indian Reservation, Sacaton Mountains, in metamorphosed sediments encased in granodiorite, associated with titanian andalusite, corundum, and cordierite (Bideaux et al., 1960).

Yavapai County: Santa Maria Mountains, Eureka district, near Camp Wood, as veins and nodules in schist. Along Copper Creek near Bagdad, in the Hillside mica schist (Anderson, C.A., et al., 1955).

SILVER

Silver, Ag. Commonly formed in the upper portions of silver-bearing deposits and in the zone of sulfide enrichment of copper deposits with chalcocite. Also, but less commonly, of primary origin, associated with galena or tetrahedrite.

Cochise County: Tombstone district, as disseminated flakes at the Empire mine, and as small masses of wire silver at the Flora Morrison mine (Guild, 1917; Butler, B.S., et al., 1938b). Warren district, notably in the Campbell and Cole mines, in small amounts, commonly associated with, and in places coating, secondary chalcocite (H 94731, 94733; S 97831; UA 1249); Holbrook mine, in a few places with halloysite (Schwartz and Park, 1932). Pearce district, Commonwealth mine, with chlorargyrite, embolite, jarosite, and acanthite (Endlich, 1897).

Gila County: Globe district, Continental mine, as minute flakes in calcite; Old Dominion mine, as stout wires in the oxidized ores. About 4 miles north of Globe, as fine specimens in placers (Ransome, 1903a). Stonewall Jackson mine, in siderite gangue with acanthite and chlorargyrite (Guild, 1917). Richmond Basin, as one of the chief ore minerals, in fairly large masses (Peterson, N.P., 1962). Silver Butte mine at Payson, as wire silver in the oxidized ore (Lausen and Wilson, 1925). Saddle Mountain district, Little Treasure mine, as wire silver (Ross, C.P., 1925b). Four Peaks, as small dendritic pieces in calcite (MM K989).

Graham County: Aravaipa district, La Clede and Grand Reef mines, with hematite (Frank Valenzuela, UA x572).

Greenlee County: Detroit, Arizona-Copper, Shannon, Silver King, Gold Bar, Capote, Silver Bonanza, and other mines.

Maricopa County: White Picacho district, in pegmatites (Jahns, 1952).

Mohave County: Cerbat Mountains, Distaff mine, as chunks weighing several pounds, with acanthite in the deeper workings (Bastin, 1925); Chloride district, Lucky Boy and Samoa mines (Thomas, B.E., 1949); Mineral Park district, Golden Bee, Queen Bee, and Rural mines (Bastin, 1925); Stockton Hill district, Banner group of claims, in solid chunks and as masses of wire silver. Wallapai district, Tennessee-Schuylkill mine (Schrader, 1909). Buckeye mine, noted for large masses of the solid mineral and for beautiful specimens of wire silver (Newhouse, 1933).

Pima County: Tortolita Mountains, Apache property, with chalcocite and chlorargyrite. Cerro Colorado Mountains, Cerro Colorado mine, partly as wire silver, with stromeyerite and tetrahedrite (Guild, 1917; UA 2873). LeConte (1852) noted the presence of silver in a small mountain range about 40 miles southeast of Tucson; it was associated with galena and "blende." Rincon Mountain foothills, Tanque Verde district, as flakes "in considerable quantity" in copper ore (Engineering Mining Journal, 1892b). Slate Mountains, Jackrabbit mine, as flakes and thin sheets in fractures (Hammer, 1961).

Pinal County: Pioneer district, as fine specimens in the Silver King mine, where large masses of silver fill cracks in stromeyerite, bornite, and chalcopyrite; also in "beautiful filiform (specimens), the branches of which envelop individual chalcocite grains, some of the finer filaments even extending into fractures and cleavage cracks of the chalcocite" (Guild, 1917; S 65154, 65155; UA 616; H 99620); in the upper portions of the Magma mine (UA 884, 9524). Galiuro Mountains, Saddle Mountain district, Little Treasure and Adjust mines, as wire silver. Mineral Creek district, Ray mines, on the west side of the Pearl Handle pit, with secondary copper minerals (Metz and Rose, 1966). Mineral Hill district, Reymert mine, as tiny blebs in chalcopyrite (Wilson, K.S., 1984).

Santa Cruz County: Patagonia Mountains, Palmetto district, Domino mine, with crystallized cerussite and wulfenite; Harshaw district, World's Fair mine, with tetrahedrite (UA 211). Southern slopes of the Santa Rita Mountains, as small crystals surrounded by magnetite in diorite (Schrader and Hill, 1915). Oro Blanco district, Eureka-Mabel mine (Blake, W.P., 1904).

Yavapai County: Verde district, United Verde mine, as a thin layer of high-grade ore in gossan immediately above the sulfide orebody (Anderson, C.A., and Creasey, 1958). Bradshaw Mountains, at several properties, e.g., the Dos Oris mine in the Hassayampa district, with acanthite and chlorargyrite. Big Bug district, Arizona-National mine, as wire silver in cavities with acanthite (Anderson, C.A., and Creasey, 1958). Turkey Creek district, Goodwin properties, with chlorargyrite. Black Canyon district, Thunderbolt mine, with proustite. Tip Top district, Tip Top mine, with ruby silver and chlorargyrite (Lindgren, 1926). Wickenburg Mountains, Monte Cristo mine, where it formed contemporaneously with nickel-skutterudite, chalcopyrite, tennantite, enargite, and acanthite (Bastin, 1922).

SKUTTERUDITE

Cobalt nickel arsenide, $(Co,Ni)As_{2-3}$. The cobalt end member of a mineral series that forms a solid solution with nickel-skutterudite, the nickel end member. Most of the minerals in the series are arsenic deficient; iron is a common substitutional element in the series. Formed in veins at moderate temperatures. Associated with other cobalt and nickel minerals.

Graham County: Santa Teresa Mountains, Blue Bird mine, 15 miles west of Fort Thomas, as skutterudite.

SMITHSONITE

Zinc carbonate, $ZnCO_3$. A secondary mineral commonly found in the oxidized zone of zinc deposits in limestone gangue. Formed from the alteration of sphalerite and commonly associated with hemimorphite, cerussite, malachite, azurite, anglesite, and other oxidized copper, lead, and zinc minerals.

Cochise County: Tombstone district, Toughnut mine, as tiny rhombohedral crystals (Butler, B.S., et al., 1938b; UA 35). Turquoise district, Mystery and Silver Bill mines, as blue to green incrustations and crystalline masses (Knudsen, 1983; UA 6517); San Juan mine (Trischka et al., 1929). Huachuca Mountains (UA 1430). Warren district, commonly associated with siderite in the typical boxwork gossan areas (Trischka et al., 1929).

Coconino County: Grand Canyon National Park, Horseshoe Mesa, Grandview (Last Chance) mine, in small amounts, associated with malachite and azurite, lining vugs in clay in limestone (Leicht, 1971).

Gila County: Curtin and Humphrey mine, with cerussite and anglesite. Banner district, 79 mine, as a cuprian variety, as crystals lining vugs, associated with wulfenite, hemimorphite, and aurichalcite (Keith, 1972).

Graham County: Aravaipa district, Head Center mine (Simons, 1964).

Greenlee County: Shannon Mountain, Clifton-Morenci district.

La Paz County: Trigo Mountains, associated with cerussite and yellow lead oxide in cellular to crystalline masses. Silver district (Wilson, E.D., 1933).

Pima County: Empire Mountains, Hilton mines. Santa Rita Mountains, Old Baldy district (Schrader, 1917). Helvetia district, Omega mine, as microcrystals (Brian Bond, UA x2675). Sierrita Mountains, Pima district, as "dry bone ore"; Papago district, Yellow Bird mine (UA 1338, 1363). Silver Bell district, as earthy mixtures of smithsonite and cerussite. Waterman Mountains, Silver Hill mine, as small rhombohedra, pale-blue botryoidal masses (similar to material from the Kelly mine in New Mexico), and "dry bone ore," associated with rosasite (UA 1186). Tucson Mountains, Thunderbird mine (UA 1710) and Gila Monster mine (UA 2667). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as crusts and porous masses (UA 6569) and crude crystals, in some places with wulfenite.

Santa Cruz County: Patagonia Mountains, Westinghouse property at Duquesne, associated with cerussite, anglesite, chrysocolla, and cuprite (Schrader and Hill, 1915; Schrader, 1917). Santa Rita Mountains, Tyndall district, at the Glove mine in Cottonwood Canyon, abundant as "dry bone ore" incrustations in the intermediate zone of the replacement orebodies in limestone; also as rare gray balls (Olson, H.J., 1966).

Yavapai County: Eureka district, Hillside mine, in the oxidation zone of sulfide-bearing veins in mica schist, associated with cerussite, anglesite, and hemimorphite (Axelrod et al., 1951).

Yuma County: Castle Dome district, in channels and vugs, associated with hydrozincite, wulfenite, vanadinite, and mimetite (Batty et al., 1947).

#SODIUM-ZIPPEITE

Sodium uranyl sulfate hydroxide hydrate, $Na_4(UO_2)_6(SO_4)_3(OH)_{10}\cdot 4H_2O$. The sodium analog of zippeite; its properties, mode of occurrence, and associated minerals are very similar to those of that mineral.

Gila County: Cherry Creek district, reported in the Sue mine; Granger and Raup (1969) originally reported it as the sodium analog of zippeite; C. Frondel et al. (1976) subsequently established the mineral as a distinct species.

Yavapai County: Eureka district, Hillside mine, with other secondary uranium minerals (Frondel, C., et al., 1976).

SONORAITE

Iron tellurite hydroxide hydrate, $FeTeO_3(OH)\cdot H_2O$. A rare oxide-zone mineral found only at a few localities.

Cochise County: Tombstone district, Joe mine, as distinctive yellow crystal fibers up to 2 mm long, in goethite gossan with emmonsite and rodalquilarite; also replaces emmonsite spicules and tubes.

SPANGOLITE

Copper aluminum sulfate hydroxide chloride hydrate, $Cu_6Al(SO_4)(OH)_{12}Cl\cdot 3H_2O$. A rare secondary mineral associated with other oxidized copper minerals in the oxidized portions of copper deposits. First described in 1890 by S.L. Penfield on a specimen from an uncertain locality thought to be near Tombstone. Palache and Merwin (1909), however, subsequently argued that the type specimen was from Bisbee. A specimen at Yale University (No. 3482) that contains spangolite on cuprite with connellite and is identified as the type specimen from Tombstone strongly resembles known Bisbee material. A chemical analysis by S.L. Penfield of the type material gave the following results (wt %):

CuO	59.51	Al_2O_3	6.60	Cl	4.11
SO_3	10.11	H_2O	20.41	(−)O = Cl	0.92
				TOTAL	99.82

Specific gravity: 3.14

Cochise County: Warren district, Czar mine, in cuprite-azurite matrix with readily identifiable spots of spangolite up to 1/8 in. in diameter (Frondel, C., 1949); Copper Queen mine (Ford, 1914); Southwest mine, with claringbullite, atacamite, and paratacamite (Graeme, 1993); some crystal cleavages are up to 1 in. across. Turquoise district, Maid of Sunshine mine, as good crystals up to 1 mm long, with cyanotrichite, and as microcrystals (Marvin Deshler, UA x1808).

Greenlee County: Clifton-Morenci district, as a scaly coating on chrysocolla from Metcalf (Lindgren and Hillebrand, 1904; Lindgren, 1905).

#SPERTINIITE

Copper hydroxide, $Cu(OH)_2$. A rare secondary mineral.

Cochise County: Bisbee, Warren district, as sparse, pale-blue-green incrustations with internal scaly structure, on a matrix of crystalline atacamite (Graeme, 1993).

SPESSARTINE

Manganese aluminum silicate, $Mn_3Al_2(SiO_4)_3$. A less common member of the garnet group formed in skarns and other manganese-rich associations of metamorphic origin. Also formed in granite pegmatites.

Maricopa County: Southwestern slope of Squaw Peak in Phoenix, as microcrystals in schist, with manganese-rich andalusite (Thorpe, 1980).

Mohave County: Near Wright Creek Ranch, 15 miles south of Peach Springs, as a salmon-pink or wine-red accessory mineral in several pegmatite dikes in schist and granite (Schaller et al., 1962).

Pima County: Along the Mount Lemmon (General Hitchcock) Highway, as good-quality crystals (Thomas Trebisky, UA x2279).

Pinal County: Near Saddle Mountain, Winkelman area, as highly perfect crystals, with pseudobrookite, topaz, and bixbyite (White, 1992).

Yavapai County: White Picacho district, in nearly all of the pegmatites, as grains up to 0.5 in. in diameter (Jahns, 1952).

#SPHAEROCOBALTITE

Cobalt carbonate, $CoCO_3$. A member of the calcite group. Found in cobalt-bearing veins and some uranium mineral deposits.

Coconino County: Cameron area, associated with well-oxidized uranium occurrences (Austin, 1964).

SPHALERITE

Zinc sulfide, ZnS. The most abundant and important ore mineral of zinc. A widespread sulfide mineral common in the base-metal deposits in which it is formed under a wide range of conditions. Far more abundant in Arizona than is suggested by the listings below.

Cochise County: Warren district, Campbell mine, from which large quantities were mined, particularly during the years 1945 to 1949 (Trischka et al., 1929; Hewett and Rove, 1930; Schwartz and Park, 1932; Wilson, E.D., et al., 1950; Bain, 1952); triboluminescent at the Junction mine (Mitchell, 1920; S 11794). Tombstone district, Silver Thread and Sulfuret mines, and less abundant elsewhere in the district (Butler, B.S., et al., 1938b; Rasor, 1939). Little Dragoon Mountains, Cochise district, Johnson Camp area, in copper ores (Kellogg, 1906; Wilson, E.D., et al., 1950; Cooper, 1957; Cooper and Silver, 1964); Keystone and St. George deposits (Romslo, 1949). Turquoise district, as scattered bunches in pyritic ore, locally well crystallized (Wilson, E.D., et al., 1951). Huachuca Mountains, State of Texas mine (Wilson, E.D., et al., 1951). Dragoon Mountains, Abril mine, as the most abundant sulfide ore mineral (Perry, D.V., 1964).

Gila County: Banner district, as an abundant ore mineral in the lower levels of the 79 mine; as well-formed tetrahedral crystals (Kiersch, 1949; Wilson, E.D., et al., 1951; Keith, 1972); Christmas mine, as a moderately common sulfide in skarn (Knoerr and Eigo, 1963; David Perry, pers. commun., 1967). Globe-Miami district, where it is sparingly but widely distributed (Peterson, N.P., 1962).

Graham County: Aravaipa district, as gem-quality, green to yellow crystals at the Iron Cap mine (UA 5829) and other properties (Denton, 1947b; Simons and Munson, 1963; Wilson, W.E., 1988); Stanley district (Wilson, E.D., et al., 1950).

Greenlee County: Clifton-Morenci district, in large quantities in the deeper levels of many older mines (Lindgren, 1905; Guild, 1910; Reber, 1916).

Mohave County: Chloride district, Tennessee and Towne mines. Mineral Park district, Keystone mine. Cerbat Mountains, Cerbat district. Wallapai district (Haury, 1947), in most of the ores, especially at the Vanderbilt and Flores mines. Union Pass district (Schrader, 1909; Thomas, B.E., 1949; Wilson, E.D., et al., 1950). Ithaca Peak, in veins with chalcopyrite, pyrite, and galena in a quartz monzonite stock (Eidel, 1966). Near Yucca, as the most abundant sulfide in a lenticular orebody, with tremolite gangue and chalcopyrite, pyrrhotite, and minor amounts of löllingite (Rasor, 1946).

Pima County: Santa Rita and Empire Mountains, in many mines and prospects (Schrader and Hill, 1915). Sierrita Mountains, Pima district, as sulfide orebodies in limestone (Guild, 1910); Paymaster mine, Olive Camp (Ransome, 1922; Wilson, E.D., et al., 1951; Nye, 1961); San Xavier mine (UA 7220). Silver Bell district (Stewart, C.A., 1912). Twin Buttes mine near Continental, in a drill hole in the arkose (Stanley B. Keith, pers. commun., 1973).

Pinal County: Pioneer district, Belmont and Magma mines, as fine, dark-colored and green crystals up to 2.5 cm (Short et al., 1943; Barnes and Hay, 1983); Silver King mine, as the most abundant sulfide in the ore, and as cleavable masses described as being "held together by threads of native silver" (Guild, 1917; Short et al., 1943; Wilson, E.D., et al., 1950). Galiuro Mountains, Saddle Mountain district, Adjust, Saddle Mountain, and Little Treasure properties. Mammoth district, Mammoth–St. Anthony mine, on the lower levels, but extensively altered to smithsonite and hemimorphite in the oxidized zone (Peterson, N.P., 1938a,b; Fahey et al., 1950; Wilson, E.D., et al., 1950). Vekol district, Reward (Vekol) mine, marmatitic, with pyrrhotite, malachite, chrysocolla, pyrite, and chalcopyrite (Denton and Haury, 1946).

Santa Cruz County: Santa Rita and Patagonia Mountains, common in the copper and silver ores (Schrader and Hill, 1915; Schrader, 1917). As magnificent crystal groups at the Westinghouse property at Duquesne, where a single crystal measured nearly 2.5 in. in diameter; Callaghan lead-zinc mine (UA 1099) and Indiana mine (Stanley B. Keith, pers. commun., 1973). Oro Blanco Mountains, Montana mine, with galena (Guild, 1910; Wilson, E.D., et al., 1951). Ruby district, Idaho and Montana mines (Warren, H.V., and Loofburrow, 1932; Anderson, R.Y., and Kurtz, 1955). Tyndall district, Cottonwood Canyon, Glove mine (Olson, H.J., 1966).

Yavapai County: United Verde mine, in the pyritic ores (Fearing, 1926; Lausen, 1928; Moxham et al., 1965); Verde district, Copper Chief mine. Bradshaw Mountains, in most of the districts. Hassayampa district, Davis mine, as an unusual golden-yellow variety. Big Bug district, Iron King mine (Lindgren, 1926; Wilson, E.D., et al., 1950; Creasey, 1952; Anderson, C.A., and Creasey, 1958).

Sphene (see TITANITE)

SPINEL

Magnesium aluminum oxide, $MgAl_2O_4$. A relatively common mineral, the structure of which is assumed by several other oxides. Members of the spinel series that are found in Arizona are discussed individually. Spinel *sensu strictu* is formed under high-temperature conditions in contact metamorphic rocks.

Apache County: Unspecified locality near McNary (UA 3688).

Cochise County: San Bernardino Valley, in spinel lherzolite xenoliths in the basaltic and basanitic volcanic rocks of the Geronimo lavas (Evans, S.H., and Nash, 1979).

Gila County: Near Peridot, as crystals, probably of the variety picotite, in olivine volcanic bombs.

Maricopa and Yavapai Counties: White Picacho district, as greenish-black crystals of the ferroan variety, pleonaste, in pegmatites (Jahns, 1952).

Mohave County: About 9 miles south of Hoover Dam, along U.S. Highway 93, as xenoliths 1 to 2 cm in diameter, in a lherzolite rock (Garcia et al., 1980).

#SPIONKOPITE

Copper sulfide, $Cu_{39}S_{28}$. A weathering product of primary copper sulfides such as djurleite. Found in strata-bound red-bed copper deposits and in a serpentine-hosted magnetite-chromite orebody.

Cochise County: Bisbee, Warren district, in the ores of the Campbell mine (Graeme, 1993).

SPIROFFITE

Manganese zinc tellurium oxide, $(Mn,Zn)Te_3O_8$. A very rare mineral; the Tombstone locality is one of only two known in the world.

Cochise County: Tombstone district, Joe mine, very sparingly as large (0.5-in.), pale-pink, deeply corroded crystals, commonly found in intensely silicified pyritic shales; the crystals are exposed by breaking the rock "across the grain" to reveal the isolated spiroffite nuggets within.

SPODUMENE

Lithium aluminum silicate, $LiAl(SiO_3)_2$. An important ore of lithium formed in lithium-bearing granite pegmatites, where it is typically associated with quartz, albite, beryl, tourmaline, and lepidolite.

Maricopa County: White Picacho district, in some of the pegmatites, especially the Morning Star and Midnight Owl properties (Jahns, 1952, 1953). Mitchell Wash, northeast of Morristown (UA 5625).

#STANNITE

Copper iron tin sulfide, Cu_2FeSnS_4. Formed in tin-bearing vein deposits of hydrothermal origin.

Cochise County: Warren district, in the sulfide ores of the Campbell mine (Graeme, 1993).

Maricopa County: Reported from the McDowell Mountains.

STANNOIDITE

Copper iron zinc tin sulfide, $Cu_8(Fe,Zn)_3Sn_2S_{12}$. Formed in hydrothermal veins with chalcopyrite, quartz, and stannite.

Cochise County: Warren district, Campbell mine, as a coating on, or an infilling between, pyrite grains; associated with canfieldite. Selected samples of this ore (now mined out) assayed as much as 4% Ag and 4% Sn.

STARKEYITE (Leonhardtite)

Magnesium sulfate hydrate, $MgSO_4 \cdot 4H_2O$. A water-soluble secondary mineral that forms efflorescences in mine openings.

Coconino County: In breccia pipes mined for uranium (Wenrich and Sutphin, 1988).

Pinal County: Mammoth district, San Manuel mine, one of several secondary sulfate minerals formed in drifts; on the 2,015- and 2,700-ft levels with epsomite. The starkeyite may have formed when epsomite dehydrated after it was removed from the humid environment of the mine (material collected by Joseph Urban; Anthony and McLean, 1976).

STAUROLITE

Iron magnesium aluminum silicate hydroxide, $(Fe,Mg)_2Al_9Si_4O_{23}(OH)$. A relatively common mineral formed in schists during intermediate-grade metamorphism of argillaceous sediments. Commonly associated with garnet, kyanite, andalusite, sillimanite, and tourmaline in mica schists.

Coconino County: Grand Canyon, Lone Tree Canyon, as brownish-red, stout, prismatic crystals, with garnet in metamorphic rocks (Campbell, 1936).

Maricopa County: Squaw Peak in Phoenix, as small, 0.5×2 mm crystals in schist, with chloritoid, garnet, and biotite; contains 11 to 14% of the zincian end member (Thorpe and Burt, 1980).

Yavapai County: Bradshaw Mountains, in schist near contacts with intrusive granite bodies; as twinned crystals from Cleator (AM 35853).

STEIGERITE

Aluminum vanadate hydrate, $AlVO_4 \cdot 3H_2O$. A rare secondary mineral formed in sandstone with gypsum, corvusite, and secondary uranium and vanadium minerals.

Apache County: Monument Valley, Monument No. 2 mine, with navajoite and tyuyamunite (Weeks et al., 1955; Witkind and Thaden, 1963; AM 19436).

STELLERITE

Calcium aluminum silicate hydrate, $CaAl_2Si_7O_{18} \cdot 7H_2O$. A member of the zeolite group that closely resembles stilbite and, like this mineral, is commonly found in cavities and vesicles in flow rocks, especially basalt.

Cochise County: Unspecified locality near Douglas (UA 6337).

STEPHANITE

Silver antimony sulfide, Ag_5SbS_4. A late-forming vein mineral in hydrothermal deposits, where it is associated with galena, tetrahedrite, and other silver minerals.

Gila County: Richmond Basin district, Mack Morris mine, with stromeyerite (UA 1358).

Santa Cruz County: Patagonia Mountains, Patagonia district, Golden Rose mine (Schrader, 1917).

Yavapai County: Bradshaw Mountains, Bradshaw district, Tuscumbria mine.

STERNBERGITE

Silver iron sulfide, $AgFe_2S_3$. A rare mineral found in silver ores, with the ruby silvers.

Cochise County: Dos Cabezas Mountains, 150-ft level of the Leroy mine, as euhedral crystals up to 2 mm long enclosed in galena and sphalerite, in a silver-rich ore shoot.

STETEFELDTITE

Silver antimony oxide hydroxide, $Ag_2Sb_2(O,OH)_7$(?). A rare secondary mineral regarded by some authorities as the silver analog of bindheimite; others believe it to be a mixture.

Cochise County: In a prospect on the east side of the Johnny Lyon Hills, as waxy white crusts on mercurian tetrahedrite, schwatzite.

La Paz County: Trigo Mountains, Silver district, Red Cloud mine, as a yellow powder or crust on wulfenite (Gary M. Edson, pers. commun., 1973; Edson, 1980).

Pima County: Tucson Mountains, Snyder Hill mine.

STEVENSITE

Magnesium silicate hydroxide, $Mg_3Si_4O_{10}(OH)_2$. A member of the montmorillonite group of minerals. Of hydrothermal origin.

Cochise County: Warren district, Holbrook pit, in the oxide ores, intimately intergrown with clinochrysotile.

STEWARTITE

Manganese phosphate hydrate, $Mn_3(PO_4)_2{\cdot}4H_2O$. A rare secondary mineral formed from the alteration of primary phosphate minerals in granite pegmatites.

Maricopa and Yavapai Counties: White Picacho district, as numerous pale-yellow films, as finely crystallized aggregates cementing microbreccias of hureaulite and lithiophilite, and as thin, subparallel fibers along fractures in other minerals, principally strengite and purpurite (Jahns, 1952).

STIBICONITE

Antimony oxide hydroxide, $Sb_3O_6(OH)$. A secondary mineral formed by the oxidation of stibnite and other antimony minerals.

Cochise County: Warren district, 1,000-ft level of the Cole mine, with chalcocite (AM 28997).

La Paz County: Dome Rock Mountains, as radiating blades of stibnite that are partly altered to cervantite and stibiconite, in veins.

Maricopa County: Clifford claims, northeast of Tonopah, as an alteration product of massive stibnite (MM 1454).

Pima County: South Comobabi Mountains, Cababi district, Silver-Lead claim, as a granular white powder in small pockets with lead oxides (Williams, S.A., 1962).

Pinal County: Vekol Mountains, associated with galena and sphalerite.

Yavapai County: Bradshaw Mountains near Cañon, in a 2- to 3-ft vein.

STIBNITE

Antimony sulfide, Sb_2S_3. Typically formed in low-temperature hydrothermal veins with other antimony minerals. The most important ore mineral of antimony.

Gila County: Near Payson, in small amounts in some copper ores. Reported in the Mazatzal Mountains, on Slate Creek. Sunflower district, Wimpy claims (MM K070).

Graham County: Stanley district, Cold Springs prospect, in contact metamorphic ores (Ross, C.P., 1925a).

La Paz County: Dome Rock Mountains, 8 miles southwest of Quartzsite, as radiating blades, with cervantite and stibiconite.

Maricopa County: Clifford claims, northeast of Tonopah, as massive material partially altered to stibiconite (MM 1454).

Mohave County: Cerbat Mountains, Cerbat district, Golden Gem and Vanderbilt mines, with galena, sphalerite, and pyrite (Schrader, 1909; Thomas, B.E., 1949).

Pima County: Pima district, Whitcomb property, near the Olivette mine (UA 1718); Twin Buttes mine (UA 10764, x2653). Tucson Mountains (UA 1296).

Santa Cruz County: Patagonia Mountains, Nogales district, Dura mine (Schrader, 1919).

Yavapai County: Bradshaw Mountains, Tip Top district, Seventy-six, Swastika (S 116870), and Ritha B mines (Kortemeir, C.P., 1984), as well as other properties; Bradshaw district, near Tuscumbria mine and at Malley Hill mine on Lynx Creek; Walker district, Robinson property (Lindgren, 1926); Turkey Creek district.

STILBITE

Sodium calcium aluminum silicate hydrate, $NaCa_2Al_5Si_{13}O_{36} \cdot 14H_2O$. A widespread member of the zeolite group, most commonly found in vesicles and cavities in lavas, especially basalt.

Gila County: Banner district, Christmas mine, as the most common zeolite in hydrothermally altered diorite, in veinlets with associated sulfides; locally replaces diorite pervasively; also as radiating clusters of prismatic crystals that line vugs in diorite; typically light pink (David Perry, pers. commun., 1967, 1969). Globe-Miami district, Castle Dome mine, sparse in altered quartz monzonite (Peterson, N.P., et al., 1951; Peterson, N.P., 1962).

La Paz County: Moores claim (sec. 14, T. 3 N., R. 16 W.), with heulandite in basalt (William Hunt, pers. commun., 1985).

Pima County: Esperanza mine, found in drill core in 1967. Duval-Sierrita open-pit mine, in gypsum (UA 9588). Ajo district, New Cornelia mine, as yellow, bladed crystals (Thomas, W.J., and Gibbs, 1983).

Pinal County: Tortolita Mountains, Azurite mine, with laumontite and copper silicates in quartz veins (Bideaux et al., 1960).

Santa Cruz County: Patagonia Mountains, Washington Camp, on adularia (UA 8479).

Yavapai County: Burro Creek, as small, clear crystals in tuff (William Hunt, pers. commun., 1985).

#STILPNOMELANE

Potassium iron aluminum silicate hydroxide, $K(Fe^{2+},Fe^{3+},Al)_{10}Si_{12}O_{30}(OH)_{12}$. Widely distributed in iron ore deposits and certain schists.

Yavapai County: Binghampton mine, as microcrystals (Roe, A., 1980; William Hunt, UA x764).

STISHOVITE

Silicon oxide, tetragonal SiO_2. A high-density polymorph of SiO_2, notable for being the only polymorph in which silicon is in six-fold (octahedral) coordination with oxygen. A product of the high-pressure shock waves produced by meteor impact. Meteor Crater is the type locality.

Coconino County: Meteor Crater, in shock impact-metamorphosed Coconino Sandstone, with coesite (Chao, E.C.T., et al., 1962; Fahey, 1964; Bohn and Stöber, 1966; Gigl and Dachille, 1968).

STOLZITE

Lead tungstate, $PbWO_4$. A rare secondary mineral and member of the scheelite group. Found in oxidized lead deposits with cerussite, wulfenite, vanadinite, mimetite, and limonite.

Cochise County: Dragoon Mountains, Bluebird district, Boerich claims; Primos mine, as small, highly complex, pale-yellow crystals in cavities in a quartz vein containing scheelite, chalcopyrite, sphalerite, hübnerite, fluorite, and galena (Palache, 1941a; H 101780, UA x1190). Huachuca Mountains, Reef mine, as pale-yellow crystals, 1 to 2 mm long, on the walls of cavities in a quartz vein, associated with scheelite, galena, chalcopyrite, pyrite, and limonite (Palache, 1941a; H 94680). Northwest flank of the Dos Cabezas Mountains, Dos Cabezas district, as small white tablets up to 3 mm across, in quartz veins bearing scheelite, galena, and pyrite; unit cell parameters are as follows: a = 5.40, c = 12.054 Å. Bisbee, Warren district, Campbell shaft (Graeme, 1981).

Gila County: Globe-Miami district, Lost Gulch area, on the east flank of Day Peaks, as a molybdenian variety (Dale, 1961). An analysis by F.G. Hawley (Peterson, N.P., 1962) gave the following results (wt %):

PbO	56.27	As_2O_5	4.56	CaO	0.80
WO_3	25.40	P_2O_5	2.14	Fe_2O_3	0.28
MoO_3	8.62			TOTAL	98.07

Locality about 0.75 mile southwest of the Copper Cities mine, as imperfectly formed crystals in cavities in quartz and disseminated in limonite, associated with scheelite (Faick and Hildebrand, 1958).

La Paz County: Livingstone claims, south of Quartzsite.

Maricopa County: Near the mouth of Amazon Wash, east of Wickenburg.

Pima County: Helvetia district, Omega mine, as small (less than 1 mm) crystals on rosasite (Vi Frazier, UA x2147).

Yavapai County: Bradshaw Mountains, Fat Jack mine, as rough, cubic to platy crystals up to 5 cm across, with pyromorphite, mottramite, and quartz (Modreski and Scovil, 1990; Scovil and Wagner, 1991).

STRENGITE

Iron phosphate hydrate, $FePO_4 \cdot 2H_2O$. A member of the variscite group; forms a solid-solution series with the aluminum end member, variscite. Formed under surface or near-surface conditions as a product of the alteration of iron-bearing phosphate minerals.

Maricopa and Yavapai Counties: White Picacho district, as crusts and cavity fillings that are commonly small, pinkish-lavender or deep-red, felted aggregates, associated with purpurite (Jahns, 1952).

Yavapai County: 7U7 Ranch near Bagdad, as small, glassy pink crystals, with other phosphates (Peacor et al., 1984).

STRINGHAMITE

Calcium copper silicate hydrate, $CaCuSiO_4 \cdot 2H_2O$. Probably a late-stage hydrothermal mineral. Known from only a few localities.

Gila County: Banner district, Christmas open-pit mine, in tactite ores with kinoite and apophyllite; the crystals are a distinctive lavender color ("cornflower blue") but are minute and invariably form only on fractures in retrogressively altered tactites formerly rich in wollastonite.

Pima County: Pima district, Twin Buttes mine, with kinoite, copper, and apophyllite, in wollastonite (William Hefferon, pers. commun., 1983).

STROMEYERITE

Silver copper sulfide, AgCuS. An uncommon secondary mineral found in zones of sulfide enrichment. Associated with argentian tetrahedrite and bornite, with which it is commonly intimately intergrown.

Cochise County: Tombstone district (Romslo and Ravitz, 1947), Empire and Toughnut mines, where it was probably an important source of silver (Guild, 1917; Butler, B.S., et al., 1938b). Warren district, Campbell mine (Schwartz and Park, 1932) and Cole mine (Bideaux et al., 1960).

Gila County: Globe district, in the ores of the Old Dominion mine; also reported from the Mack Morris mine, Richmond Basin.

Pima County: Cerro Colorado Mountains, Cerro Colorado (Heintzelman) mine, associated with tetrahedrite and silver. South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963).

Pinal County: Pioneer district, Silver King mine, as the most important silver mineral in the ores (Guild, 1910, 1917); Magma mine, sparingly in the hypogene ores (Short et al., 1943; Hammer and Peterson, 1968; H 108641). Galiuro Mountains, lower levels of the Blue Bird mine, associated with tennantite (Kuhn, 1951).

Santa Cruz County: Patagonia Mountains, Tyndall district, Ivanhoe mine near Squaw Gulch, associated with proustite, polybasite, silver, and galena (Engineering Mining Journal, 1912).

STRONTIANITE

Strontium carbonate, $SrCO_3$. A low-temperature hydrothermal mineral formed as a gangue mineral in veins with sulfides. Also formed in veins in limestone with barite, calcite, and celestite.

Maricopa County: Sauceda Mountains, Gila Bend celestite prospect, about 15 miles south of Gila Bend, sec. 26, T. 7 S., R. 5 W., with celestite and gypsum (Moore, B.N., 1935).

Mohave County: Locality 10 miles south of Lake Mead City (Robert O'Haire, pers. commun., 1972).

#STÜTZITE

Silver telluride, $Ag_{5-x}Te_3$. Formed as replacement masses in hydrothermal deposits. Associated with other tellurides and sulfides.

Cochise County: Bisbee, Warren district, in the sulfide ores of the Campbell mine (Harris et al., 1984).

SULFUR

Sulfur, S. Formed in a variety of ways: as a result of volcanic activity; in the oxidized portions of sulfide deposits; as a product of mine-fire activity; as a result of reduction of gypsum and other sulfates; and by the partial oxidation of pyrite under special conditions, e.g., from pyritic waste in old mine dumps.

Apache County: Monument Valley, Monument No. 2 mine, as rare crystals in silicified wood (Jensen, 1958; Witkind and Thaden, 1963).

Cochise County: Tombstone district, fourth level of the Empire mine, as small, resinous, amber-yellow crystals that resemble sphalerite and replace anglesite and galena in the Skipjack shaft fissure (Butler, B.S., et al., 1938b). Warren district, Mary Jo mine; 1,500-ft level of the Junction mine, as small crystals with sphalerite; Lavender pit, in cavities left by leaching of pyrite.

Coconino County: San Francisco Mountains, in small amounts at Sunset Crater and other nearby craters (Guild, 1910).

Gila County: Globe-Miami district, Castle Dome mine, as small, well-formed crystals in open spaces in veins, formed by the oxidation of galena and sphalerite (Peterson, N.P., et al., 1951; Peterson, N.P., 1962).

Maricopa County: Surprise claims, northeast of Morristown, as crystals in cavities in quartz, formed by the decomposition of pyrite.

Pima County: Sierrita Mountains (William Kurtz, UA x392).

Pinal County: About 2.5 miles east of Winkelman, as tiny crystals lining small vugs in a quartz vein. Mammoth district, Mammoth–St. Anthony mine, in small amounts in the oxidized zone.

Santa Cruz County: Duquesne area, as microcrystals on quartz (H. Peter Knudsen, UA x1040).

Yavapai County: United Verde mine, deposited under solfataric conditions caused by the partial burning of the pyritic orebody.

SVANBERGITE

Strontium aluminum phosphate sulfate hydroxide, $SrAl_3(PO_4)(SO_4)(OH)_6$. A member of the beudantite group, found in aluminous schists. Also formed as a product of hydrothermal alteration of igneous rocks.

La Paz County: Unspecified locality near Quartzsite, in pyrophyllite with hematite (UA 9725; collected by Richard L. Jones).

Pima County: South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963).

SWARTZITE

Calcium magnesium uranyl carbonate hydrate, $CaMg(UO_2)(CO_3)_3 \cdot 12H_2O$. A rare secondary mineral formed as efflorescences on the walls of mine workings. The Hillside mine is the type locality.

Yavapai County: Hillside mine, with gypsum, schröckingerite, bayleyite, andersonite, johannite, and uraninite, as an efflorescence on the walls (Axelrod et al., 1951). A chemical analysis by F.S. Grimaldi on 0.25 g gave the following results (wt %):

MgO	5.24	UO_3	37.19	Acid Insol., Ignited	0.30
CaO	8.40	CO_2	17.16		
Na_2O	0.25	SO_3	1.98		
K_2O	0.47	H_2O	29.31	TOTAL	100.30

Specific gravity: 2.3

#SWITZERITE

Manganese iron phosphate hydrate, $(Mn^{2+},Fe^{2+})_3(PO_4)_2 \cdot 12H_2O$. Found in granite pegmatites associated with other phosphate minerals, notably spodumene.

Yavapai County: 7U7 Ranch near Hillside (Peacor et al., 1984).

#SYLVANITE

Gold silver telluride, $(Au,Ag)_2Te_4$. Most commonly formed in low-temperature hydrothermal veins but also found in moderate- and high-temperature deposits.

Cochise County: Bisbee, Warren district, among the sulfide minerals of the Campbell orebody (Criddle et al., 1983).

SYLVITE

Potassium chloride, KCl. A member of the halite group commonly formed as a widespread precipitate from oceanic waters.

Apache and Navajo Counties: East-central Arizona, encountered in drill holes that delineate a northeast-trending potash zone beneath an area of about 300 square miles, in Permian evaporites (Peirce, H.W., 1969). The log of a hole drilled at sec. 24, T. 18 N., R. 25 E. also listed carnallite, polyhalite, halite, anhydrite, and gypsum (H. Wesley Peirce, pers. commun., 1972).

SZOMOLNOKITE

Iron sulfate hydrate, $FeSO_4 \cdot H_2O$. A water-soluble secondary mineral precipitated from highly acidic solutions derived from the breakdown of pyrite. Associated with other sulfates.

Cochise County: Warren district, Lavender pit, as brown, warty crusts enclosing corroded pyrite grains, especially in intensely pyritized areas.

Pinal County: Superior district, Magma mine, as clear, colorless to tan, crystalline material with rhomboclase and voltaite.

T

TAENITE

Gamma nickel iron, γ-(Ni,Fe). Face-centered cubic structure. Contains variable amounts (from about 27 to 65%) of nickel. Associated with kamacite, a major constituent of the iron meteorites of the state.

TALC

Magnesium silicate hydroxide, $Mg_3Si_4O_{10}(OH)_2$. A layer-structured, micalike mineral formed by low-grade metamorphism of siliceous dolomites and by hydrothermal alteration of ultramafic rocks. Commonly associated with serpentine.

Apache County: Monument Valley, Garnet Ridge, in mineral fragments and in a breccia dike that pierces sedimentary rocks (Gavasci and Kerr, 1968).

Cochise County: Gunnison Hills, as an alteration product of silty dolomite pebbles in Glance Conglomerate (Cooper and Silver, 1964). Little Dragoon Mountains, near Johnson Camp, in contact-metamorphosed dolomites around the Texas Canyon stock (Cooper, 1957).

Gila County: Banner district, Christmas mine, associated with tremolite and phlogopite in diopside hornfels in the footwall of the lower Martin orebody (Perry, D.V., 1969).

Greenlee County: Clifton-Morenci district, northern part of the Morenci open-pit mine, locally formed with other calc-silicate minerals in an extensive contact metamorphic assemblage (Moolick and Durek, 1966).

Maricopa County: About 10 miles south of Wickenburg, as massive, green, waxy material in pegmatite.

Pima County: Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

Pinal County: Santa Catalina Mountains, Campo Bonito area (UA 8842).

Yavapai County: Eureka district, reported as abundant, relatively pure material.

Yuma County: Tank Mountains, as light-green foliated masses (MM 6254-6257).

#TALMESSITE

Calcium magnesium arsenate hydrate, $Ca_2Mg(AsO_4)_2.2H_2O$. A secondary mineral formed under oxidizing conditions.

Mohave County: West side of Peach Springs Canyon, as a part of bright-white incrustations with green bands and spotty yellow patches, containing hörnesite, powellite, carnotite, conichalcite, calcite, and aragonite coating the walls of a cave (Wenrich and Sutphin, 1989).

TANTALITE (see COLUMBITE-TANTALITE)

Tapiolite (see FERROTAPIOLITE)

TEINEITE

Copper tellurite sulfite hydrate, $Cu(Te,S)O_3 \cdot 2H_2O$. A very rare secondary mineral previously reported only from the Teine mine, Hokkaido, Japan, where it is associated with tellurium and sylvanite.

Cochise County: Warren district, 1,200-ft level of the Cole shaft, associated with cuprite, malachite, and graemite in a specimen collected from an ore car in 1959. One teineite crystal at least 2 cm long was totally replaced by graemite (Williams, S.A., and Matter, 1975). Analysis gave the following results (wt %):

CuO	27.4	TeO_2	56.2	H_2O	16.7
				TOTAL	100.3

Shattuck shaft, as bright-blue, oriented, partial overgrowths on graemite pseudomorphs after teineite (Graeme, 1993).

#TELLURITE

Tellurium oxide, TeO_2. An oxidation product of tellurium minerals. Commonly associated with tellurium.

Cochise County: Bisbee, Warren district, in the ores of the Campbell mine (Graeme, 1993).

TELLURIUM

Tellurium, Te. Rare; found in hydrothermal quartz veins with gold and telluride minerals.

Cochise County: Tombstone district, as microscopic blebs in galena (Butler, B.S., et al., 1938b); with mackayite and emmonsite (Bideaux et al., 1960). Warren district, Campbell orebody (Graeme, 1993).

La Paz County: Granite Wash Mountains, 4 miles north of Vicksburg.

#TELLUROBISMUTHITE

Bismuth telluride, Bi_2Te_3. Typically formed in hydrothermal, low-sulfur, gold-quartz veins. Associated with gold, gold tellurides, bismuth, tetradymite, pyrite, and other minerals.

Cochise County: Bisbee, Warren district, in the ores of the Campbell mine (Graeme, 1993).

TENNANTITE

Copper iron arsenic sulfide $(Cu,Fe)_{12}As_4S_{13}$. A common, widespread sulfosalt mineral formed in hydrothermal vein deposits with other sulfosalts and sulfides. Tennantite forms a complete solid-solution series with the antimony end member, tetrahedrite (see also this mineral description).

Cochise County: Warren district, Campbell mine, with tetrahedrite, chalcocite, bornite, enargite, and famatinite in Escabrosa Limestone, probably of hypogene origin (Schwartz and Park, 1932).

Gila County: Richmond Basin, Helene vein, silver-bearing. East slope of the Mazatzal Mountains, Ord mine, as the mercurian variety (Faick, 1958). An analysis by R.E. Stiles gave the following results (wt %):

Hg	16.8	As	9.6	MgO	1.1
Cu	31.8	Sb	6.8	Insol.	3.5
S	20.0	Fe	3.7	TOTAL	93.3

(Recalculation with Fe and MgO as siderite contaminants gives a total approaching 100%.) Globe-Miami district, Miami mine, with aikinite and enargite in veinlets that cut chalcopyrite (Legge, 1939).

Mohave County: Cerbat Mountains, as a common constituent of the high-grade silver ores, typically associated with proustite (Bastin, 1925; Thomas, B.E., 1949).

Pima County: Ajo district, rare (Gilluly, 1937). Pima district, Pima open-pit mine, as a minor primary mineral (Himes, 1972).

Pinal County: Tortilla Mountains, Florence Lead-Silver mine (Williams, S.A., and Anthony, 1970). Galiuro Mountains, Copper Creek district, Childs-Aldwinkle mine, with bornite and chalcopyrite (UA 543).

Santa Cruz County: Washington Camp–Duquesne district, with digenite, johannsenite, palygorskite, and phlogopite (Lehman, 1978).

Yavapai County: Wickenburg Mountains, Monte Cristo mine, argentiferous, with tetrahedrite, enargite, nickeline, and silver (Bastin, 1922). Verde district, United Verde mine (Anderson, C.A., and Creasey, 1958). Analyses gave the following results (wt %):

(1)					
Cu	41.6	Sb	tr.	Ag	38.08 oz/ton
Fe	0.3	As	17.4	Au	0.075 oz/ton
Zn	10.9	S	27.3		
(2)					
Cu	36.95	As	16.0	Ag	31.76 oz/ton
Sb	2.2	S	24.4	Au	0.14 oz/ton

Big Bug district, Iron King mine (Creasey, 1952).

TENORITE

Copper oxide, CuO. A relatively common mineral of secondary origin found in the oxidized zones of copper deposits, characteristically with chrysocolla, malachite, cuprite, limonite, and hematite. Only a few representative localities can be listed below.

Cochise County: Warren district, as earthy material mixed with manganese oxides (Ransome, 1904; Schwartz, 1934; Frondel, C., 1941). Dragoon Mountains, Turquoise district, Maid of Sunshine and other mines.

Gila County: Globe-Miami district, sparingly in oxidized copper ores (Schwartz, 1921, 1934); Van Dyke mine, with chrysocolla (Peterson, N.P., 1962). Banner district, 79 mine, associated with malachite and chrysocolla (Keith, 1972).

Greenlee County: Clifton-Morenci district.

La Paz County: Success mine, near Quartzsite, altering from chalcopyrite (UA 6898).

Mohave County: Kingman district, Emerald Isle mine, with chrysocolla.

Pima County: Santa Rita Mountains, Rosemont area. Pima district, Twin Buttes open-pit mine, in the oxidized portions (Stanley B. Keith, pers. commun., 1973). Helvetia district, as rare microcrystals (William Kurtz, UA x4284).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as coal-black nodules surrounded by thin shells of chrysocolla (Peterson, N.P., 1938a,b); San Manuel orebody, in lesser quantities, associated with the more abundant chrysocolla, cuprite, malachite, and copper in the oxidized portions (Thomas, L.A., 1966). Mineral Creek district, south of Ray, with chrysocolla and malachite, cementing part of the White Tail Conglomerate (Phelps, 1946; Clarke, O.M., 1953); also in Holocene gravels with jarosite, goethite, malachite, and azurite (Phillips et al., 1971).

Yavapai County: Walnut Grove district, Zonia copper mine, with malachite, cuprite, and chrysocolla (Kumke, 1947).

TEPHROITE

Manganese silicate, Mn_2SiO_4. A member of the olivine group. Of metamorphic origin, formed in iron-manganese ore deposits and their associated skarns.

Mohave County: Near Alamo Crossing (AM 34347).

TETRADYMITE

Bismuth tellurium sulfide, Bi_2Te_2S. An uncommon mineral found in gold-quartz veins and in contact metamorphic deposits associated with tellurides and sulfides.

Cochise County: Warren district, in the ores of the Campbell mine (Graeme, 1993). As an exsolution phenomenon in galena of the tungsten veins in the Texas Canyon stock (Cooper and Silver, 1964). Little Dragoon Mountains, Precious Chemical Co. property (UA 6323).

La Paz County: Reported near Vicksburg, but the exact locality is unknown.

Yavapai County: Bradshaw Mountains, in small quantities at the Montgomery mine (Guild, 1910). About 2 miles south of Bradshaw City, as bladed crystals in quartz, associated with pyrite (Genth, 1890).

TETRAHEDRITE

Copper iron antimony sulfide, $(Cu,Fe)_{12}Sb_4S_{13}$. A common, widespread sulfosalt mineral found in hydrothermal veins with other sulfosalts and sulfides. Forms a complete solid-solution series with the arsenic end member, tennantite. Crystals are typically complex and may be in zonal relationships with the isostructural minerals, freibergite and goldfieldite.

Cochise County: Tombstone district, notably at the Toughnut (UA 36), Lucky Cuss, and Ingersoll mines, but present in most ores of the district, and containing silver (Butler, B.S., et al., 1938b; Rasor, 1939; Romslo and Ravitz, 1947). Warren district, Cole mine (S 115256). Pearce Hills, Commonwealth mine, with proustite. Cochise district, Johnson Camp area, in small quartz veins at the Republic mine (Cooper and Silver, 1964), and in fissure veins of the Moore orebody (Cooper and Huff, 1951). Chiricahua Mountains, Humboldt mine, argentiferous and associated with alabandite and other sulfides, rhodonite, and rhodochrosite (Hewett and Rove, 1930).

Gila County: Globe district, Old Dominion mine, as crystals in cavities (Lausen, 1923). Payson district, as the principal ore mineral at the Silver Butte mine, where it reportedly carried considerable amounts of silver (Lausen and Wilson, 1925). Banner district, on the dump of the 79 mine (Keith, 1972).

Graham County: Aravaipa district, Grand Reef mine.

Mohave County: Reported in the Hualapai Mountains, with galena (UA 148).

Pima County: Santa Rita Mountains, Helvetia-Rosemont district, Silver Spur and Busterville mines; Greaterville district, Summit mine (Schrader and Hill, 1915). Pima district, Paymaster mine (Waller, 1960; Nye, 1961); Twin Buttes mine (William Hefferon, pers. commun.). Cerro Colorado Mountains, Cerro Colorado (Heintzelman) mine, with stromeyerite and silver. Tucson Mountains, very rare as spots on galena (Guild, 1917).

Pinal County: Pioneer district, Silver King mine (Guild, 1917); assays showed up to 3,000 oz of silver per ton, but much of the value was thought to have been due to undetected stromeyerite. Abundant in the Magma mine below the 900-ft level (Short et al., 1943). Galiuro Mountains, Copper Creek district, Blue Bird and Childs-Aldwinkle mines, associated with stromeyerite (Kuhn, 1938; Simons, 1964).

Santa Cruz County: Santa Rita Mountains, Tyndall district, Alta, Treasure Vault, and other mines; Wrightson district, as fine crystals at American Boy mine (Schrader and Hill, 1915). Patagonia Mountains, at several localities, including the World's Fair mine, where it is argentiferous (UA 1520, 7307). Ruby district, Montana and Idaho mines (Warren, H.V., and Loofburrow, 1932); analyses by F.E. Gregory and R.W. Loofburrow on 100-mg samples yielded the following results (wt %):

Idaho mine					
S	24.90	Zn	8.52	Sb	22.08
Ag	1.21	As	4.50	Insol.	3.50
Cu	32.40			TOTAL	97.11
Montana mine					
S	24.63	Zn	7.60	Sb	25.83
Ag	4.00	As	2.52	Fe	1.45
Cu	30.87	Pb	2.48	TOTAL	99.38

Warsaw property (S 118120). Armada mine, as microcrystals with sphalerite (Peter Megaw, UA x2293).

Yavapai County: Wickenburg Mountains, Monte Cristo mine, with enargite, argentiferous tennantite, nickeline, and silver (Bastin, 1922). Black Hills, United Verde, Shea, Yeager, and Shylock mines (Anderson, C.A., and Creasey, 1958). Bradshaw Mountains, at several properties in the Walker, Hassayampa, Agua Fria, and other districts (Lindgren, 1926). A partial analysis (Anderson, C.A., and Creasey, 1958) of tetrahedrite from the Shea mine, Verde district, gave the following results (wt %):

Cu	31.7	As	2.1	Ag	583.57 oz/ton
Fe	3.3	S	22.8	Au	0.21 oz/ton
Sb	23.4				

Genth (1868) reported a "Fahlerz-like" mineral associated with quartz at the Goodwin mine near Prescott.

#TETRATAENITE

Iron nickel, FeNi (ideal formula). Found in several metallic meteorites, probably formed by the ordering of Fe and Ni atoms in taenite through very slow cooling.

Coconino County: Meteor Crater near Winslow, sparsely in the Canyon Diablo meteorite (E.R.D. Scott, pers. commun., 1988).

THALENITE

Yttrium silicate hydroxide, $Y_3Si_3O_{10}(OH)$. A rare mineral formed in granite pegmatites.

Mohave County: About 5 miles southwest of Kingman, in NE1/4 NW1/4 sec. 15, T. 20 N., R. 17 W., in a prospect in claims formerly known as the Guy Hazen group (Adolph Papst, pers. commun.; Pabst and Woodhouse, 1964; Fitzpatrick and Pabst, 1986); associated with microcline and cyrtolite (zircon, the crystal structure of which has been damaged by radioactivity) in a quartz outcrop, which is part of a pegmatite in coarse granitic rock; as rough, grayish to flesh-colored crystals up to several centimeters long that have been bleached white to a depth of up to 3 mm. The specific gravity ranges from 4.16 to 4.41. Electron microprobe analysis by J. Fitzpatrick showed the following yttrium and rare earth content (wt %):

Y	44.53	Dy	3.61	Yb	5.14
Nd	0.40	Er	2.99	Ce	0.28
Ho	0.50			TOTAL	57.45

THAUMASITE

Calcium silicate hydroxide carbonate sulfate hydrate, $Ca_3Si(OH)_6(CO_3)(SO_4)\cdot 12H_2O$.

Cochise County: Tombstone district, Lucky Cuss mine, in small fissures and replacing limestone (Butler, B.S., et al., 1938b; Schaller, 1939; UA 23, 615).

THENARDITE

Sodium sulfate, Na_2SO_4. Widespread in the arid Southwest, where it may be prevalent in dry lakes and playas; also formed as white incrustations on lavas. An ephemeral mineral, which is quite common as white crusts on dark rocks, especially in the more arid parts of the state. It is more abundant in Arizona than the few localities noted below would suggest.

Cochise County: San Simon Basin, about 7 miles northeast of Bowie, in tuff-bearing, bedded lake deposits, associated with a variety of zeolite minerals (Regis and Sand, 1967; Edson, 1977).

Coconino County: Near Sunset Crater, as tufts in ice caves and as coatings on basaltic lavas.

Pima County: Tucson Mountains, as ephemeral, thin, spotty crusts on andesitic volcanic rocks.

Pinal County: Reported near Maricopa.

Yavapai County: About 3 miles southwest of Camp Verde, in salt deposits of the Verde Valley lake beds, with halite, mirabilite, and glauberite (Silliman, 1881; Blake, W.P., 1890; Guild, 1910; Peirce, H.W., 1969; Thompson, J.R., 1983). An analysis by George M. Dunham gave the following results (wt %):

Cl	0.095	CaO	0.12	Na_2O	(42.96)
SO_3	56.41	MgO	0.12	Insol.	0.39
				TOTAL	100.10

Specific gravity: 2.681

THOMSONITE

Sodium calcium aluminum silicate hydrate, $NaCa_2Al_5Si_5O_{20}\cdot 6H_2O$. A member of the zeolite group. Typically formed in cavities and vesicles in mafic igneous rocks, especially in amygdaloidal basalts.

Cochise County: Warren district.

Mohave County: San Francisco district near Oatman, in amygdules in vesicular basalt (UA 8515, 8516).

Pima County: Santa Rita Mountains, Mount Fagan, with clinochlore (variety penninite), pumpellyite, prehnite, epidote, and copper (Bideaux et al., 1960).

Pinal County: Just east of U.S. Highway 89 about midway between Tucson and Florence. In a wash 5.5 miles south of Superior, as radiating fibrous material in amygdules in basalts.

THORITE

Thorium silicate, $ThSiO_4$. Commonly contains substantial amounts of uranium, which substitutes for thorium. A primary mineral most commonly found in pegmatites.

La Paz County: Scott Lode near Quartzsite, in small amounts in a quartz vein that cuts a biotite schist (Adams, J.W., and Staatz, 1969).

Mohave County: Uranium Basin claims, as the variety uranothorite, sparsely distributed in a vein at the contact between granite and pegmatite (Adams, J.W., and Staatz, 1969).

Yavapai County: Fairview claims, south side of the Verde River, in small amounts in veinlets that cut stockwork in green metavolcanic rocks (Olson, J.C., and Adams, 1962).

Thulite (a variety of ZOISITE)

Thuringite (a variety of CHAMOSITE)

TILASITE

Calcium magnesium arsenate fluoride, $CaMg(AsO_4)F$. A rare secondary mineral formed in veins in limestone and dolomitic limestones. Associated with braunite or hausmannite. The Bisbee locality is one of only four known in the world.

Cochise County: Warren district, in an outcrop near the White Tail Deer mine, as complex crystals up to 6 mm, with braunite, conichalcite, and calcite in veinlets in clean crystalline limestone (Williams, S.A., 1970b; Bladh, K.W., et al., 1972; UA 9679).

TINZENITE

Calcium manganese iron aluminum borate silicate hydroxide, $(Ca,Mn,Fe)_3Al_2(BO_3)(SiO_3)_3(OH)$. A member of the axinite group. Commonly found in contact metamorphic aureoles formed where intrusive rocks have invaded sediments, especially limestones. Typically associated with other calcium silicate minerals.

Cochise County: Huachuca Mountains, as yellow cleavage plates in massive quartz (H 95332).

TITANITE (Sphene)

Calcium titanium silicate, $CaTiSiO_5$. A common accessory mineral in igneous rocks; also found in pegmatites and skarn.

Cochise County: Tombstone district, as microscopic crystals in granodiorite and porphyritic rocks (Butler, B.S., et al., 1938b). Little Dragoon Mountains, near Johnson Camp, with wollastonite, grossular, epidote, and other contact silicate minerals in the calcareous rocks (Cooper, 1957). Warren district, as a common accessory mineral in the Juniper Flat Granite, in some places as well-formed crystals in vugs with chlorite and quartz.

Gila County: Globe-Miami district, locally abundant in the Willow Spring Granodiorite (Peterson, N.P., 1962); Castle Dome mine, as a minor accessory mineral in quartz monzonite (Peterson, N.P., et al., 1946).

Graham County: Mount Turnbull, Aravaipa district, in micropegmatite at the Fisher prospect.

Greenlee County: Morenci district, as an accessory mineral in quartz monzonite, associated with zircon (Schwartz, 1947).

Mohave County: Aquarius Mountains, as small euhedral and long anhedral grains in pegmatite in a granite dike, associated with monazite, apatite, cronstedtite, chevkinite, and quartz; cross-cuts and apparently replaces chevkinite (Kauffman and Jaffe, 1946). Cerbat Mountains, Wallapai district, common as an alteration product in wall rocks associated with sulfide vein deposits, as long stringers and lenses replacing muscovite (Thomas, B.E., 1949). Near Wright Creek Ranch, Blue Bird (Bountiful Beryl) prospect, in several irregular pegmatite dikes in schist and granite (Schaller et al., 1962).

Pima County: East flank of the Quijotoa Mountains, Linda Lee claim, as tiny grains in spessartine-actinolite rock and in quartz monzonite (Williams, S.A., 1960). Ajo district, as a primary constituent of all igneous rocks (Gilluly, 1937). Silver Bell area, as an accessory mineral (Kerr, 1951). Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

Yavapai County: Bradshaw Mountains, Big Bug district, in schist at the Butternut mine; Pine Grove district, Springfield group of claims, as large crystals in granodiorite.

TLAPALLITE

Hydrogen calcium lead copper zinc sulfate tellurite tellurate, $H_6(Ca,Pb)_2(Cu,Zn)_3$-$(SO_4)(TeO_3)_4(TeO_6)$. A rare mineral found with other tellurium minerals in the oxidized portion of two base-metal deposits.

Cochise County: Tombstone district. A specimen labeled emmonsite, presumably from the Lucky Cuss mine, was identified as tlapallite (Williams, S.A., and Duggan, 1978). This specimen, about 50% tlapallite, cemented a calc-silicate tactite gangue. The chemical analysis of this specimen was definitive in characterizing the species, whose type locality is near Moctezuma, Sonora. That analysis gave the following results (wt %):

CaO	4.3	PbO	13.6	CuO	15.8
ZnO	0.7	TeO_2	44.3	TeO_3	12.5
SO_3	5.57	H_2O	4.25	TOTAL	101.02

TOBERMORITE

Calcium silicate hydrate, $Ca_5Si_6O_{17}\cdot5H_2O$. Formed in retrograde contact-metamorphosed carbonate sediments.

Gila County: Banner district, Christmas mine, as rare pearly-white plates plastered on fracture surfaces in metalimestone; in these rocks, the assemblage diopside-grossular has reacted to form xonotlite, then tobermorite, zeolites, and apophyllite.

#TOCORNALLITE

Silver mercury iodide, (Ag,Hg)I(?). Of uncertain composition. Associated with embolite at the type locality, Broken Hill, Australia.

La Paz County: Silver district, Padre Kino mine, as massive green material, which darkens to black on exposure to light; associated with chlorargyrite.

TODOROKITE

Manganese calcium magnesium oxide hydrate, $(Mn^{2+},Ca,Mg)Mn_3^{4+}O_7 \cdot H_2O$. A rare secondary mineral formed from the alteration of other manganese-bearing minerals.

Cochise County: Turquoise district, in prospect pits north of Courtland, intimately mixed with birnessite; the mixtures form films on fractures in altered quartz monzonite.

Pinal County: Mineral Hill district, Reymert mine, among manganese oxide minerals, including psilomelane, hollandite, coronadite, and chalcophanite.

Yuma County: Kofa district, North Star mine, No. 2 vein, with psilomelane, bixbyite, groutite, and manganite (Hankins, 1984); King of Arizona mine, with groutite, chalcophanite, aurorite, and pyrolusite (Hankins, 1984).

#TOLBACHITE

Copper chloride, $CuCl_2$. As incrustations at fumaroles associated with basaltic lava flows.

Cochise County: Bisbee, Warren district, Southwest mine, as filmy brown crusts on masses of nantokite; alters to paratacamite under humid conditions (Graeme, 1993).

TOPAZ

Aluminum silicate fluoride hydroxide, $Al_2SiO_4(F,OH)_2$. A widespread mineral typically associated with granites, pegmatites, and rhyolites. Also formed in greisen and pneumatolytic bodies.

Cochise County: Dos Cabezas Mountains, 6 miles east-southeast of Dos Cabezas and 0.75 mile southeast of the Cottonwood mine, on the William DeBorde property, as masses weighing up to several hundred pounds, with quartz and muscovite in coarse-grained granite.

Gila County: Flying W Ranch, in a quartz-topaz-sodic-plagioclase rock ("ongonite") and quartz-topaz ("topazite") dikes in three areas northwest of the ranch: the Breadpan claim, 0.5 km away, Dysart claim, 2.0 km away, and Spring Creek area, 1.3 km away; associated with muscovite, fluorite, tourmaline, and blue, acicular beryl (Kortemeir, W.T., 1986; Kortemeir, W.T., and Burt, 1988).

Mohave County: Aquarius Mountains, south of the Rare Metals mine, in pegmatites, as euhedral crystals up to 2.5 in. long (Heinrich, 1960). Negro Ed quadrangle, Negro Ed Mesa, as small crystals associated with spessartine garnets in cavities in a rhyolitic lava flow (Burt et al., 1981).

Pima County: Ajo district, rare in the New Cornelia Quartz Monzonite west of the Gibson Arroyo Fault (Gilluly, 1937). Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

Pinal County: Near Saddle Mountain, Winkelman area, in rhyolite with pseudobrookite, spessartine, and bixbyite (White, 1992).

TORBERNITE

Copper uranyl phosphate hydrate, $Cu(UO_2)_2(PO_4)_2 \cdot 8\text{-}12H_2O$. A member of the autunite group of layer-structured minerals. The water content varies between 8 and 12%; desiccation will produce the lower hydrated form, metatorbernite, and the inversion may or may not be reversible. A secondary mineral formed in the oxidized portions of uranium deposits. Commonly associated with metatorbernite, metazeunerite, autunite, and other secondary uranium minerals.

Coconino County: Cameron district, at several properties, including the Huskon claims; Grand Canyon National Park, west of Maricopa Point, in a shear zone in Coconino Sandstone. Breccia Pipe district, Riverview group of claims, with uranophane and metatorbernite (Wenrich and Sutphin, 1989).

Gila County: Sierra Ancha Mountains, with bassetite and coffinite in the Dripping Spring Quartzite. Lucky Boy mine, south of Globe, as small plates (MM 4903).

Mohave County: Hack Canyon district, Hack Canyon copper mine, associated with metatorbernite, tyuyamunite, and coffinite (Wenrich and Sutphin, 1989). Chapel district, Chapel prospect, with uranophane and autunite (Wenrich and Sutphin, 1989).

Navajo County: Monument Valley, Monument No. 1 mine (Witkind and Thaden, 1963); Mitten No. 2 mine (Witkind, 1961).

Pima County: New Cornelia open-pit mine at Ajo, reportedly formed on copper. Linda Lee claims, with gummite and hematite in a vein in arkose (Robinson, R.L., 1955). Silver Bell district, Silver Bell mine, Oxide and El Tiro pits, as transparent, emerald-green, euhedral tabular crystals up to 1 cm; readily alters to apple-green, opaque metatorbernite on exposure to air; associated with turquoise(?) crystals and cacoxenite, both of which grow on torbernite (Kenneth W. Bladh, pers. commun., 1974).

Pinal County: Mineral Creek district, 1 mile south of Kelvin, associated with turquoise (Charles L. Fair, pers. commun., 1975).

Yavapai County: Eureka district, 7U7 Ranch, in small amounts with bermanite and triplite in a pegmatite (Hurlbut, 1936).

Yuma County: Castle Dome Mountains (UA 6162).

Tourmaline (a group name)

Minerals with a common structure and complex compositions, which may be represented by this general formula: Sodium calcium magnesium iron aluminum lithium borate silicate hydroxide, $(Na,Ca)(Mg,Fe^{2+},Fe^{3+},Al,Li)_3Al_6(BO_3)Si_6O_{18}(OH)_4$. Several species and varieties of tourmaline, which typically differ in color, have been discovered. A widespread mineral group found in granite pegmatites, pneumatolytic veins, and granites. Also formed as products of metasomatism involving boron. Their resistance to mechanical and chemical weathering results in their accumulation in sands and in some sedimentary rocks. By far, the most abundant tourmaline variety is the black, iron-bearing schorl; unless otherwise indicated, the listings below refer to that species.

Apache and Navajo Counties: Common as a heavy mineral in the basal member of the Monitor Butte Sandstone, associated with apatite, leucoxene, and zircon (Young, R.G., 1964).

Cochise County: Warren district, northwest of Bisbee, as nests of small, prismatic crystals in muscovite. Johnny Lyon Hills, as a common mineral at the contact zone of the Johnny Lyon Granodiorite (Cooper and Silver, 1964).

Coconino County: Grand Canyon, Hermit Creek, as black crystals in pegmatites.

Gila County: Globe-Miami district, as a bluish-black variety widespread in the Pinal Schist (Peterson, N.P., 1962).

La Paz County: Dome Rock Mountains, with magnetite and siderite in gangue in cinnabar veins. Plomosa Mountains, Night Hawk and White Dike mines, 5.7 miles south of Quartzsite, as black, massive material associated with scheelite and quartz (Dale, 1959).

Maricopa County: Mazatzal Mountains, in cinnabar veins (Lausen, 1926). White Picacho district, in pegmatites, as schorl and elbaite, some of the latter being of the colorful "watermelon" variety (Jahns, 1952). Mummy Mountain, northeast of Phoenix.

Mohave County: Cottonwood district, near the Wright Creek Ranch, in several irregular pegmatite dikes in schist and granite, as large, podlike masses enclosing crystals of microcline, quartz, albite, fluorite, and sphene; also as abundant well-formed, prismatic crystals in the cores of pegmatites (Schaller et al., 1962). Cerbat Mountains, in small amounts with beryl in pegmatites (Thomas, B.E., 1953).

Pima County: Santa Rita Mountains, Old Baldy district, Iron Mask mine, with magnetite and siderite (Schrader, 1917). Sierrita Mountains, Papago district, as veinlike masses with quartz in granite. Little Ajo Mountains, widely distributed as brilliant black prisms coating joint planes in the Cardigan Gneiss and other rocks (Gilluly, 1937). Sierra Blanca Mountains (UA 2465). North end of the Baboquivari Mountains (UA 2470). Pima district, Twin Buttes mine (William Hefferon, pers. commun.).

Pinal County: Santa Catalina Mountains, in pegmatites in the Oracle Granite (Guild, 1910; Ward, 1931); in vein quartz in the Pinal Schist near post-Cambrian granite contacts (Ransome, 1919). Galiuro Mountains, Copper Creek district, as radiating groups of slender prismatic crystals, notably in the breccia pipe of the American Eagle mine (Simons, 1964); Childs-Aldwinkle mine, as a gangue mineral in the breccia pipe deposit (Kuhn, 1941); Copper Creek Canyon, as gray to green dravite crystals in masses and small fan-shaped aggregates enclosed in quartz crystals, some of which are Japan twins (William and Mildred Schupp, pers. commun.; Gary M. Edson, pers. commun., 1972).

Santa Cruz County: Patagonia district, Duquesne and Washington Camp areas, abundant in contact metamorphic deposits. Tyndall district (Schrader, 1917).

Yavapai County: Bradshaw Mountains, in pegmatites of the Bradshaw Granite, in lenses in schist, and scattered throughout the schist near granite contacts. In veins of the Prescott district. Big Bug district, Iron King mine, as blue-gray prisms in quartz and dolomite (Lindgren, 1926; Creasey, 1952). Eureka district, in pegmatites of the Bagdad area (Anderson, C.A., 1950).

TREMOLITE

Calcium magnesium silicate hydroxide, $Ca_2Mg_5Si_8O_{22}(OH)_2$. A member of the amphibole group. Typically formed in contact-metamorphosed limestones and dolomites with other calcium silicate minerals. In Arizona, a common gangue mineral associated with contact metamorphic base-metal deposits.

Cochise County: Warren district, as an abundant gangue mineral of the unoxidized pyritic ores. Tombstone district, Toughnut mine, as long, fibrous masses (Butler, B.S., et al., 1938b). Little Dragoon Mountains, in the metamorphosed dolomites (Cooper and Huff, 1951; Cooper, 1957; Cooper and Silver, 1964).

Coconino County: Grand Canyon, in tremolite-talc dikes in the Vishnu Schist; the largest, at mile 83, is 80 m wide (Clark, M.D., 1979).

Gila County: Banner district, Christmas mine, associated with diopside, a prominent gangue mineral formed by contact metamorphism of dolomitic rocks (Peterson, N.P., and Swanson, 1956; Perry, D.V., 1969); 79 mine, with andradite, diopside, and epidote in contact-metamorphosed limestones (Keith, 1972).

Greenlee County: Clifton-Morenci district, in contact-metamorphosed limestones with other calc-silicate minerals (Lindgren, 1905; Moolick and Durek, 1966).

La Paz County: Harquahala Mountains, in sec. 14, T. 5 N., R. 10 W., in a large outcrop of crystalline material containing crystals up to 4 cm long, in marble (David Shannon, pers. commun., 1988). Northern Dome Rock Mountains, as an asbestiform variety in marbleized limestones.

Maricopa County: Near Aguila, replacing limestone (UA 5907).

Mohave County: Copper World mine near Yucca, as a gangue mineral in a lenticular copper-zinc sulfide orebody (Rasor, 1946). Hualapai Mountains, Antler mine (Romslo, 1948).

Pima County: Pima district, Pima mine, abundant in limestone hornfels with diopside and grossular (Journeay, 1959); Twin Buttes mine, in the tactites and skarns (Stanley B. Keith, pers. commun., 1973); Mission mine, in the hornfels host rock (Richard and Courtright, 1959); Mineral Hill mine and other properties, associated with mineral deposits of contact metamorphic origin (Ransome, 1922). Helvetia district, in contact-metamorphosed sedimentary rocks at several properties, including the Copper World, Leader, Narragansett, and Isle Royal mines (Creasey and Quick, 1955).

Santa Cruz County: Patagonia Mountains, as gangue at the Westinghouse property (Schrader and Hill, 1915); Washington Camp and Duquesne areas, in contact metamorphic deposits in limestone (Schrader, 1917).

TRIDYMITE

Silicon oxide, SiO_2. A high-temperature polymorph of silica typically formed in felsic volcanic rocks. Commonly associated with sanidine and hornblende or augite.

Greenlee County: Big Laue Mountain, in road cuts along State Highway 78, about 6 miles west of the New Mexico border, as crystals up to 8 mm in light-colored volcanic rock, with pseudobrookite and titanite (William Hunt, pers. commun., 1989).

Mohave County: Cerbat Mountains, along the western edge of the Chloride district, in a tuffaceous breccia found among stratiform volcanic rocks (Thomas, B.E., 1953).

Pima County: Roskruge Mountains, with cristobalite and clay in cavities in andesite.

TRIPHYLITE

Lithium iron manganese phosphate, $Li(Fe^{2+},Mn^{2+})PO_4$. A primary mineral formed in granite pegmatites. A complete solid-solution series probably extends between the end members triphylite and lithiophilite, $Li(Mn^{2+},Fe^{2+})PO_4$.

Yavapai County: White Picacho district, with lithiophilite in the Midnight Owl and other pegmatites, as rough-faced, equant to stubby, prismatic crystals up to 6 in. long (Jahns, 1952).

TRIPLITE

Manganese iron magnesium calcium phosphate fluoride hydroxide, $(Mn,Fe,Mg,Ca)_2(PO_4)(F,OH)$. A primary mineral formed in phosphate-rich granite pegmatites.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites, especially well crystallized in the Midnight Owl pegmatite, as rough-faced tabular crystals up to 7 in. long (Jahns, 1952).

Yavapai County: Eureka district, 7U7 Ranch, as a spherical aggregation about 2 ft in diameter in a small pegmatite knot (Hurlbut, 1936; Leavens, 1967). An analysis by F.A. Gonyer gave the following results (wt %):

FeO	11.68	CaO	2.48	P_2O_5	33.32
MnO	34.55	Na_2O	0.52	F	8.02
MgO	11.87	H_2O	0.75	(−)O = F	3.38
				TOTAL	99.81

Also at other localities in the same area.

#TRIPLOIDITE

Manganese iron phosphate hydroxide, $(Mn^{2+},Fe^{2+})_2(PO_4)(OH)$. Found in granite pegmatite.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites (London, 1979).

TROILITE

Iron sulfide, FeS. Closely related to pyrrhotite. In Arizona, found only in metallic meteorites and what are probably meteor impact-produced spheroids.

Coconino County: Meteor Crater, as a minor constituent of metallic spheroids, which were probably formed upon impact of the Canyon Diablo meteorite; intergrown with schreibersite, formed interstitially along grain boundaries of the kamacite cores; also associated with maghemite and a goethitelike iron oxide, both produced by weathering (Mead et al., 1965).

#TSCHERMAKITE

Calcium magnesium iron aluminum silicate hydroxide, $Ca_2(Mg,Fe^{2+})_3Al_2(Si_6Al_2)O_{22}(OH)_2$. Formed in both igneous and metamorphic rocks.

Santa Cruz County: Blue Jay mine, with graphite in metamorphosed limestone.

TSUMEBITE

Lead copper phosphate sulfate hydroxide, $Pb_2Cu(PO_4)(SO_4)(OH)$. A very rare secondary mineral formed in the oxidized portion of base-metal deposits. The Arizona localities are some of the very few reported in the world.

Greenlee County: Morenci, with wulfenite in the oxidized portion of the Clay orebody (Bideaux et al., 1960; UA 2393, 2394, 5687).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, very rare as yellow-green spherules, with mimetite and wulfenite (Bideaux, 1980).

TUNGSTITE

Tungsten oxide hydrate, $WO_3 \cdot H_2O$. An uncommon mineral formed by the alteration of primary tungsten minerals such as wolframite and scheelite, with which it is commonly associated. Reported in small amounts at several tungsten districts in the state.

Mohave County: Boriana mine (Chatman, 1988; MM 1019).

TURQUOISE

Copper aluminum phosphate hydroxide hydrate, $CuAl_6(PO_4)_4(OH)_8 \cdot 5H_2O$. Commonly iron bearing. The aluminum-rich end member that forms a solid-solution series with the iron-rich end member, chalcosiderite (see also this mineral description). A widely distributed mineral commonly thought to be of secondary origin. Associated with limonite and clay minerals in the upper, oxidized portions of some base-metal deposits in the Southwest. A few representative localities are listed below.

Cochise County: Turquoise district near Gleeson, mined at Turquoise Mountain, where it formed stringers up to a few inches wide, and small nuggetlike masses in granite and Bolsa Quartzite (Crawford and Johnson, 1937; UA 9688). Warren district, 1,200-ft level of the Cole shaft, as minute stringers in massive pyrite (UA 1243); Lavender open-pit mine, as large, rich masses (UA 6669). Reported in the Pearce area (Guild, 1910).

Gila County: Globe-Miami district, in small amounts with copper ores in several deposits; Sleeping Beauty mine near Miami, as beautiful, gem-quality material (Jackson, 1955; H 106506; UA 8944); Castle Dome and Copper Cities mines, in substantial quantities (Peterson, N.P., et al., 1946, 1951; Peterson, N.P., 1962; Simmons and Fowells, 1966; UA 1162, 1163). Reported in Canyon Creek.

Graham County: Gila Mountains, Lone Star district, Safford porphyry copper deposit, intimately associated with jarosite and alunite in the oxidized zone (Robinson, R.F., and Cook, 1966).

Greenlee County: Clifton-Morenci district, as thin plates and nodules that are closely associated with a diabase dike system that crosses the Morenci orebody (Moolick and Durek, 1966); with alunite, wavellite, conichalcite, and "bisbeeite," in seams that cut the Candelaria breccia pipe (Bennett, K.C., 1975).

Maricopa County: Nine miles northeast of Morristown. Near Mineral Peak, at several mines that reportedly yielded large quantities of gem-quality material.

Mohave County: Cerbat Mountains, Wallapai district, Ithaca Peak (Sterrett, 1908; Crawford and Johnson, 1937; Thomas, B.E., 1949; Eidel et al., 1968), as gem-quality material in a porphyry body that cuts schist and gneiss (Schrader, 1907; Guild, 1910; UA 1161, 6675; NHM 86815). Turquoise Mountain, as gem-quality material in veins in gold-bearing quartz (Frenzel, 1898).

Pima County: Pima district, Esperanza mine (Schmidt, H.A., et al., 1959; Loghry, 1972); Twin Buttes mine (William Hefferon, pers. commun., 1983). Silver Bell district, Silver Bell mine, Oxide pit, as transparent, tabular green crystals up to 1 mm, in subparallel aggregates; associated with torbernite and cacoxenite at the contact of an andesite dike (Kenneth W. Bladh, pers. commun., 1974; UA x215).

Pinal County: Mineral Creek district, 1 mile south of Kelvin, associated with torbernite (Charles L. Fair, pers. commun., 1975).

Yavapai County: Reported in the county, but the specific locality is unknown.

TYROLITE

Copper calcium arsenate carbonate hydroxide hydrate, $Cu_5Ca(AsO_4)_2(CO_3)(OH)_4 \cdot 6H_2O$. A rare secondary mineral found in oxidized portions of copper deposits.

Pinal County: Superstition Mountains, as films on mercurian tetrahedrite (variety schwatzite).

TYUYAMUNITE

Calcium uranyl vanadate hydrate, $Ca(UO_2)_2(VO_4)_2 \cdot 5\text{-}8H_2O$. A widespread secondary mineral associated with carnotite, uranophane, and other uranium and vanadium minerals. Resembles carnotite but is less common.

Apache County: Lukachukai Mountains, Mesa No. 1 and No. 5 mines. Carrizo Mountains, Cove Mesa, Chinle area. Black Mesa Basin, at numerous claims (Garrels and Larsen, 1959). Monument Valley, Monument No. 2 mine (Rosenzweig et al., 1954; Mitcham and Evensen, 1955; Weeks et al., 1955; Finnell, 1957; Evensen and Gray, 1958; Young, R.G., 1964). Garnet Ridge near Dinnehotso (Witkind and Thaden, 1963; Gavasci and Kerr, 1968).

Cochise County: Warren district, Cole mine, lining cracks and fissures in limestone country rock adjacent to massive chalcocite-covellite orebodies (Hutton, 1957; UA 6158, 6239; S 96427); Campbell mine (AM 21108).

Coconino County: Cameron area, Black Point–Murphy mine (Austin, 1964). Prospect Canyon district, Ridenaur mine, with vesignieite, naumannite, bromargyrite, calciovolborthite, and metatyuyamunite (Wenrich and Sutphin, 1989).

Mohave County: Hack Canyon.

Navajo County: Monument Valley, at several mines and claims, notably at the Monument No. 1 mine (Evensen and Gray, 1958; Holland et al., 1958; Witkind, 1961; Witkind and Thaden, 1963).

U

#ULVÖSPINEL

Titanium iron oxide, $TiFe_2^{2+}O_4$. A common constituent of titaniferous magnetites, in which it may form fine exsolution lamellae. Provenance is much like that of magnetite.

Gila County: San Carlos Indian Reservation, Soda Springs vent, as skeletal-growth octahedral megacrystals up to 2 cm in a mugearite (rock), with ferrokaersutite, anorthoclase, and ferroan biotite (Caporuscio, 1980).

UMOHOITE

Uranyl molybdate hydrate, $(UO_2)MoO_4{\cdot}4H_2O$. A secondary mineral formed during the early stages of oxidation of primary uranium minerals.

Coconino County: Cameron district, Alyce Tolino mine, as a blue-black, opaque, isotropic mineral contained in sooty masses and carbonaceous trash replacements (Hamilton, P., and Kerr, 1959).

URANINITE

Uranium oxide, UO_2. Typically partially oxidized. Uraninite is commonly formed in hydrothermal veins. In Arizona, it is most notable in deposits in the sedimentary rocks of the Colorado Plateau, where it may be associated with coffinite and a wide variety of secondary uranium, vanadium, and copper minerals. C. Frondel (1958) collected the unit cell parameters of the cubic mineral for several Arizona localities, including Workman Creek, Globe, 5.430 Å; Monument No. 2 mine, Apache County, 5.427 Å, 5.421 Å, 5.415 Å, and 5.412 Å; Cato Sells mine, Apache County, 5.40 Å; Monument No. 2 mine, 5.40 Å; and Huskon mine, Cameron, 5.39 Å.

Apache County: Lukachukai Mountains, at several claims and mines, including Luki, Mesa 1³/₄, Mesa 2, Cove School, and Mesa 4¹/₂ (Joralemon, 1952). Monument Valley, Monument No. 2 mine (Rosenzweig et al., 1954; Mitcham and Evensen, 1955; Jensen, 1958; Witkind and Thaden, 1963; Young, R.G., 1964); Bootjack mine; Garnet Ridge near Dinnehotso (Witkind and Thaden, 1963).

Cochise County: Warren district, reported in very small amounts in some of the underground workings (Richard Graeme, pers. commun., 1974).

Coconino County: Hosteen Nez claim, near Tuba City. Cameron district (Austin, 1964), Henry Sloan No. 1 mine, with marcasite in calcite cement in sandstone bordering carbonaceous fossil wood; Ramco No. 22 mine; Huskon No. 7 mine; Sun Valley mine, as replacements of rounded detrital grains with pyrite and sphalerite (Petersen et al., 1959; Petersen, 1960); Arrowhead mine (Rosenzweig et al., 1954; Holland et al., 1958); Boyd Teise No. 2 mine, in flattened nodules with pyrite in sandstone (AEC mineral collection). South Rim of the Grand Canyon, Orphan mine, as the fairly pure mineral in disseminations and as veins and lenses up to several inches thick, in a nearly vertical, circular or ellipsoidal, pipelike body of collapse breccia developed primarily in the Permian Coconino Sandstone; associated with pyrite and other sulfides and sulfosalts of copper, lead, zinc, cobalt, nickel, and molybdenum; secondary minerals of uranium are common in the mine workings (Granger and Raup, 1962).

Gila County: Several localities in the Dripping Spring Quartzite, adjacent to diabase (Granger, 1956). Turquoise mines, in T. 5 N., R. 15 E., associated with pyrite, marcasite, and chalcopyrite (Granger and Raup, 1959, 1962). Northern region, in Dripping Spring Quartzite at the Black Bush, Hope, Little Joe, Lucky Stop, Red Bluff, Rock Canyon, Suckerite, Sue, Tomato Juice, and Workman deposits, as fissure and open-space fillings or as lenses and blebs in host rock (Granger and Raup, 1969). Globe district, Old Dominion vein; Iron Cap mine near Miami, with iron oxides (S 112722).

Mohave County: Hack Canyon (UA 6115, 6116, 6118).

Navajo County: Several localities, including the Monument No. 1 mine in Monument Valley (Evensen and Gray, 1958; Witkind and Thaden, 1963). Petrified Forest near Holbrook, Ruth group of claims. Stinking Spring near Hunt (Rosenzweig et al., 1954).

Pima County: Rincon Mountains, Black Rock claims.

Santa Cruz County: Oro Blanco district, Annie Laurie prospect near Ruby (Anderson, R.Y., and Kurtz, 1955; Granger and Raup, 1962). Alamo Spring, with uranophane and autunite. Santa Rita Mountains, Wrightson district, Happy Jack mine (Butler, G.M., and Allen, 1921).

Yavapai County: Hillside mine (Granger and Raup, 1962).

URANOCIRCITE

Barium uranyl phosphate hydrate, $Ba(UO_2)_2(PO_4)_2{\cdot}12H_2O$. An uncommon member of the autunite group. Of secondary origin.

Coconino County: Cameron area, associated with meta-uranocircite in some of the uranium deposits of the area (Austin, 1964).

URANOPHANE

Calcium uranyl silicate hydrate, $Ca(UO_2)_2Si_2O_7{\cdot}6H_2O$. One of the most common of the secondary uranium minerals. In some places, formed as fine crystals.

Apache County: Monument Valley, Monument No. 2 and Cato Sells mines (Witkind and Thaden, 1963).

Coconino County: Cameron area, in minor amounts in uranium ore in the Shinarump Conglomerate, in paleo-stream channels, and in the Chinle Formation in sandy portions of mounds, associated with uraninite, metatorbernite, and meta-autunite (Holland et al., 1958); Black Point–Murphy mine, intimately mixed with uranophane-beta in Pleistocene gravels (Austin, 1964). Breccia Pipe district, Riverview group of claims, with torbernite and metatorbernite (Wenrich and Sutphin, 1989).

Gila County: Northwestern region, in Dripping Spring Quartzite at the Fairview, Little Joe, and Red Bluff deposits (Granger and Raup, 1969).

Mohave County: Chapel district, Chapel prospect, with autunite and torbernite (Wenrich and Sutphin, 1989).

Pima County: East flank of the Quijotoa Mountains, Linda Lee claims, as fracture coatings in a contact metamorphic assemblage (Williams, S.A., 1960).

Santa Cruz County: In a vein near Alamo Springs, associated with autunite and uraninite. Santa Rita Mountains, Duranium claims, in arkosic sandstone with kasolite and autunite (Robinson, R.L., 1954). Nogales district, White Oak property, with kasolite and oxidized lead ore in shear zones in rhyolite (Granger and Raup, 1962).

Yavapai County: Weaver Mountains, Peeples Valley mine (Granger and Raup, 1962).

URANOPHANE-BETA

Calcium uranyl silicate hydrate, $Ca(UO_2)_2Si_2O_7 \cdot 6H_2O$. A secondary mineral, dimorphous with uranophane.

Coconino County: Near Cameron (Bollin and Kerr, 1958).

Gila County: Northwestern region, Red Bluff, Lucky Stop, and Hope deposits, in Dripping Spring Quartzite (Granger and Raup, 1969).

URANOSPINITE

Calcium uranyl arsenate hydrate, $Ca(UO_2)_2(AsO_4)_2 \cdot 10H_2O$. A member of the autunite group. Of secondary origin.

Coconino County: Grand Canyon National Park, Orphan mine (AM 33454).

Ureyite (see KOSMOCHLOR)

UVANITE

Uranium vanadium oxide hydrate, $U_2V_6O_{21} \cdot 15H_2O$(?). An uncommon mineral associated with the uranium-vanadium ores of the Colorado Plateau, where it probably forms by the alteration of uraninite and possibly tyuyamunite.

Apache County: Monument Valley, Monument No. 2 mine (Frondel, C., 1958).

UVAROVITE

Calcium chromium silicate, $Ca_3Cr_2(SiO_4)_3$. An uncommon member of the garnet group. Formed with chromite in serpentines and granular limestones.

Mohave County: Cerbat Mountains, Wallapai district; an emerald-green garnet found in migmatite just east of the Tennessee mine staff house is believed to be this mineral (Thomas, B.E., 1953).

#UYTENBOGAARDTITE

Silver gold sulfide, Ag_3AuS_2. Formed in low-temperature, silver-gold quartz veins.

Cochise County: Dos Cabezas Mountains, Comstock mine, as small patches up to 0.5 mm in galena; the uytenbogaardtite is separated from the host galena by a phase whose composition, determined by microprobe analysis, is Ag_2PbS_2.

≡ V

VAESITE

Nickel sulfide, NiS_2. A rare mineral of primary origin. A member of the pyrite group.

Coconino County: Grand Canyon National Park, Orphan mine, as brilliant, tin-white crystals up to 2 mm in diameter perched on coarse, yellow barite crystals; $a = 5.632$ Å.

VALLERIITE

Iron copper sulfide magnesium aluminum hydroxide, $4(Fe,Cu)S \cdot 3(Mg,Al)(OH)_2$. An uncommon mineral thought to be of high-temperature origin.

Gila County: Banner district, Christmas mine, as rod-shaped grains in chalcopyrite in the pyrrhotite-chalcopyrite outer ore zone of orebodies, replacing dolomite (Perry, D.V., 1969).

Pima County: Pima district, Pima mine, associated with magnetite; Twin Buttes mine (William Hefferon, pers. commun., 1983).

VANADINITE

Lead vanadate chloride, $Pb_5(VO_4)_3Cl$. A comparatively rare mineral formed in some oxidized lead deposits. Typically associated with wulfenite, cerussite, and descloizite. The discovery of vanadinite in Arizona during the 19th century, at localities such as the Vulture and Red Cloud mines, aroused considerable interest among eastern mineralogists and led to several reports in the *American Journal of Science.* A sparse but widely distributed mineral in the state.

Cochise County: Tombstone district, on calcite at the Tribute and Tombstone Extension mines (Butler, B.S., et al., 1938b); Gallagher Vanadium property near Charleston, as masses of brownish crystals (S 15016; UA 6903). Huachuca Mountains, Davis property (UA 8172). Swisshelm Mountains near Elfrida (UA 5668, 9349).

Coconino County: Bright Angel Creek, as hollow incrustation pseudomorphs of brown vanadinite after calcite scalenohedra, in places only incrusting calcite (Frondel, C., 1935; S 94280).

Gila County: Dripping Spring Mountains, Banner district, 79 mine (Keith, 1972), and McHur, Premier and C & B (International) properties (Allen, M.A., and Butler, 1921c); southwest and northeast workings of the Kullman-McCool (Finch, Barking Spider, D.H. claims) mine, as single crystals and as a replacement of wulfenite. Near Hayden, with calcite and siderite (S 115636; UA 134). Globe-Miami district, Lockwood claims; Clark and Stewart claims, near the Old Dominion mine; Defiance and Albert Lea deposits (Peterson, N.P., 1962). Apache mine, abundant as fine specimens of deep-red, well-crystallized, stocky prismatic vanadinite, characteristically having a background of dark mottramite on mottled quartzite of the Precambrian Pioneer Formation; crystals are commonly 1 to 2 mm long, although the best range up to 6 to 7 mm; crystals up to 2 or 3 cm have been reported (Guild, 1910; Wilson, W.E., 1971; UA 6228, 7092). Ruby Star mine near the Apache mine, as small, red crystals up to 0.5 mm long. Tonto Basin (UA 8603).

Greenlee County: North of Metcalf, as doubly terminated, single crystals in gravels of the Haggin placers along the Coronado Trail.

La Paz County: Trigo Mountains, Silver district, North Geronimo mine, as bright red crystals, some with wulfenite; Silver King mine, as small, red to orange crystals, many with fluorite. Silver Clip and Princess mines, as fine crystal aggregates. As deep-red, brilliant crystals at the Red Cloud mine, where Silliman (1881) noted their great beauty and extraordinary color (see also Hills, 1890); Hamburg mine (Shannon, D.M., 1980; H 64115); Ronaldo Pacheco's mine, as crystals of outstanding beauty (S 48793).

Maricopa County: Hieroglyphic Mountains, with wulfenite in veins (Silliman, 1881). Vulture Mountains, Collateral, Phoenix, Montezuma, and Frenchman mines. Painted Rock Mountains, Rowley mine near Theba (Wilson, W.E., and Miller, 1974); White Picacho district (Jahns, 1952). Baldy Mountain quadrangle, Prince mine, with wulfenite (Flagg, 1942).

Mohave County: Cerbat Mountains, El Dorado and Climax mines; Gold Basin district (Schrader, 1909). Western (Western Union) mine, as sheaflike bundles and single, doubly terminated crystals of the variety endlichite.

Pima County: Tucson Mountains, Old Yuma mine, as exceptionally beautiful specimens (Jenkins and Wilson, 1920), and as pseudomorphs after wulfenite

(Frondel, C., 1935; AM 18716; UA 6294; NHM 1968,1097, and others). Bowman (1903) determined the indices of refraction for red light of a ground crystal from the Old Yuma mine using the method of minimum deviation, with the following result: E-2.299, O-2.354. Empire Mountains, Total Wreck mine (Schrader and Hill, 1915; Schrader, 1917). South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Pima district, Twin Buttes mine (Stanley B. Keith, pers. commun., 1973). Helvetia-Rosemont district, as a secondary mineral in replacement deposits in metamorphosed limestones, associated with wulfenite, jarosite, and iron and manganese oxides (Schrader, 1917).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, first noted by Genth (1887a), with descloizite; Royal Dane property, 7 miles southeast of Oracle. Dripping Spring Mountains, Riverside district, Grey Horse mine, as crystals exceeding 2.5 cm in length, in large groups (Newhouse, 1934; Clark, A., and Fleck, 1980). Galiuro Mountains, Table Mountain mine, as the arsenian variety endlichite, with wulfenite. Pioneer district, Black Prince (Olsen) mine, as doubly terminated crystals (Blake, W.P., 1881a; Penfield, 1886; AM 15129). Slate Mountains, Jackrabbit mine, as coarse crystalline masses with manganese oxides, in vugs in limestone (Hammer, 1961). Northeast side of the Santa Catalina Mountains, Bear Cat claims (Dale, 1959).

Santa Cruz County: Patagonia Mountains, Patagonia district, Mowry mine; J.C. Holmes claims, near Temporal Gulch in sec. 36, T. 21 s., R. 15 E., about 3 km northwest of Patagonia, as splendid crystals, some of good color, obtained in 1982 and 1983 (Pellegrin, 1911; Novak and Besse, 1986). Harshaw district, Flux mine. Tyndall district, Cottonwood Canyon, Glove mine, with wulfenite and smithsonite (Olson, H.J., 1966).

Yavapai County: Kirkland gold mines, as fine specimens. Big Bug district, near the Silver Belt mine. Humboldt, as masses of 0.25-in., yellow-brown crystals (H 103031).

Yuma County: Castle Dome district, in channels and vugs (Wilson, E.D., 1933); Hull mine, as small yellow to brown crystals; Puzzler mine, as large, green to brown crystals up to 3 cm long, some of which are barrel-shaped, associated with barite, cerussite, anglesite, and wulfenite. Reported in the Chocolate Mountains. Muggins Mountains, Red Knob mine, associated with wulfenite, cuprite, chalcedony, limonite, weeksite, opal, and carnotite (Honea, 1959; Outerbridge et al., 1960).

VANDENDRIESSCHEITE

Lead uranium oxide hydrate, $PbU_7O_{22}\cdot 12H_2O$. A secondary mineral closely associated with uraninite, of which it is an oxidized alteration product.

Apache County: Monument Valley, Monument No. 2 mine (specimen collected by Joseph Urban).

#VANMEERSSCHEITE

Uranium uranyl phosphate hydroxide hydrate, $U^{6+}(UO_2)_3(PO_4)_2(OH)_6 \cdot 4H_2O$. Formed in granite pegmatite at the type locality, Kobokobo, Zaire.

Coconino County: In some uranium prospects east of Cameron, as bright-yellow, scaly crusts coating fractures that cut sandstone impregnated with carbon.

VANOXITE

Vanadium oxide hydrate, $V_4^{4+}V_2^{5+}O_{13} \cdot 8H_2O$. An associate of the uranium-vanadium ores of the Colorado Plateau, where it formed massively, as cement in sandstone.

Apache County: In the Lukachukai Mountains, at King Tut Mesa, and on the Rattlesnake anticline (both north of the Lukachukai Mountains), impregnating certain beds of the Salt Wash Member of the Morrison Formation, associated with carnotite (Masters, 1955).

VARISCITE

Aluminum phosphate hydrate, $AlPO_4 \cdot 2H_2O$. Formed under near-surface conditions by the action of phosphatic waters on aluminous rocks.

Apache County: Monument Valley, Monument No. 2 mine, as white to gray coatings and minute sprays of white crystals (Patrick Haynes, pers. commun., 1992).

Cochise County: Warren district, Cole mine, as unusual, pale-green, massive, ferrian material (Sinkankas, 1964).

#VATERITE

Calcium carbonate, $CaCO_3$. A trimorph with calcite and aragonite.

Maricopa County: In drill cores taken in basins of the Phoenix area (H. Wesley Peirce, pers. commun., 1989).

VAUQUELINITE

Lead copper chromate phosphate hydroxide, $Pb_2Cu(CrO_4)(PO_4)(OH)$. A rare mineral of secondary origin found in the oxidized portions of metalliferous deposits. Typically associated with other chromates, including phoenicochroite and crocoite.

Cochise County: About 8 miles north of Benson, in quartz veins that cut gneiss, in minor amounts with pyromorphite, chrysocolla, and perite (Phelps Dodge Corp., pers. commun., 1972).

Maricopa County: Vulture region, east of Trilby Wash, at the Collateral, Chromate, Blue Jay, and Phoenix properties (Silliman, 1881). South of Wickenburg at several localities, including the Moon Anchor mine, Rat Tail claim, and Potter-Cramer property, as a minor mineral in the oxidized zone of lead-zinc ore, associated with wickenburgite, willemite, mimetite, phoenicochroite, and hemihedrite (Williams, S.A., 1968; Williams, S.A., et al., 1970; Williams, S.A., and Anthony, 1970). Osborn district, Tonopah-Belmont mine, as greenish-brown to brown crystals up to 2 mm, with willemite and pyromorphite (Allen, G.B., and Hunt, 1988).

Pinal County: Tortilla Mountains, Florence Lead-Silver mine, in an oxide mineral assemblage that replaced galena, sphalerite, pyrite, and tennantite along a sheared and mineralized fault zone separating limestone and quartzite; associated with a variety of other oxidized minerals, including wulfenite, hemihedrite, willemite, cerussite, minium, and mimetite (Williams, S.A., and Anthony, 1970).

#VELIKITE

Copper mercury tin sulfide, $(Cu,Hg)_{11}Sn_4S_{16}$. A rare sulfide mineral probably formed under hydrothermal conditions.

Cochise County: Bisbee, Warren district, in the Campbell sulfide orebody (Graeme, 1993).

VERMICULITE

Magnesium iron aluminum silicate hydroxide hydrate, $(Mg,Fe,Al)_3(Al,Si)_4O_{10}(OH)_2 \cdot 4H_2O$. A member of the group of mica minerals that have chemical properties analogous to those of the smectite (montmorillonite) minerals. The vermiculites have the property of expanding perpendicular to the micaceous layers when rapidly heated.

Cochise County: Willcox Playa, where it is, after illite and montmorillonite, the most abundant clay mineral in the younger playa sediments (Pipkin, 1968).

La Paz County: Formed by the alteration of biotite (UA 8651); near Bouse (UA 8646).

Maricopa County: Reported near Aguila and at a locality between Wickenburg and the Vulture Mountains (North and Jensen, 1958; UA 8753). Bar FX Ranch, southwest of Wickenburg (Wilson, E.D., and Roseveare, 1949).

Mohave County: Hualapai Mountains, in a deposit 15 miles southwest of Kingman (Engineering Mining Journal, 1940; Wilson, E.D., 1944).

Pima County: Tucson Mountains, in rocks metamorphosed by igneous intrusions (Brown, W.H., 1939).

Pinal County: Near Oracle (Moore, R.T., 1969b).

VESIGNIEITE

Barium copper vanadate hydroxide, $BaCu_3(VO_4)_2(OH)_2$. A rare secondary mineral associated with oxidized uranium minerals.

Apache County: Monument Valley, Monument No. 2 mine (Joseph Urban, pers. commun., 1967; UA 9501; NHM 1967,148).

Coconino County: Prospect Canyon district, Ridenaur mine, with naumannite, bromargyrite, tyuyamunite, calciovolborthite, and metatyuyamunite (Wenrich and Sutphin, 1989).

Pinal County: Copper Creek district, in a prospect pit 2 miles south of Mercer Ranch, as crude, rounded, pistachio-green crystals up to 1.5 mm long, in albitized quartz monzonite with cuprite and chrysocolla. A chemical analysis by the Schwartzkopf Laboratory gave the following results (wt %):

CuO	36.97	V_2O_5	32.78	SrO	<0.005
BaO	23.69	H_2O	5.95	TOTAL	99.40

Specific gravity: observed, 4.604; calculated, 4.628. Monoclinic, 2/m. Unit cell parameters: a=7.134, b=5.910, c=5.122 Å, β=103°33.7'.

VESUVIANITE

Calcium aluminum magnesium boran silicate hydroxide oxide fluoride, $Ca_{19}(Al,Mg)_{13}B_{0-5}Si_{18}O_{68}(OH,O,F)_{10}$. Typically formed in contact-metamorphosed limestones, where it is associated with other calcium silicate minerals.

Cochise County: Tombstone district, in the contact zone of Comstock Hill; Lucky Cuss mine, with monticellite, hillebrandite, and thaumasite (Butler, B.S., et al., 1938b). Little Dragoon Mountains, Johnson district, as pale-green, square, vertically striated prisms up to 2 mm long (Romslo, 1949; Cooper and Huff, 1951; Cooper, 1957; Cooper and Silver, 1964); northern end of Stronghold Canyon, as crystals up to 3 cm long in radiating prismatic clusters, with diopside, marialite, clinozoisite, and garnet (Rushing, 1978).

Gila County: Dripping Spring Mountains, Christmas mine, in fibrous masses showing anomalous birefringence and color zoning; moderately common in skarn (Ross, C.P., 1925b; David Perry, pers. commun., 1967).

Greenlee County: Clifton-Morenci district, northern part of Morenci, locally formed with other calc-silicate minerals, including garnet, tremolite, diopside, and epidote, in a large contact-metamorphosed zone (Moolick and Durek, 1966).

Pima County: Unspecified locality at the northern end of the Baboquivari Mountains; in schist at the east end of the Coyote Mountains (UA 8095). Tucson Mountains, in contact-metamorphosed rocks (Brown, W.H., 1939). Pima district, Twin Buttes mine, in the skarns and tactites (Stanley B. Keith, pers. commun., 1973). Southern end of the Rosemont district (McNew, 1981).

Santa Cruz County: Patagonia Mountains, Washington Camp, as lime-green crystal fragments in a wash, uphill behind the local store (Bideaux et al., 1960).

Yuma County: Locally abundant in metamorphosed limestones. Gila Mountains, in a contact zone (Wilson, E.D., 1933).

VIVIANITE

Iron phosphate hydrate, $Fe_3(PO_4)_2 \cdot 8H_2O$. Formed in the weathered portion of base-metal deposits and as an alteration product of primary iron-manganese phosphates in pegmatites.

Maricopa and Yavapai Counties: White Picacho district, as finely crystalline, bluish-gray films in triplite (Jahns, 1952). Hillside mine, as thin, blue coatings with montmorillonite and böhmite, on mica schist in old mine workings.

VOGLITE

Calcium copper uranyl carbonate hydrate, $Ca_2Cu(UO_2)(CO_3)_4 \cdot 6H_2O$(?). A very rare secondary mineral formed as an alteration product of uraninite. Known from Frey Point, Utah, and the Elias mine, Joachimsthal, Czech Republic, where it formed with liebigite (Frondel, C., 1958).

Navajo County: Red Mesa district, near the Red Mesa Trading Post; thought to be the third known locality.

VOLBORTHITE

Copper vanadate hydrate, $Cu_3(VO_4)_2 \cdot 3H_2O$. A rare secondary mineral formed in the oxidized zones of base-metal deposits. Also associated with certain uranium deposits on the Colorado Plateau.

Apache County: Monument Valley, Monument No. 2 mine, as a barian variety (Witkind and Thaden, 1963; UA 1569, 9797).

Gila County: Undisclosed locality north of Globe (Robert O'Haire, pers. commun., 1972).

Navajo County: Monument Valley, Mitten No. 2 mine (Witkind and Thaden, 1963); Monument No. 1 mine (Holland et al., 1958; Witkind, 1961).

#VOLKONSKOITE

Calcium chromium magnesium iron aluminum silicate hydroxide hydrate, $Ca_{0.3}$-$(Cr^{3+},Mg,Fe^{3+})_2(Si,Al)_4O_{10}(OH)_2 \cdot 4H_2O$.

Cochise County: Bisbee, Warren district, Campbell mine, as waxy green masses with pyrite and quartz (Graeme, 1993).

VOLTAITE

Potassium iron sulfate hydrate, $K_2Fe^{2+}_5Fe^{3+}_4(SO_4)_{12} \cdot 18H_2O$. Found at many localities throughout the world. Commonly associated with other sulfates under conditions that suggest that it may be a low-temperature, late-stage, primary mineral. Also of secondary origin.

Cochise County: Warren district, Copper Queen mine, in irregular, porous crusts several inches thick, associated with coquimbite, kornelite, copiapite, and rhomboclase (Merwin and Posnjak, 1937).

Pinal County: Pioneer district, Magma mine, as crystals up to 0.25 in., associated with copiapite.

Yavapai County: Black Hills, United Verde mine, as black, resinous cubo-octahedral crystals up to 5 mm, formed as a result of burning pyritic ore (Anderson, C.A., 1927; Lausen, 1928; Hutton, 1959a; UA 64, 3074, and others; H 85680, 90536). An analysis by C.A. Anderson gave the following results (wt %):

SO_3	47.83	FeO	8.82	K_2O	4.52
Al_2O_3	6.06	MgO	1.55	H_2O	16.13
Fe_2O_3	14.34			TOTAL	99.25

Specific gravity: 2.75

The aluminum content is apparently the highest reported for the species.

#VOLYNSKITE

Silver bismuth telluride, $AgBiTe_2$. A rare hydrothermal mineral, found at only a few localities worldwide.

Cochise County: Warren district, Campbell mine, among the pyritic ores, with altaite, rhodostannite, and melonite (Graeme, 1993).

W

Wad (see also Psilomelane and ROMANECHITE)

Mixtures of manganese oxide minerals. *Wad* is a generic or field term for aggregates of more or less soft manganese oxides, the mineralogy of which has not been defined in detail. Together with psilomelane, it is related to the manganese oxide minerals in the same way that "limonite" and "bauxite" are related to the unspecified iron and aluminum oxide and hydroxide minerals that compose them. The mineral romanechite is doubtless a major constituent of most wad. Many localities of black manganese oxides in Arizona must be referred to by this appellation until they are more carefully examined. Where knowledge of their mineralogies permits, reference is made to specific minerals in this compilation (Jones, E.L., and Ransome, 1920; Wilson, E.D., and Butler, 1930; Farnham and Stewart, 1958).

Cochise County: Tombstone, as veins and replacements mined for their silver content (UA 6956). Warren district, as large bodies. Cochise district, Johnson Camp (UA 9359).

Coconino County: Long Valley region, Iron Mine Canyon, as nodules and masses in the Kaibab Limestone. Near Williams (Farnham and Stewart, 1958; UA 7370, 7751).

Gila County: Globe district, as earthy material along many faults. Roosevelt

Lake area (UA 7423). Medicine Butte area, in the Apache and Accord manganese deposits, as fracture fillings and as cement in Cenozoic conglomerate (Moore, R.T., 1968). Banner district, common in many of the fault zones and solution channels, associated with oxide copper and iron minerals, commonly as bands alternating with goethite (Keith, 1972).

Graham County: Arivaca district.

Greenlee County: Ash Peak district, in shear zones with manganite and pyrolusite.

La Paz County: Plomosa and Trigo Mountains (Farnham and Stewart, 1958). Granite Wash Hills, east of Bouse. About 33 miles west of Congress Junction. Planet mine, with hematite, malachite, azurite, and chrysocolla (Bancroft, H., 1911).

Maricopa County: Big Horn Mountains, Aguila district, as extensive bedded deposits (Lasky and Webber, 1944, 1949; UA 6999). Little Chemehuevis Valley, Topock district. Aguila district, at the Sambo Aguila, Black Crow, Pumice, Valley View and Yarnell, Purple Pansy, Kat Head, Black Rock, Black Bart, and many other groups of claims (Farnham and Stewart, 1958).

Mohave County: Artillery Peak Mountains, as an extensive low-grade deposit (Lasky and Webber, 1949; Farnham and Stewart, 1958).

Pinal County: Pioneer district, abundant in fractures and fault planes; Magma mine, eastern part of the 1,600-ft level, as veins and irregular masses. Globe district, Old Dominion mine, in surface gash veins. Black Hills, Camp Grant Wash, Tarr and Harper mines. Galiuro Mountains, Florence district, Chamberlain mine. Copper Creek district, Blue Bird mine.

Santa Cruz County: Santa Rita Mountains, Rosario group. Patagonia Mountains, Mowry, La Plata, Hermosa, Jarrilla, and Isabella mines.

Yavapai County: Castle Creek district, 23 miles northeast of Morristown. Reported near Mayer. Southern region, at several properties, including the Harris, Box Canyon, Black Rock, Blind Child, Black Dome, Black Buck, Cummings, Fiscus and Mitchell, Burmeister, Black Duke, La McCoy, and other properties (Farnham and Stewart, 1958).

#WAKEFIELDITE-(Y)

Yttrium vanadate, YVO_4. A rare mineral found in granite pegmatites.

Maricopa County: White Tank Mountains, as good-quality, clear to milky-white plates that line voids in massive, vuggy, and corroded euxenite (material collected by P. Hooker).

WAVELLITE

Aluminum phosphate hydroxide hydrate, $Al_3(PO_4)_2(OH)_3{\cdot}5H_2O$. An uncommon but widespread mineral formed by low-grade metamorphism and as a product of hydrothermal alteration in mineral deposits.

Gila County: Globe-Miami district, Castle Dome mine, where it is localized along fractures that cross the trend of ore veins; probably of hypogene origin (Peterson, N.P., 1947; Peterson, N.P., et al., 1951).

Mohave County: Wallapai district, Mineral Park mine, as microcrystals and spheroidal aggregates on quartz (Wilkinson et al., 1980; UA x570).

WEEKSITE

Potassium uranyl silicate hydrate, $K_2(UO_2)_2(Si_2O_5)_3 \cdot 4H_2O$. A rare secondary mineral intimately associated with other oxidized uranium minerals. Closely resembles uranophane.

Yavapai County: Near Congress Junction, as microcrystals (William Kurtz, UA x4477). Anderson mine, as bright-yellow coatings with chalcedony and carnotite; also as microcrystals with celestite and gypsum (William Hunt, pers. commun., 1985).

Yuma County: Muggins Mountains, Red Knob claims, as radial aggregates of fibrous to acicular crystals coating and intergrown with chalcedony, wulfenite, carnotite, vanadinite, cuprite, azurite, calcite, gypsum, and limonite (Honea, 1959; Outerbridge et al., 1960).

WEISSITE

Copper telluride, Cu_5Te_3, or perhaps $Cu_{2-x}Te$, with $x = 0$ to 0.33. Associated with pyrite, petzite, rickardite, and tellurium at a few localities in the world.

La Paz County: Dome Rock Mountains, in trace amounts with blebs of bornite in massive djurleite, in a quartz-tourmaline gangue (Williams, S.A., and Matter, 1975).

#Whelanite

Copper calcium silicate carbonate hydroxide hydrate, $CuCa_5Si_6O_{17}(CO_3)(OH)_2 \cdot 4H_2O$. Hindman (1976) mentioned this mineral as an "undescribed silico-carbonate of copper and calcium" found with the type specimen of stringhamite. Hindman (1985) gave the name *whelanite* and the chemical formula quoted here. Although the mineral was quite common at the Bawana mine near Milford, Utah, a description was never completed. The same mineral was earlier noted at Crestmore, California, and later at two localities in Chile.

These few data are provided as a service to our readers. Although not officially a species, whelanite clearly deserves that status. The name has gained currency among collectors. The name honors Dr. James A. Whelan, professor at the University of Utah, Provo, Utah.

Gila County: Banner district, Christmas mine, moderately abundant as cleavable, turquoise-blue prisms up to several centimeters long. Crystals are monoclinic, with a = 13.57Å, b = 3.64, and c = 5.65; β = 94.5°. Strong diffraction lines are 6.763(200), 4.509(300,201), 2.705(102,500), and 1.675.

WHERRYITE

Lead copper carbonate sulfate chloride hydroxide oxide, $Pb_4Cu(CO_3)(SO_4)_2(Cl,OH)_2O$. A rare secondary mineral found in the oxidized portion of some lead deposits. The Mammoth–St. Anthony mine is the type locality. The species has been further substantiated by McLean (1970).

Mohave County: Artillery Peak area, in a small base-metal prospect.

Pinal County: Mammoth district, 760-ft level of the Mammoth–St. Anthony mine, in small vugs, with matlockite, leadhillite, hydrocerussite, paralaurionite, diaboleite, phosgenite, chrysocolla, anglesite, and cerussite (Fahey et al., 1950). An analysis by J.J. Fahey gave the following results (wt %):

PbO	72.9	CO_2	3.1	Insol.	2.2
CuO	7.3	Cl	0.9	(−)O = Cl	0.2
SO_3	13.0	H_2O	1.2	TOTAL	100.4

Silver Reef Mountains, Silver Reef mine, near Casa Grande.

WHEWELLITE

Calcium oxalate hydrate, $Ca(C_2O_4)\cdot H_2O$. Found in hydrothermal veins and coal seams. Formed as very abundant, minute, needlelike, colorless crystals in the cuplike depressions in the bases of dead agave in the southwestern deserts. In Arizona the material is so abundant it sparkles in the brilliant desert sunlight.

WICKENBURGITE

Lead aluminum calcium silicate hydroxide, $Pb_3Al_2CaSi_{10}O_{24}(OH)_6$. A rare secondary lead mineral formed from the oxidation of lead ores. Locally abundant in the Wickenburg area. The Potter-Cramer property is the type locality.

La Paz County: Silver district, Red Cloud and Padre Kino mines (Bancroft, P., and Bricker, 1990).

Maricopa County: Several localities south of Wickenburg, including the Moon Anchor mine and Potter-Cramer property, as transparent, colorless crystals and rare salmon-pink crystals; also as dull-white, granular to fine-grained masses; in the oxidized portion of galena-sphalerite veins, associated with many secondary minerals, some of which are quite exotic, e.g., phoenicochroite, crocoite, duftite-beta, ajoite, vauquelinite, shattuckite, minium, and hemihedrite (Williams, S.A., 1968). A chemical analysis gave the following results (wt %):

PbO	44.0	Al_2O_3	7.6	CaO	3.80
SiO_2	42.1	$H_2O(+)$	3.77	TOTAL	101.27

Mohave County: In a base-metal prospect near Artillery Peak, with luddenite, alamosite, and shattuckite, associated with drusy quartz (Williams, S.A., 1982).

WILLEMITE

Zinc silicate, Zn_2SiO_4. An uncommon mineral found in crystalline limestones, possibly formed by metamorphism of other zinc minerals. Far more common as a secondary or mesogene mineral in the oxidized portions of zinc deposits. Most willemite does not fluoresce.

Cochise County: Warren district, 1,500-ft level of the Campbell mine, as a fluorescent variety (UA 6793). Chiricahua Mountains, Hill Top mine, as small white- to rose-colored prisms in cavernous rock (Pough, 1941; AM 21263). Gunnison Hills, Texas Arizona mine, as minute, glassy prisms that fluoresce straw-yellow, in metamorphosed limestones (Cooper, 1957); near the Little Fanny mine, in a quartz vein (Cooper and Silver, 1964). Turquoise district, Defiance mine, as microcrystals with wulfenite (William Kurtz, UA x4615).

Gila County: Abundant at the Apache mine, north of Globe, with vanadinite; Defiance mine, with vanadinite and descloizite (Petersen, 1960).

Greenlee County: Clifton-Morenci district, Modoc Mountain, as small grayish crystals in garnet rock in the Modoc open cut (Lindgren, 1905).

La Paz County: Plomosa Mountains, Black Mesa mine, in sec. 16, T. 3 N., R. 17 W., as brilliant, nonfluorescing, elongated hexagonal crystals, with aurichalcite and malachite on limonite (David Shannon, pers. commun., 1971). Trigo Mountains, Silver district, Red Cloud mine, as minute prismatic crystals, commonly associated with wulfenite (Edson, 1980); Padre Kino mine, very abundant as both white acicular crystals and black botryoidal masses. Reported from an unspecified locality near Wenden.

Maricopa County: South of Wickenburg, at several localities, including the Moon Anchor mine, Rat Tail claim, and Potter-Cramer property, as a secondary mineral in the oxidized zone of lead-zinc veins (Williams, S.A., 1968); Tonopah Belmont mine (Robert O'Haire, pers. commun., 1970; Allen, G.B., and Hunt, 1988). Painted Rock Mountains, Rowley mine near Theba (Wilson, W.E., and Miller, 1974).

Pima County: Tucson Mountains, as crystals on the dump of a prospect 1 mile south of the Old Yuma mine (UA 5691) and at the Old Yuma mine. Waterman Mountains, Silver Hill mine, as small, barrel-shaped crystals near the head of the inclined surface tram. South Comobabi Mountains, Cababi district, Mildren and Steppe claims (Williams, S.A., 1963). Cimarron Mountains, Paul Hinshaw property, in T. 11 S., R. 2 E., as fluorescent material (Wilson, E.D., and Roseveare, 1949; Funnell and Wolfe, 1964).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as small, colorless rhombs and bluish barrel-shaped crystals on wulfenite and vanadinite (Fahey, 1955; Bideaux, 1980; H 101143). Galiuro Mountains, Table Mountain mine, in vugs with conichalcite, plancheite, and malachite (Bideaux et al., 1960; UA 6421; S 113802). Tortilla Mountains, Florence Lead-Silver mine, with hemihedrite, wulfenite, cerussite, and other oxidized secondary minerals (Williams, S.A., and Anthony, 1970); Silver Reef mine, near Casa Grande (UA 6855). Slate Mountains, Jackrabbit mine, as the most abundant zinc ore mineral (Hammer, 1961). Mineral Mountain district, as microcrystals with hematite (Robert Mudra, UA x467).

WINSTANLEYITE

Titanium tellurite, $TiTe_3O_8$. A rare mineral formed by the oxidation of other tellurium minerals. The Grand Central mine dump is the type locality.

Cochise County: Tombstone, in the dumps of the Grand Central mine, as simple cubes up to 0.5 mm on an edge, commonly yellow, but tan or cream in places; associated with pyrite, jarosite, chlorargyrite, and rodalquilarite in a quartz-adularia-opal rock formed by the alteration of a granodiorite. Marjorie Duggan (Williams, S.A., 1979) reported the following analyses (wt %):

(1)

TiO_2	11.0	Fe_2O_3	3.15	TeO_2	82.6
				TOTAL	96.75

(2)

TiO_2	10.3	Fe_2O_3	3.15	TeO_2	83.9
				TOTAL	97.35

Withamite (a variety of CLINOZOISITE)

WITHERITE

Barium carbonate, $BaCO_3$. An uncommon mineral formed in low-temperature hydrothermal veins with barite and galena.

Pima County: Pima district, Mission mine, as microcrystals (William Kurtz, UA x378).

Yuma County: Castle Dome Mountains, Castle Dome district, De Luce mine, as gangue in lead ores.

WITTICHENITE

Copper bismuth sulfide, Cu_3BiS_3. An uncommon mineral of primary origin in vein deposits; less commonly formed during secondary enrichment of copper ores. Typically associated with chalcocite.

Cochise County: Warren district, as a primary mineral in some of the mines; as exsolution blebs in bornite from an unspecified mine (Julie DeAzevado Harlan, unpublished manuscript, 1966); Campbell orebody (Graeme, 1993).

Pinal County: Pioneer district, Magma mine, reported in the hypogene ores (Hammer and Peterson, 1968).

#WITTITE

Lead bismuth sulfide selenide, $Pb_9Bi_{12}(S,Se)_{27}$. Found in amphibolite (rock) at the type locality, Fahlan, Sweden, associated with nordströmite, friedrichite, magnetite, pyrite, and other minerals.

Cochise County: In an open-pit prospect northeast of Middlemarch Pass, as frayed prisms up to 10 mm long in grossularite-rich marble.

WOLFRAMITE

Iron manganese tungstate, $(Fe,Mn)WO_4$. The end members, iron-rich ferberite ($\geq$ 80% Fe) and manganese-rich hübnerite ($\geq$ 80% Mn), form a solid-solution series. Minerals of intermediate or unspecified composition are termed *wolframite.* In this listing, species whose composition has not been specifically identified are called *wolframite.* Most abundant in quartz veins in granite and in schist associated with pegmatites. Commonly the only metallic mineral present, but locally accompanied by scheelite or sulfides. Widespread but sparse in Arizona; only representative localities are noted below.

Cochise County: Bisbee, Warren district, in the sulfide ores of the Campbell mine. Western slope of the Whetstone Mountains, in veins and as replacements with scheelite (Hess, 1909; Dale et al., 1960). Little Dragoon Mountains, in quartz veins and placer gravels (Kellogg, 1906; Palache, 1941a; Wilson, E.D., 1941; Dale et al., 1960). Dragoon Mountains, near the Southern Pacific Railroad station at Dragoon (Guild, 1910), as crystals of hübnerite 2 in. long (see also Kuck, 1978). An analysis by S.V. Peppel (Hobbs, 1905) gave the following results (wt %):

SiO	1.10	WO_3	75.10	MnO	22.87
FeO	0.81			TOTAL	99.88

Russellville, 8 miles north of Dragoon, as a highly manganiferous hübnerite in quartz veins that cut porphyritic granite; as prismatic and bladelike masses, associated with small quantities of scheelite and gold (Blake, W.P., 1898). Little Dragoon Mountains, Cochise district, in quartz veins and placer gravels (Rickard, 1904; Kellogg, 1906), and as hübnerite, the principal ore mineral in tungsten veins in the Texas Canyon Quartz Monzonite; as platy crystals up to 10 cm long (Palache, 1941a; Wilson, E.D., 1941; Cooper and Silver, 1964).

Gila County: Pinal Mountains, at several places south of Globe; Bobtail mine, west of Miami on Spring Creek, southwest of Young, as hübnerite, with galena and sphalerite (Ransome, 1903a; Dale, 1961). Mazatzal Mountains, near Four Peaks (Dale, 1961).

La Paz County: Ellsworth district, Colorado mine, as large, platy crystals over 5 cm long in a quartz-muscovite vein (MM K128).

Maricopa County: Cave Creek district, as ferberite containing 2.19% combined niobium-tantalum as oxides (Wherry, 1915). White Picacho district, as wolframite in pegmatites. Gold Cliff group, in sec. 11, T. 6 N., R. 4 E., about 27 miles north of Phoenix, as ferberite, associated with tungstite, cuprotungstite, fluorite, molybdenite, pyrite, and chalcopyrite (Dale, 1959).

Mohave County: Hualapai Mountains, in quartz veins of the Boriana mine (Hobbs, 1944); Myers (1983) reported ferberite in veins in phyllite from this property. Telluride Chief, Laxton, and Moon properties. Aquarius Mountains (Engineering Mining Journal, 1910; Dale, 1961), Aquarius Mountains district, in quartz veins in the Williams and other mines near Boner Canyon (Hobbs, 1944). West of Cottonwood Cliffs and west of Greenwood Peak. White Hills, Gold Basin district, O.K. mine (Schrader, 1909; Wilson, E.D., 1941; Dale, 1961).

Pima County: Las Guijas and Baboquivari Mountains (Dale et al., 1960) and Comobabi Mountains (Guild, 1930; Wilson, E.D., 1941; H 89695). Arivaca district, as hübnerite in quartz veins that cut granite (Blake, W.P., 1896). An analysis by Easton and Moss (1966) of hübnerite from the Las Guijas district gave the following results (wt %):

FeO	1.2	MnO	21.8	MoO_3	0.4
WO_3	74.5	SiO_2	1.0	TOTAL	98.9

Cerro Colorado district, in quartz veins (H 89698).

Pinal County: Mammoth district, Tarr property, northwest of the Mammoth–St. Anthony mine, with schorl (Dale, 1959). Galiuro Mountains, Blue Bird mine (Wilson, E.D., 1941). Antelope Peak area and at several properties in the Crook National Forest, northeast of Superior, with scheelite in quartz veins (Dale, 1959).

Santa Cruz County: Patagonia Mountains, Nogales district, Mount Benedict and Reagen Camp, with scheelite in narrow quartz veins in lamprophyre dikes that cut quartz monzonite (Schrader, 1917); Cox Gulch, as ferberite in the Ventura breccia pipe (Kuck, 1978); Red Mountain property (Hill, 1910b). San Cayetano district, southeast of Calabasas (Pellegrin, 1911; Dale et al., 1960).

Yavapai County: Bradshaw Mountains, Tip Top mine, Thule Creek area (DeWolfe, 1916; Dale, 1961); Eureka district, in quartz veins at the Black Pearl and Joy properties, south of Camp Wood (Dale, 1961); Silver Mountain district (Wilson, E.D., 1941). Camp Verde district (Dale, 1961).

WOLLASTONITE

Calcium silicate, $CaSiO_3$. A common member of the pyroxenoid group found in contact-metamorphosed limestones. A common gangue mineral in mineral deposits of contact metamorphic origin.

Cochise County: Tombstone district, Silver Thread and West Side mines, as radiating fibrous masses (Butler, B.S., et al., 1938b). In garnetite near the Texas Canyon Stock, commonly associated with vesuvianite (Cooper and Huff, 1951; Cooper and Silver, 1964). Little Dragoon Mountains, near Johnson Camp, with grossular, epidote, sphene, and other contact silicates in calcareous rocks (Cooper, 1957). Dragoon Mountains, Abril mine, abundant in contact-metamorphosed limestones (Perry, D.V., 1964). Chiricahua Mountains, Paradise area (Dale et al., 1960).

Gila County: Dripping Spring Mountains, Banner district, Christmas mine, common and typically associated with chert nodules in marble of the Naco Formation; also locally present in skarn (Ross, C.P., 1925b; Perry, D.V., 1969).

La Paz County: Harcuvar Mountains, Cabrolla prospect, where an entire bed of limestone is replaced (Bancroft, H., 1911).

Maricopa County: Estrella Mountains, in NW1/4 sec. 33, T. 2 S., R. 1 E., as radiating fibrous masses associated with garnet in metamorphosed limestone (Robert O'Haire, pers. commun., 1971).

Mohave County: Hualapai Mountains, in gangue at the Antler mine (Romslo, 1948).

Pima County: Santa Rita Mountains, Helvetia-Rosemont district, where large masses of limestone are completely converted to wollastonite (Creasey and Quick, 1955). Sierrita Mountains, Pima district, Mineral Hill area, abundant throughout metamorphosed rocks; Twin Buttes mine, in skarns and tactites (Stanley B. Keith, pers. commun., 1973). Silver Bell district, locally abundant in contact-metamorphosed limestones (Stewart, C.A., 1912; UA 4510; AM 31425); Atlas mine area, in tactites (Agenbroad, 1962).

Santa Cruz County: Duquesne–Washington Camp areas, in contact-metamorphosed limestones (Schrader and Hill, 1915).

#WOODWARDITE

Copper aluminum sulfate hydroxide hydrate, $Cu_4Al_2(SO_4)(OH)_{12} \cdot 2\text{-}4H_2O(?)$. A rare secondary mineral found with other uncommon secondary copper minerals such as cyanotrichite and langite.

Cochise County: Maid of Sunshine mine, in fibrous to spherulitic form (identified by William Wise on material collected by David Shannon in 1991).

WULFENITE

Lead molybdate, $PbMoO_4$. An uncommon mineral generally considered to be of secondary origin. Widely distributed in parts of Arizona in the oxidized portions of lead-bearing deposits, some of which have produced magnificently developed or colored crystals that are the equal of any in the world. Many collectors believe that the wulfenite from the Red Cloud mine in Yuma County is unsurpassed in beauty because of its deep-red color.

Cochise County: Tombstone district, commonly present in large amounts with silver ores, as clusters and rosettes of crystals (Butler, B.S., et al., 1938b). Turquoise district, Defiance mine at Gleeson, as magnificent specimens in large amounts in a limestone cavern (Bideaux et al., 1960; Thompson, J.R., 1980); Mystery, Silver Bill (Knudsen, 1983), and Tom Scott mines. Chiricahua Mountains, Hilltop mine, as groups of deep-yellow crystals (Miller, D.K., and Wilson, 1983; H 94678; UA 2626). Pearce district, Commonwealth mine, lining cavities with embolite (Endlich, 1897). Warren district, Campbell orebody between the 1,700- and 2,500-ft levels, as small crystals associated with copper, malachite, cerussite, smithsonite, azurite, and mimetite (Phelps Dodge Corp., pers. commun., 1974); Cole shaft, as brilliant, colorless microcrystals (Graeme, 1993). Swisshelm Mountains and district, March mine, as microcrystals (Carl Richardson, UA x1450).

Gila County: Dripping Spring Mountains, Banner district, 79 mine, as transparent, unflawed crystals up to 2 in. on an edge (Keith, 1972); McHur, Premier, and London Range properties. Less abundant in the Globe district, Castle Dome mine area, as small, pointed prisms, a few of which are over 3 mm long (Peterson, N.P., 1947; Peterson, N.P., et al., 1951). Sleeping Beauty Mountain, 2 miles northwest of the Inspiration mine, as a tungstenian variety (UA 8197).

Graham County: Aravaipa district, Silver Coin and Dogwater mines (Simons, 1964); Sinn Fein mine, as yellow plates up to 5 mm on an edge (MM K090).

La Paz County: Trigo Mountains, Silver district, Hamburg mine and other properties; most notably at the Red Cloud mine, which many regard as the world's premier wulfenite locality because of the remarkable crystals in mineral collections throughout the world. Red Cloud mine wulfenites are brilliant orange-red and up to 2 in. on an edge (Blake, W.P., 1881a; Silliman, 1881; Foshag, 1919; Wilson, E.D., 1933; Fleischer, 1959; Bideaux, 1972; Edson, 1980; UA 9949). In 1985, new finds at the Red Cloud mine yielded superb, modestly sized, red-orange crystal groupings (Wilson, W.E., 1985). Melissa mine, as specimens with unusual forms (UA 4281). Padre Kino mine, as bright-red, transparent, tabular crystals up to 1 cm on an edge, with unusual dipyramids with parallel stacking (Peter Megaw, UA x2976).

Maricopa County: Painted Rock Mountains, Rowley mine, as excellent, bright-orange to yellow crystals up to 2 cm on an edge, typically associated with mimetite and barite (Wilson, W.E., and Miller, 1974; NHM 1970,59); spectacular specimens were produced from this mine in the early 1980's; associated with microcrystals of boleite, diaboleite, and caledonite (Wilson, W.E., 1986). White Picacho district, as a rare mineral in pegmatites (Jahns, 1952).

Mohave County: Rawhide Mountains, near Artillery Peak; Gold Basin district, Climax and Mineral Park mines, as unusual modified crystals (Wilkinson et al., 1980).

Pima County: Tucson Mountains, Old Yuma mine, as deep-orange-red crystal groups associated with spectacular vanadinite (Guild, 1910, 1911; Newhouse, 1934; Jones, D., 1983). Empire Mountains, Total Wreck and Hilton mines (UA 136, etc.; R.E. Birkholz, UA x1795). South Comobabi Mountains, Cababi district, Mildren and Steppe claims, with a variety of exotic secondary minerals formed from the oxidation of sulfide ores (Williams, S.A., 1963). Silver Bell district, as brownish plates with fluorite (Stewart, C.A., 1912), and as crystals showing obvious tetartohedrism (Williams, S.A., 1966). Pima district, Twin Buttes open-pit mine (Stanley B. Keith, pers. commun., 1973).

Pinal County: Mammoth district, Mammoth–St. Anthony mine, as light-yellow to bright-red crystals containing tungsten (Guild, 1910; Newhouse, 1934; Peterson, N.P., 1938a,b; Galbraith and Kuhn, 1940; Palache, 1941b; Fahey, 1955; Fleischer, 1959; Petersen et al., 1959; Bideaux, 1980; H 101755; UA 8208; NHM 1961,539, and others). Pioneer district, Black Prince (Oleson) mine. Dripping Spring Mountains, 4 miles east of Kelvin (Newhouse, 1934). Tortilla Mountains, Florence Lead-Silver mine, with willemite, hemihedrite, vauquelinite, minium, mimetite, and other minerals, as oxidation products from the alteration of sphalerite and galena; adjacent country rocks contain chromium (Williams, S.A., and Anthony, 1970). Copper Creek district, Blue Bird mine (Kuhn, 1951). Lee Reagan property, as brown plates up to 0.5 in. on an edge, with orange mimetite (S 97899). Banner district, in the northeast workings of the Kullman-McCool (Finch, Barking Spider) mine, as yellow crystals, many coated with hemimorphite and vanadinite.

Santa Cruz County: Santa Rita Mountains, Wrightson district, Gringo mine, with gold; Tyndall district, Glove mine, as remarkable crystal aggregates of various colors (typically light-yellow to pale-orange tones) and habits; some crystals measured 4 in. or more along the edge (Olson, H.J., 1966; UA 2760, 2801; NHM 1957,56, etc.); J.C. Holmes claims near Patagonia, with vanadinite, descloizite, and cerussite, on fracture planes in quartz vein filling (Pellegrin, 1911). Patagonia Mountains, Palmetto district, as beautifully crystallized specimens associated with galena, cerussite, and silver (Schrader, 1917).

Yavapai County: Bradshaw Mountains, Fat Jack mine, as small crystals on quartz with stolzite; at a prospect near the Great Southern mine, as tabular to unusual fibrous crystals with fluorite.

Yuma County: Muggins Mountains, Red Knob mine, with weeksite, vanadinite, and cuprite (Honea, 1959; Outerbridge et al., 1960).

WURTZITE

Zinc sulfide, ZnS. A rare and unstable hexagonal polymorph of zinc sulfide. Formed in several polytypic modifications related to one another by minor structural differences.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, where it is reported below the 900-ft level.

#WÜSTITE

Iron oxide, FeO. A very rare mineral of the periclase group with the NaCl structure.

Coconino County: In specimens of the Canyon Diablo meteorite as an alteration product of barringtonite and schreibersite (source of specimen: David Shannon).

#WYLLIEITE

Sodium calcium manganese iron magnesium aluminum phosphate, $(Na,Ca,Mn^{2+})(Mn^{2+},Fe^{2+})(Fe^{2+},Fe^{3+},Mg)Al(PO_4)_3$. A primary mineral formed in granite pegmatites.

Maricopa and Yavapai Counties: White Picacho district, in pegmatites (London, 1981).

X

XENOTIME

Yttrium phosphate, YPO_4. Widely distributed in felsic igneous rocks as an accessory mineral. Also in pegmatites and gneiss.

Gila County: Northern region, at two localities in the Diamond Butte quadrangle, of authigenic origin in the hematite-rich portion of the feldspathic sandstone of the Dripping Spring Quartzite (Gastil, 1954).

Mohave County: Aquarius Mountains, Columbite prospect, as sparse crystals up to 1 in. across (Heinrich, 1960). Virgin Mountains, with monazite in Precambrian granite gneiss (Young, E.J., and Sims, 1961). Near Mesquite, on the Nevada border (Clark County, Nevada), with monazite in granite augen gneiss (Overstreet, 1967).

Pima County: North side of the Rincon Mountains, with gadolinite in biotite gneiss (Bideaux et al., 1960).

XOCOMECATLITE

Copper tellurate hydroxide, $Cu_3(TeO_4)(OH)_4$. A very rare secondary mineral formed from other tellurium minerals under conditions of severe oxidation.

Cochise County: Tombstone district, Emerald mine, where only one specimen was found on the mine dump; as pale-green spherules formed by oxidation on fracture surfaces; closely associated with parakhinite and a variety of other rare tellurates (Williams, S.A., 1978).

XONOTLITE

Calcium silicate hydroxide, $Ca_6Si_6O_{17}(OH)_2$. Commonly found in contact metamorphic terranes as a product of retrograde metamorphic breakdown of assemblages such as grossular-diopside.

Gila County: Banner district, Christmas mine, associated with an assemblage of retrograde metamorphic minerals, including tobermorite, apachite, and gilalite (Cesbron and Williams, 1980).

≡ Y

#YAFSOANITE

Zinc calcium lead tellurate, $(Zn,Ca,Pb)_3TeO_6$. A rare secondary mineral formed by oxidation of primary tellurium-bearing ores.

Cochise County: Tombstone district; a specimen from the collection of William Pinch is rich in various tellurites, including sparkling, adamantine, white dodecahedra of yafsoanite, which thinly encrust some fracture surfaces; the cubic unit cell edge (from Cr$K\alpha$ X-ray powder diffraction data) is 6.287Å.

#YARROWITE

Copper sulfide, Cu_9S_8. A rare sulfide mineral found at the type locality (Yarrow Creek area, Alberta, Canada) in red-bed copper deposits with other copper sulfides.

Cochise County: Bisbee, Warren district, in the sulfide ores of the Campbell mine (Graeme, 1993).

YAVAPAIITE

Potassium iron sulfate, $KFe(SO_4)_2$. A rare secondary mineral formed as a result of a mine fire at the United Verde mine at Jerome. This is the type and probably only known locality.

Yavapai County: United Verde mine, sparse as cement in rubble exposed in open-pit operations; also as rare, short, stumpy crystals; associated with voltaite, sulfur, and jarosite (Hutton, 1959a; Graeber and Rosenzweig, 1971; Anthony et al., 1972).

YEDLINITE

Lead chromium chloride oxide hydroxide, $Pb_6CrCl_6(O,OH)_8$. A very rare secondary mineral, known only from the Mammoth–St. Anthony mine.

Pinal County: Mammoth district, Mammoth–St. Anthony mine, sparingly on a few specimens, associated with diaboleite, quartz, wulfenite, dioptase, phosgenite, and wherryite; as red-violet rhombohedral crystals up to 1 mm long; a = 12.868 Å, c = 9.821; density: about 5.85 g/cc. (McLean et al., 1974; Wood et al., 1974).

YTTROTANTALITE

Yttrium uranium iron tantalum niobium oxide, $(Y,U,Fe)(Ta,Nb)O_4$. A rare mineral formed in granite pegmatites.

Mohave County: Aquarius Mountains, Rare Metals mine (Heinrich, 1960).

≡ Z

ZEUNERITE

Copper uranyl arsenate hydrate, $Cu(UO_2)_2(AsO_4)_2 \cdot 10\text{-}16H_2O$. A member of the autunite group. The localities noted below may be of metazeunerite (5 to 8% H_2O), a member of the meta-autunite group, because the fully hydrated form dehydrates rapidly upon storage after collection. A secondary mineral associated with other uranium minerals.

Coconino County: Grandview mine, as exceptional crystals, up to 0.25 in. on an edge, with brochantite, olivenite, scorodite, and chalcoalumite (John S. White, Jr., pers. commun., 1974; collected by Richard L. Jones).

Mohave County: Hack Canyon (AM 26907).

ZINCITE

Zinc oxide, ZnO. A rare mineral, except in the remarkable deposits at Franklin and Sterling Hill, New Jersey.

Maricopa County: Tonopah-Belmont mine, as dull, red-brown, earthy crusts, formed from sphalerite-bearing ore by a mine fire (collected by William Hunt).

#ZINCOBOTRYOGEN

Zinc magnesium manganese iron sulfate hydroxide hydrate, $(Zn,Mg,Mn^{2+})Fe^{3+}$-$(SO_4)_2(OH)\cdot 7H_2O$. Formed in the oxidized zone of a lead-zinc deposit at the type locality in China. Bisbee is the only other locality known in the world.

Cochise County: Warren district (Graeme, 1993; AM 97,317).

#ZINC-ZIPPEITE

Zinc uranyl sulfate hydroxide hydrate, $Zn_2(UO_2)_6(SO_4)_3(OH)_{10}\cdot 16H_2O$. A secondary uranium mineral, commonly of relatively recent origin, formed as secondary efflorescences on mine walls and dumps. The Hillside mine is the type locality.

Yavapai County: Hillside mine, as shreds and minute curved crystals; associated with sodium-zippeite, nickel-zippeite, and probably other zippeite-type minerals, as well as schröckingerite, bayleyite, johannite, and gypsum (Frondel, C., et al., 1976). Charles Milton originally studied material from the Hillside mine and, on the basis of its X-ray diffraction and optical properties, equated it with the synthetic zinc-zippeite characterized by C. Frondel and his coworkers.

ZINNWALDITE

Potassium lithium iron aluminum silicate hydroxide fluoride, $K(Li,Fe,Al)_3(Si,$-$Al)_4O_{10}(OH,F)_2$. An uncommon member of the mica group, typically associated with other lithium-bearing minerals, topaz, cleavelandite, beryl, tourmaline, fluorite, and monazite in tin veins and pegmatites.

Maricopa County: Rare in the pegmatites of the White Picacho district, as very dark, cleavable crystals with golden-brown cleavage flakes; associated with spodumene and amblygonite (Jahns, 1952).

Santa Cruz County: Patagonia Mountains, Duquesne district, Line Boy mine (Wilson, E.D., and Roseveare, 1949).

ZIPPEITE

Uranyl sulfate hydroxide hydrate, $(UO_2)_2(SO_4)(OH)_2\cdot 4H_2O$. A secondary mineral formed on the walls of some mine workings and dumps. Commonly associated with other secondary uranium minerals and gypsum. Several localities of zippeite-like minerals are listed below because the exact "zippeite" species is not always known (Frondel, C., et al., 1976).

Coconino County: Cameron district, in minor amounts in uranium ore in paleostream channels of the Shinarump Conglomerate and in sandy patches of mounds in the Chinle Formation, associated with uraninite, metatorbernite, and meta-autunite; Huskon No. 7 and No. 8 claims (Holland et al., 1958). Sun Valley mine, associated with a zippeitelike mineral, an unnamed uranyl phosphate, and ilsemannite (Petersen et al., 1959).

Navajo County: Holbrook district, Ruth claims. Monument Valley, Monument No. 1 and Mitten No. 2 mines (Witkind, 1961; Witkind and Thaden, 1963).

ZIRCON

Zirconium silicate, $ZrSiO_4$. A common accessory mineral in igneous rocks. Because of its resistant nature, it is contained in many sedimentary and metamorphic rocks. Commonly formed as very small crystals but may be much larger in pegmatites. The variety cyrtolite is glassy and noncrystalline owing to structural damage caused by alpha-particle bombardment from included radioactive elements.

Apache County: As an accessory mineral in boulders of garnet-bearing gneiss, associated with apatite and muscovite; also as an accessory mineral in the Navajo Sandstone, associated with magnetite and tourmaline (Gavasci and Kerr, 1968).

Apache and Navajo Counties: Monument Valley, as one of the most common heavy minerals in uranium- and vanadium-bearing Shinarump Conglomerate; also common in the basal Monitor Butte Sandstone above the Shinarump Conglomerate, associated with apatite, barite, leucoxene, and tourmaline (Young, R.G., 1964).

Cochise County: Warren district, as small crystals in Pinal Schist with tourmaline, and in granite northwest of Bisbee. Tombstone district, as microscopic grains in light-colored intrusive rocks; zircons from the Johnny Lyon Granodiorite have yielded an age of 1,655 ± 20 million years for the intrusive rock unit (Silver, L.T., and Deutsch, 1963).

Gila County: In the Pinal Schist, Madera Diorite, and Ruin Granite (Ransome, 1919). Globe district, Castle Dome mine, in quartz monzonite.

Graham County: Santa Teresa Mountains, as the variety cyrtolite, with monazite in pegmatite (Robert O'Haire, pers. commun., 1972).

Greenlee County: Clifton-Morenci district, in granite (Reber, 1916; Peterson, N.P., et al., 1946).

Mohave County: Reported north of Kingman, as the variety cyrtolite.

Pima County: Ajo district, as small, stout crystals in the New Cornelia Quartz Monzonite (Gilluly, 1937; Hutton and Vlisidis, 1960). Santa Rita Mountains, in granite porphyry and schist (Catanzaro and Kulp, 1964). Silver Bell area, as an accessory mineral (Kerr, 1951).

Santa Cruz County: Patagonia Mountains, in granite (Schrader, 1913, 1917).

Yavapai County: Bradshaw Mountains, sparingly in the Bradshaw Granite (Anderson, C.A., 1950). Kirkland-Copper Basin placers, reportedly in commercial quantities in the black sands (Wilson, E.D., 1961).

ZOISITE

Calcium aluminum silicate hydroxide, $Ca_2Al_3(SiO_4)_3(OH)$. Commonly formed in argillaceous calcareous sandstones as a product of medium-grade thermal or contact metamorphism. Much of what has been called *zoisite* is doubtless clinozoisite, the latter species being by far the more abundant of the two.

Cochise County: Cochise district, Johnson Camp area, Republic mine, sparse in contact-metamorphosed rocks containing other calc-silicate minerals; locally as the variety thulite, in vugs and as coatings on joint surfaces (Cooper, 1957; Cooper and Silver, 1964). Tombstone district, microscopically in igneous rocks (Butler, B.S., et al., 1938b). Warren district (Schwartz, 1956). Chiricahua Mountains, Paradise area (Dale et al., 1960).

Gila County: Banner district, Christmas mine, as the variety thulite, a rare mineral formed in metamorphosed diorite and in skarn (Perry, D.V., 1969); 79 mine, as lovely pink crystals of thulite up to 1 in. long, elongated on the *b* axis; as coatings on fracture surfaces in metamorphosed limestones.

Greenlee County: Clifton-Morenci district, as a product of contact metamorphism, found in highly altered granite (Reber, 1916).

La Paz County: Dome Rock Mountains, in the wall rocks of cinnabar veins.

Mohave County: Cerbat Mountains, Wallapai district, as an alteration product in the wall rocks of sulfide-bearing veins (Thomas, B.E., 1949).

Pima County: Sierrita Mountains, Sierrita open-pit mine, as an alteration product of dioritic rocks (Roger Lainé, pers. commun., 1972).

Yavapai County: Bradshaw Mountains, in scattered lenses in schist. Eureka district at Bagdad, as an accessory mineral in bodies of titaniferous magnetite in the gangue of the copper deposits.

ZUNYITE

Aluminum silicate hydroxide fluoride chloride, $Al_{13}Si_5O_{20}(OH,F)_{18}Cl$. A rare mineral probably formed as a result of metamorphic or intense hydrothermal activity.

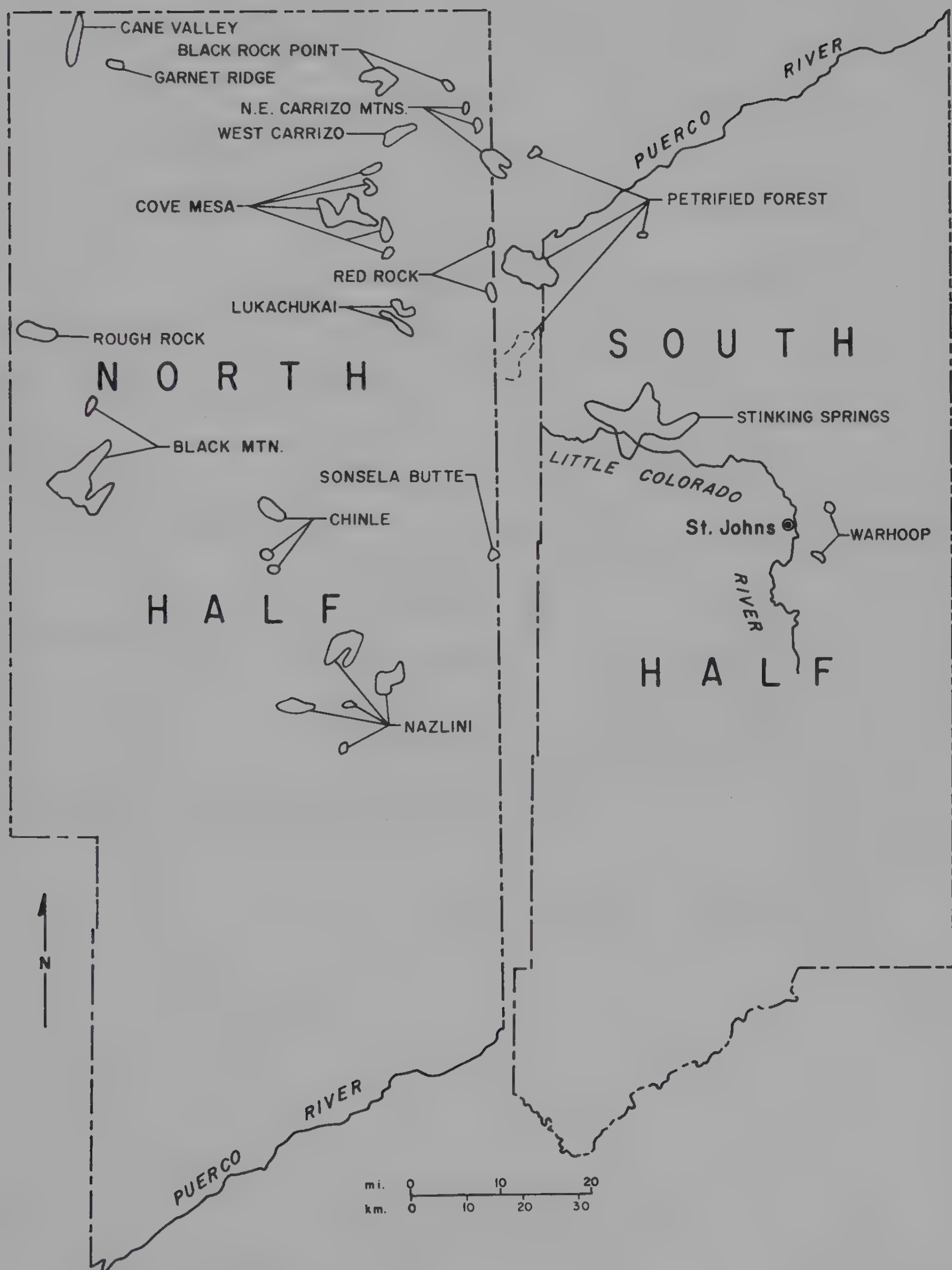
La Paz County: Dome Rock Mountains, Big Bertha (Veta Grande) mine, about 5 miles southwest of Quartzsite, as transparent, buff-colored crystals up to 2 cm on an edge (Wilson, W.E., 1986; UA 5455).

Pinal County: Mammoth district, San Manuel mine, in very small quantities in highly altered monzonite porphyry (Schwartz, 1953).

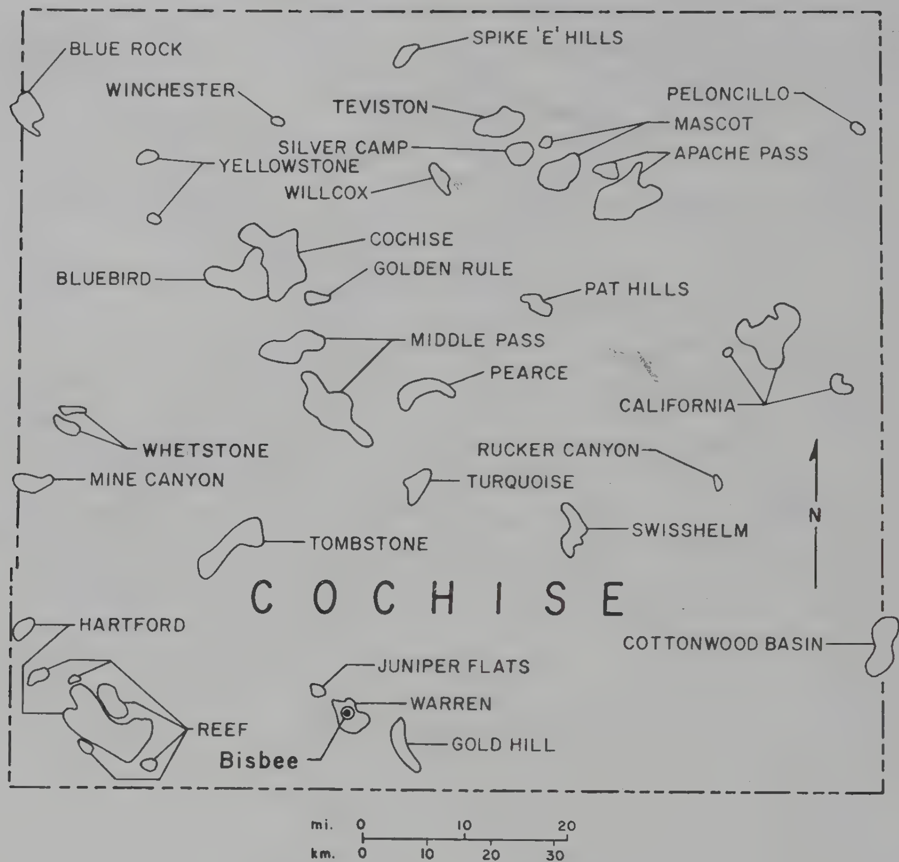
REFERENCE MATERIAL

Appendix: Maps of Arizona Mineral Districts

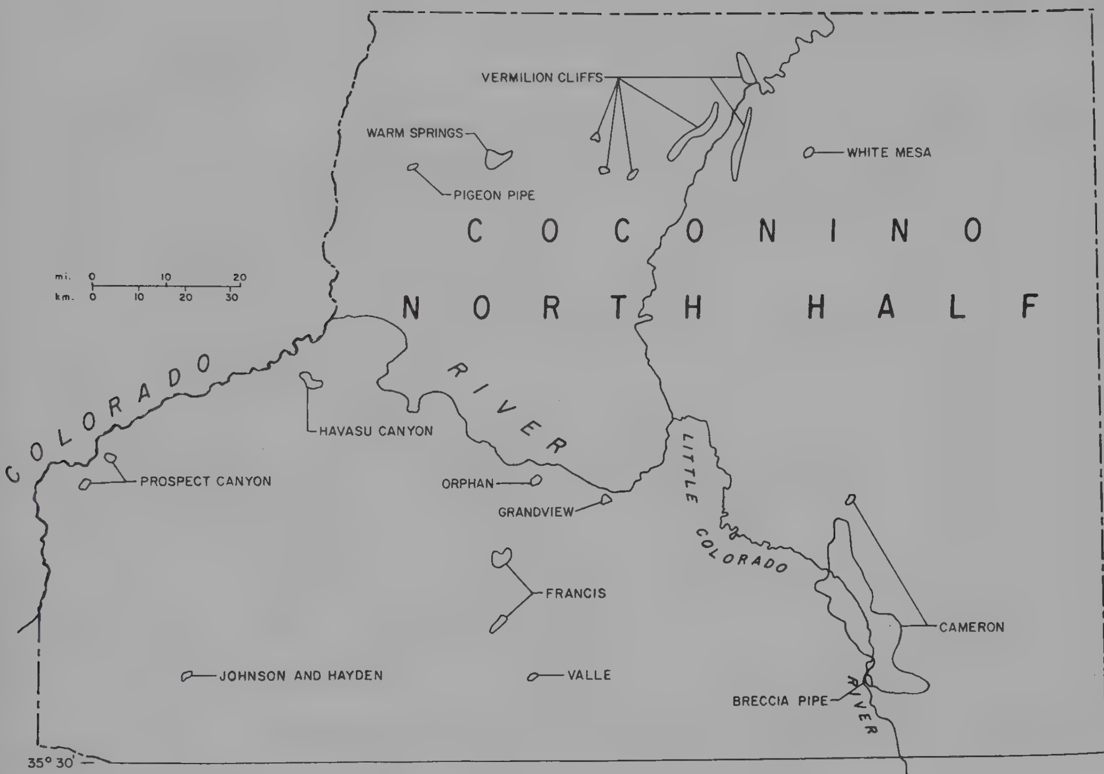
Reprinted with permission from Welty, J.W., S.J. Reynolds, S.B. Keith, D.E. Gest, R.A. Trapp, and E. DeWitt (1985) Mine Index for metallic mineral districts of Arizona. *Ariz. Bur. Geol. Min. Tech. Bull.* 196.



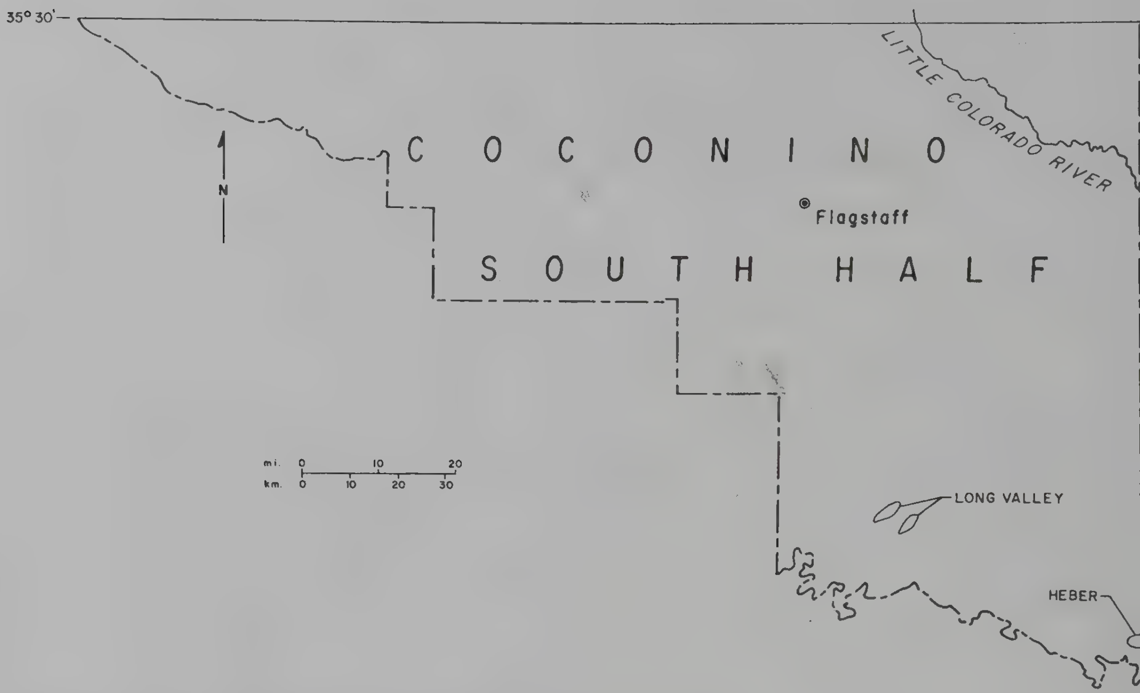
Mineral districts in Apache County, Arizona



Mineral districts in Cochise County, Arizona



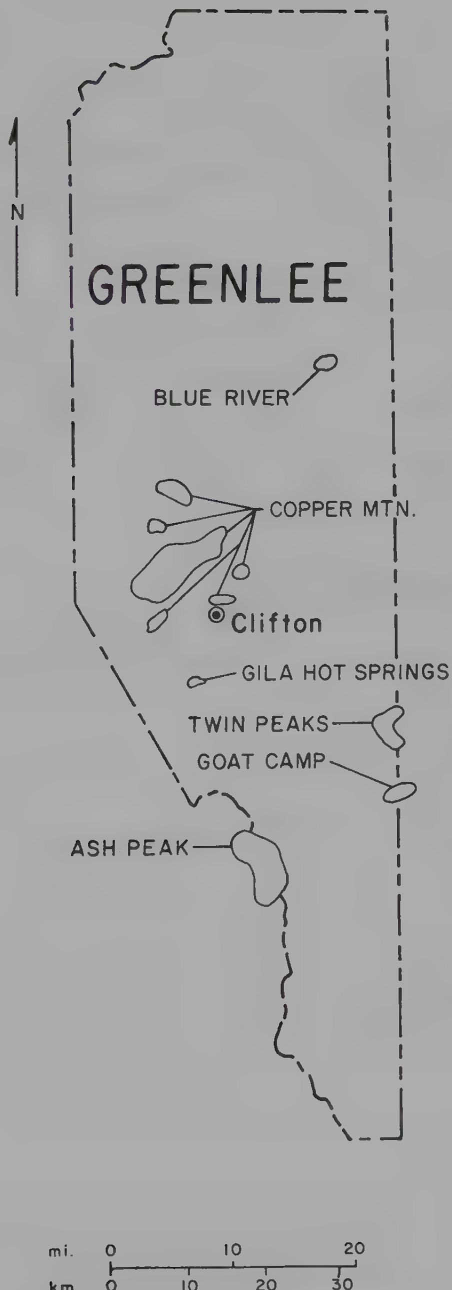
Mineral districts north of latitude 35°30′ in Coconino County, Arizona



Mineral districts south of latitude 35°30′ in Coconino County, Arizona

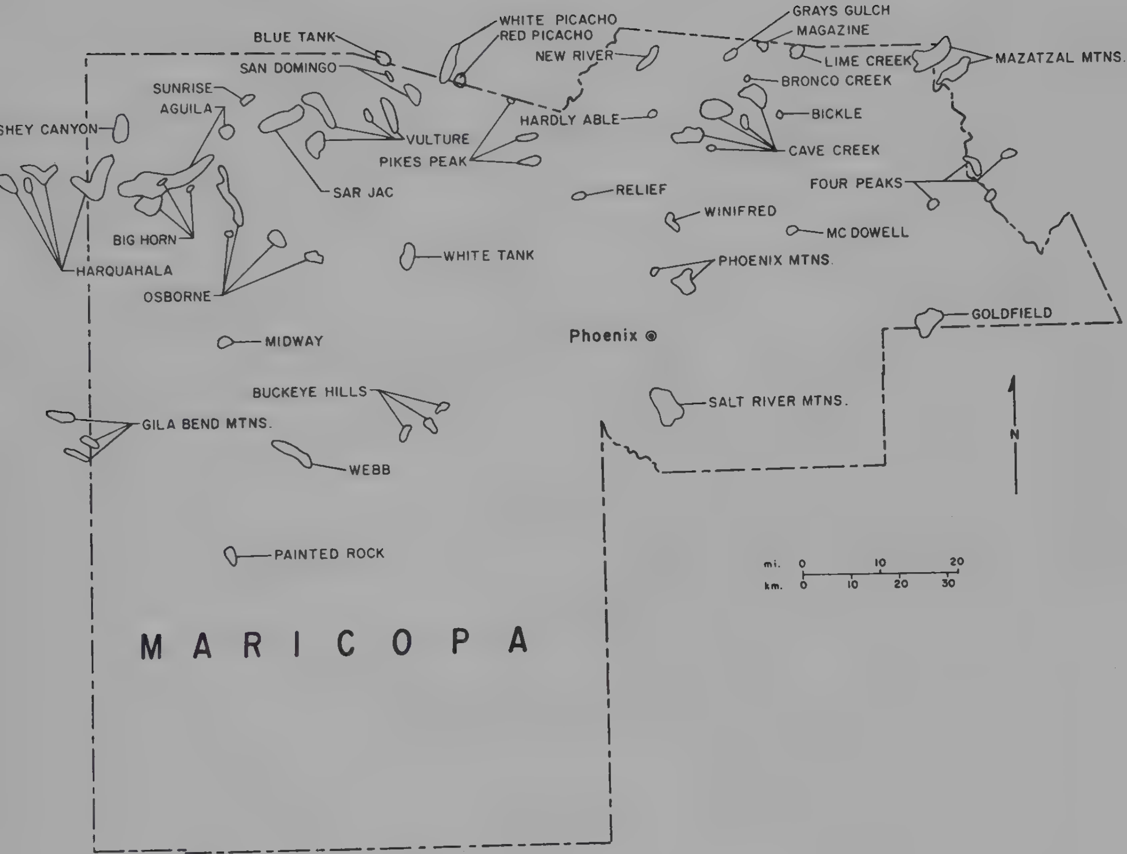
Mineral districts in Gila County, Arizona

Mineral districts in Graham County, Arizona

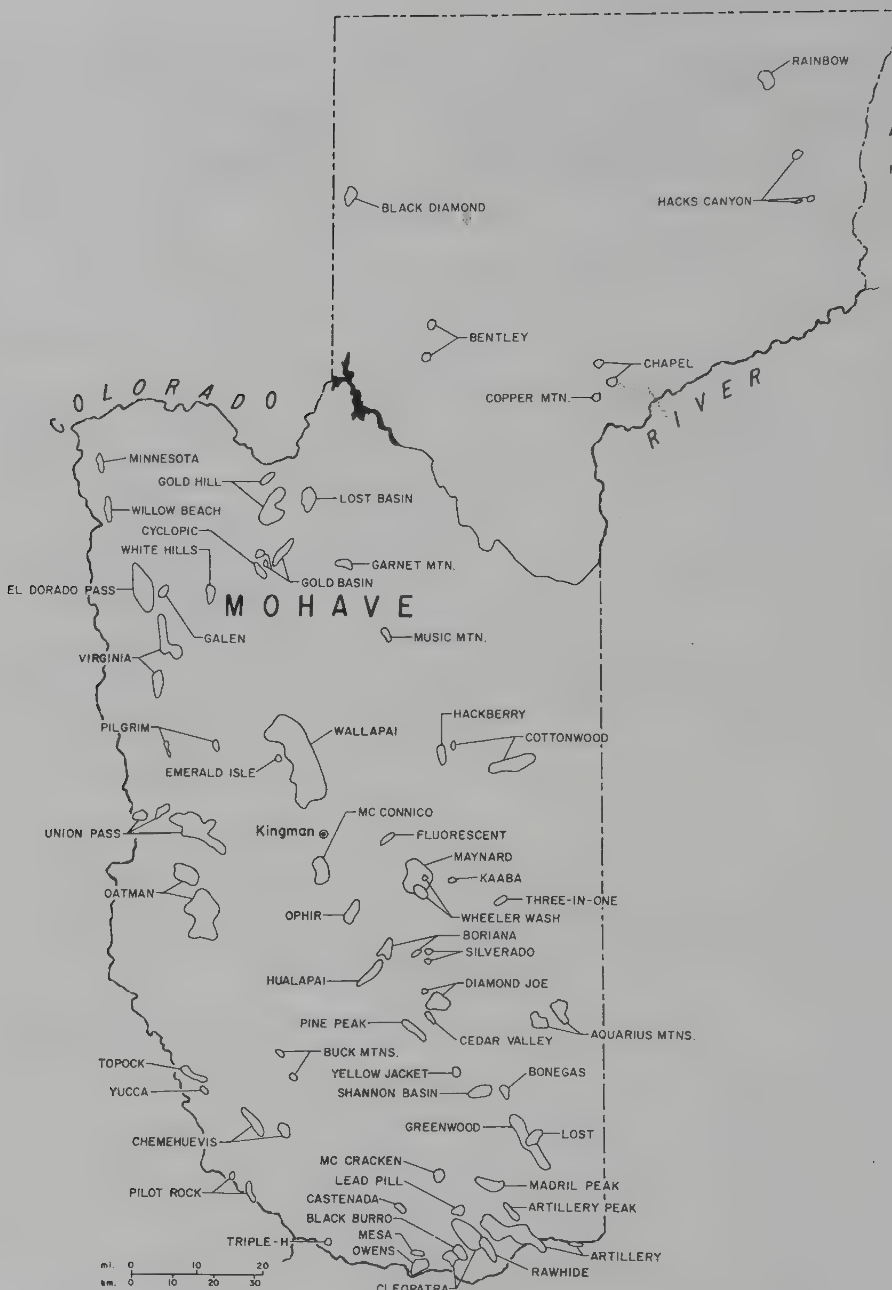


Mineral districts in Greenlee County, Arizona

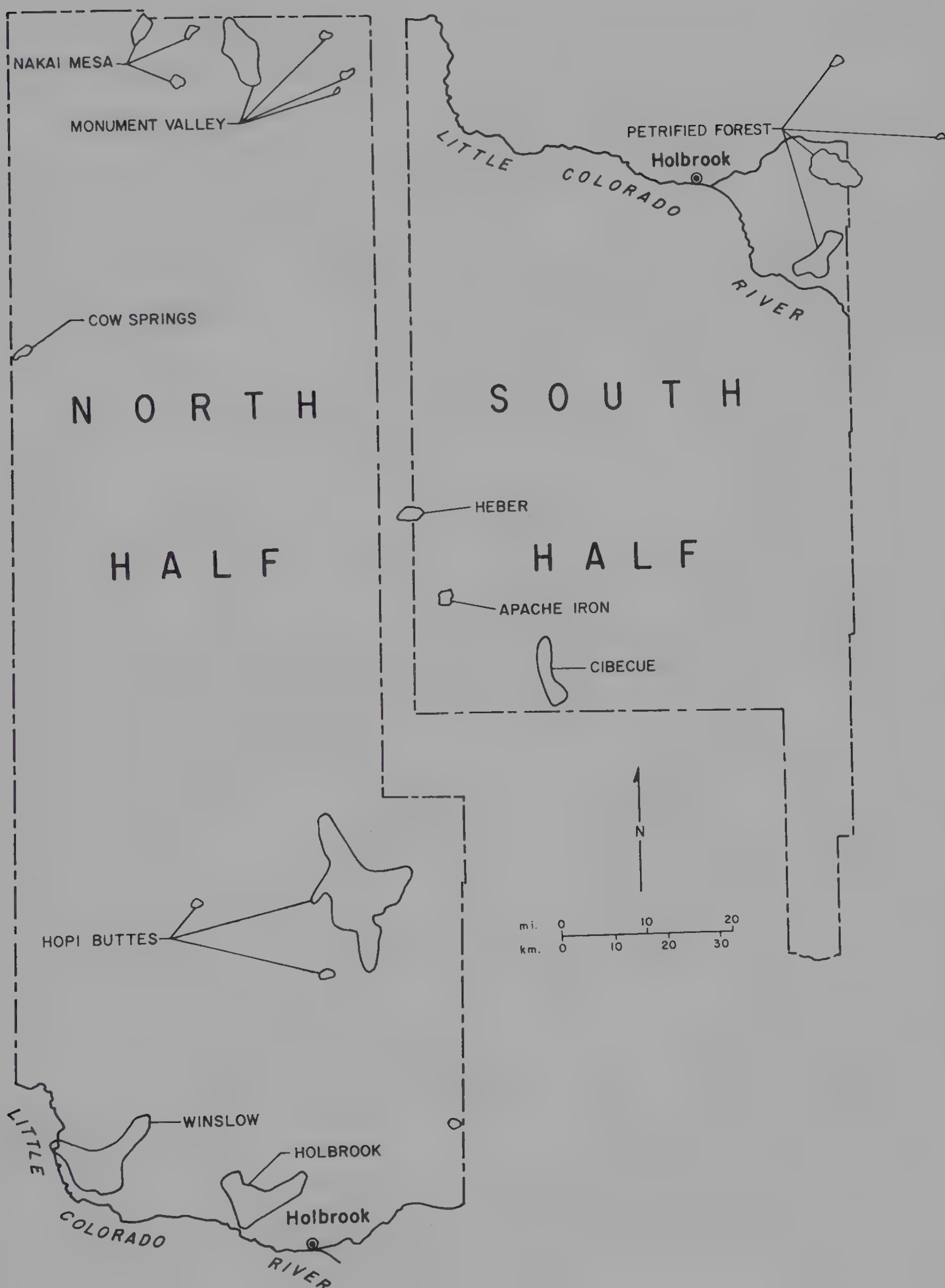
Mineral districts in La Paz County, Arizona



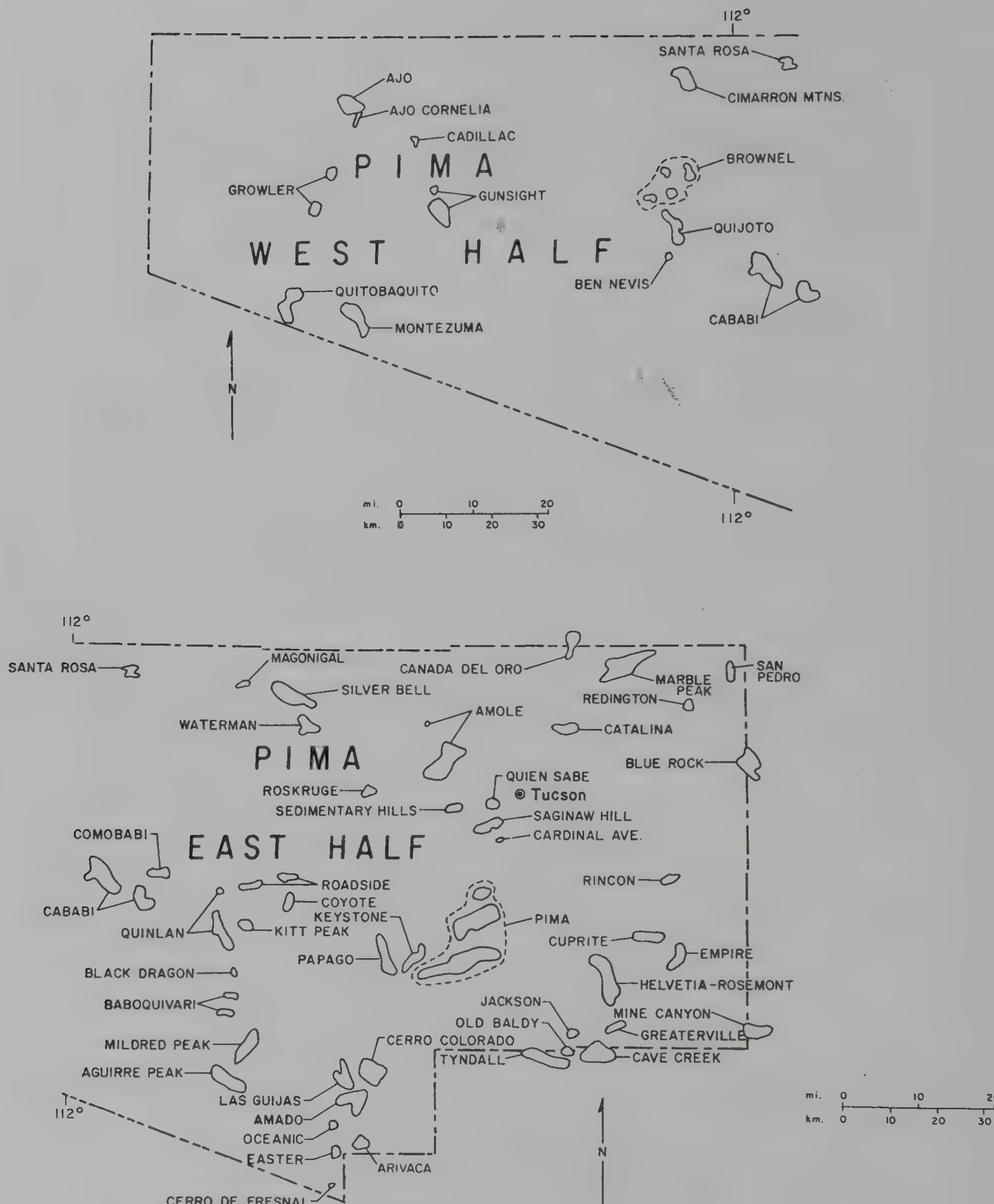
Mineral districts in Maricopa County, Arizona



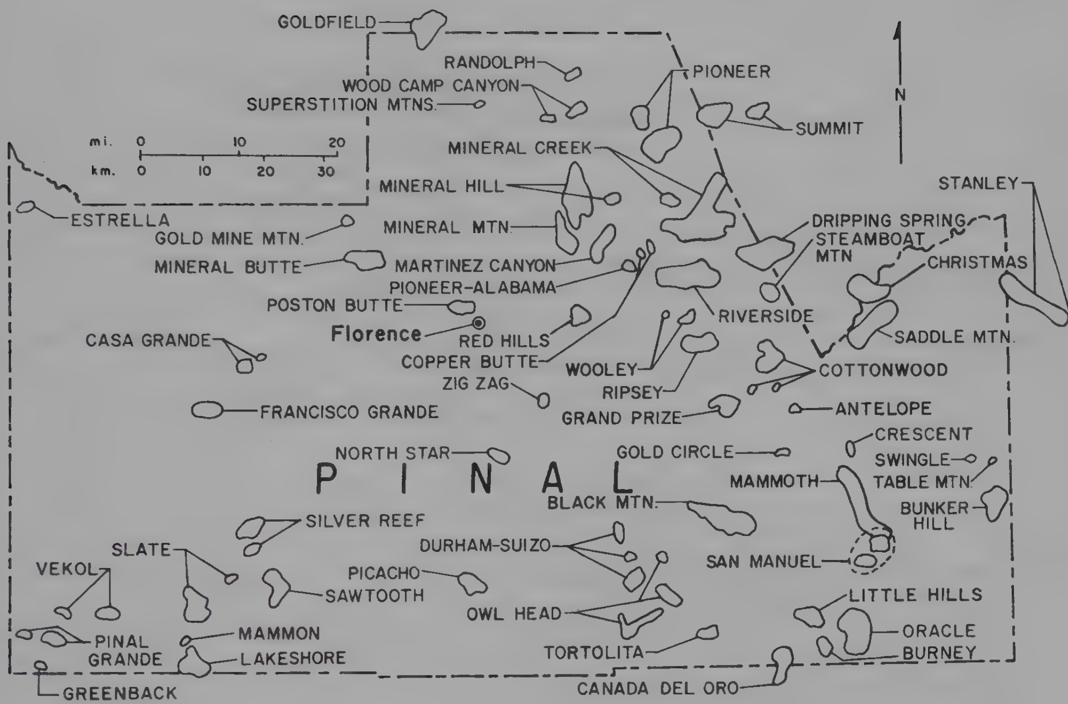
Mineral districts in Mohave County, Arizona



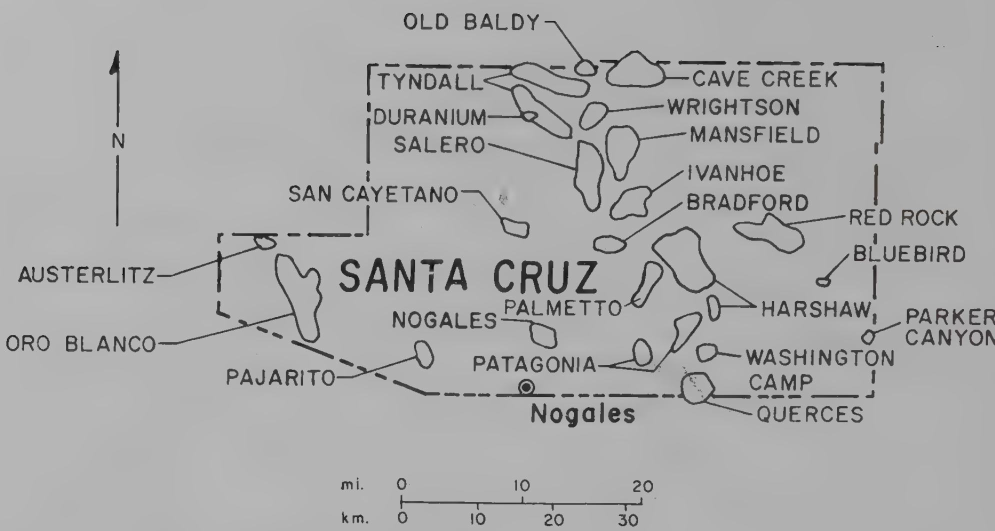
Mineral districts in Navajo County, Arizona



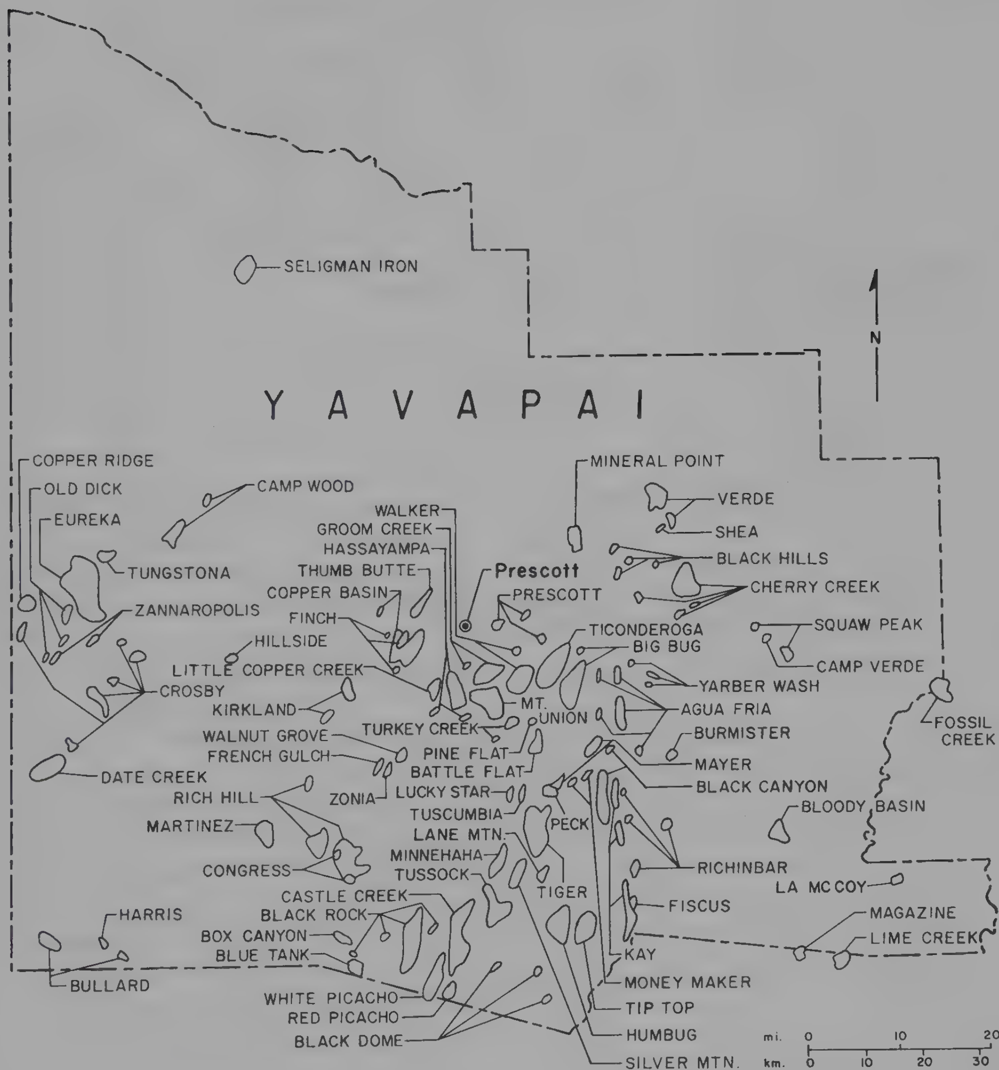
Mineral districts in Pima County, Arizona



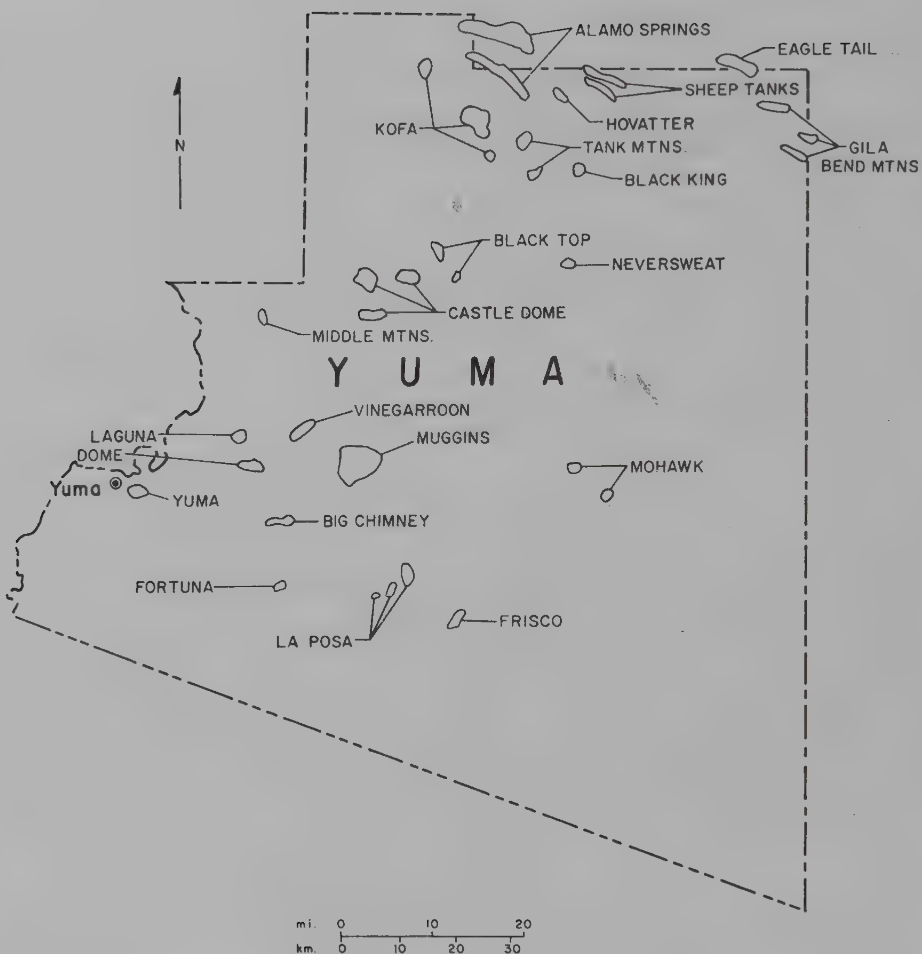
Mineral districts in Pinal County, Arizona



Mineral districts in Santa Cruz County, Arizona



Mineral districts in Yavapai County, Arizona



Mineral districts in Yuma County, Arizona

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Part 4 ("Catalog of Arizona Mineral Occurrences") has not been indexed. Minerals are indexed only if significant information is given (e.g., the year the mineral was first described or excerpts from mineral reports).

ABOUT THE AUTHORS

JOHN W. ANTHONY received bachelor's and master's degrees in geology from the University of Arizona and a doctorate from Harvard University. Following several years as mineralogist with the Arizona Bureau of Mines, he joined the faculty of the University of Arizona, where he became professor and curator of its Mineralogical Museum. His studies in mineral synthesis, crystal-structure analysis, and classical descriptive mineralogy resulted in the publication of numerous technical papers. Anthony was a coauthor of the *Handbook of Mineralogy.* He served as a consultant to the mineral industries and was founding editor of the *Digest,* the bulletin of the Arizona Geological Society. He was a fellow of the Geological Society of America, the Mineralogical Society of America, the American Association for the Advancement of Science, and the Arizona-Nevada Academy of Science. Anthony died on November 9, 1992.

SIDNEY A. WILLIAMS has authored or coauthored about 65 scientific papers and discovered 50 new mineral species, naming two of them after his coauthors. A graduate of Michigan College of Mining and Technology (now Michigan Technological University), he received his doctoral degree from the University of Arizona. He was a member of the faculty of Michigan College of Mining and Technology for 3 years, leaving that position to become mineralogist for Silver King Mines, Inc. in Nevada. In 1965 he joined Phelps Dodge Corp. as mineralogist/petrologist for the Western Exploration Office and director of the geological laboratory. He has been a consultant to the mineral exploration industry since 1982. Williams is a fellow of the Mineralogical Society of America.

RICHARD A. BIDEAUX, a University of Arizona graduate in geological engineering, received his master's degree in geology from Harvard University. He has discovered and helped to describe several new Arizona minerals, which appear in this volume. For many years he has been associated with the Tucson Gem and Mineral Society Show and also served as assistant editor and columnist for the *Mineralogical Record*. Bideaux has been a collector of and dealer in fine mineral specimens. Since 1980 he has served as a general partner of Mineral Data Publishing, which produces the *Handbook of Mineralogy*, a text he has also coauthored. Bideaux is a fellow of the Mineralogical Society of America.

RAYMOND W. GRANT received his doctoral degree in geology from Harvard University. He later joined the faculty of the University of Vermont. Since 1975 he has been professor of geology at Mesa Community College in Mesa, Arizona. His published works include several articles on Arizona mineral localities and the *Checklist of Arizona Minerals*. Grant is past president of the Mineralogical Society of Arizona and has organized symposia on Arizona minerals.

WENDELL E. WILSON, a prominent photographer of mineral specimens in his own right, has been editor of the *Mineralogical Record* since 1976. From 1980 to 1983, he produced a series of five issues of the *Mineralogical Record* devoted entirely to Arizona minerals; the issues have since become classics. Wilson is a fellow of the Mineralogical Society of America.

Graemite and cuprite. Bisbee, Cochise County. Arizona-Sonora Desert Museum. 1-cm-wide specimen. Jeff Scovil photo.

Long awaited by professional geologists and amateur rockhounds alike, the new *Mineralogy of Arizona* is a completely revised and greatly expanded edition of a book first published in 1977 and updated in 1982. New material covers 232 minerals discovered in Arizona since the first edition, including 28 first identified in the state. Also new is a section on the history of Arizona mining and mineralogy, which provides context for understanding the significance of mineral discoveries and production since prehistoric times.

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Cover photograph: Aurichalcite, 79 Mine, Gila County, Arizona. Arizona-Sonora Desert Museum collection. Photo by Wendell E. Wilson.

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