Alphabetical Mineral Reference

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A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

If you do not find the information you need here or in linked documents, try an alternative database gem database

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Acanthite ... see argentite

Accabar ... See Coral
Colors: black
Comments: can be dyed

Achrite ... see Dioptase

Achroite.... see colorless Tourmaline

Actaeonella... fossil sea snail from Austria

Acmite ... aegerine
sodium iron silicate: (Ca,Na)(Mg,Fe,Al)(Si,Al)2O6
Crystallography: monoclinic, prismatic (not over 1"); frequently massive in other rocks
Colors: black, brown or green on thin edges Luster: glassy
Hardness: 5 to 6
S.G.: 3.2 to 3.4
Cleavage: perfect
Fracture: uneven
Occurrence: common in U.S.

Actinolite ... See also Tremolite, Nephrite
calcium magnesium (iron) silicate: Ca2(Mg,Fe)5Si8O22(OH)2
Crystallography: Monoclinic; bladed crystals, usually elongated; fibrous, columnar aggregates, massive, granular, often twinned
Colors: Pale to dark green, blackish green, black white (when it is free of iron it is Tremolite)
Luster: Vitreous, at times dull glassy
Hardness: 5.5 - 6
Specific gravity: 3 to 3.05 common (3.03-3.07)
Cleavage: two directions good, fibrous, brittle, the compact variety is tough

Refractive index: 1.619-1.644
Birefringence: .022-.026
Fracture: subconchoidal to uneven
Cleavage: perfect prismatic
Pleochroism : Yellow to dark green, transparent to opaque
Occurrence: Contact metamorphic limestones and dolomites; magnesium-rich limestones and ultrabasic rocks; regionally metamorphosed rocks. Small, dark transparent crystals
Crystal or stone size: to 10 cts
Comments: Catseye, easy to cleave, hard to cut, poor jewelry stone, found in nephrite jade. Confused with: Wollastonite which is commonly fluorescent before heating, and dissolves in hydrochloric acid. Scapolite melts more easily and is or becomes on heating, fluorescent in long wave UV. Epidote melts readily to black slag

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Adamantine spar ... see Corundum

Adamite
zinc arsenate: $Zn_2(AsO_4)(OH)$
Crystallography: orthorhombic, drusy crust of short prismatic or horizontally elongated crystals
Colors: Colorless, pale green, yellowish green, yellow shades, bluish green, green, rose, violet, color zoning
Luster: Vitreous
Hardness:3.5
Specific gravity: 4.32-4.48
Cleavage: Good in one direction,fracture conchoidal to uneven
Refractive index: 1.708-1.773
Birefringence: .031-.05
Pleochroism: Colorless, blue-green, yellow-green, pale rose, pale purple, pink
Occurrence: Secondary mineral in the oxidized zone of ore deposits
Crystal or stone size: To 3 cts
Comments: Rare (crystal), poor jewelry material, but a collector's item; brilliant fluorescence in light yellow to white when free of iron, green is non fluorescent and can be distinguished from smithsonite by the lack of CO_2 bubbles in solution in HCl

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Adularia ... See Feldspar

Aegirine ... See Acmite

African Jade ... Massive green Grossular Garnet

Agalmatolite ... See Pyrophyllite, Pinite, Talc

Agate ... See quartz .. Chalcedony .. Banded Quartz

Agatized Wood...See Quartz, Fossilized Wood, Chalcedony

Agmatite ... Found in migmatites, an ultrametamorphic rock
Color: dark with lighter veins
Comments: contains: quartz, feldspar; used as building stone. Found in the Black Forest (Germany)

Alabaster ... See Calcite, Gypsum

Albite ... See Plagioclase Feldspars

Alexandrite ... see Crysoberyl

Allanite ... orthite
$(Ca,Ce,La,Na)_2(Al,Fe,Be,Mn,Mg)_3(SiO_4)_3(OH)$
Crystal: monoclinic, prismatic
Color: black to dark brown
Luster: pitchy or resinous
Hardness: 5.5 - 6
SG: 2.7 - 4.2
Fracture: subconchoidal to uneven
Cleavage: poor
Environment: pegmatites, as a minor mineral in igneous rocks
Comments: fuses quickly (with bubbling) to a dull black magnetic glass; radioactive

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Allemontite .. See Arsenic

Almandine ... See Garnet
Colors: purplish red
Hardness: 7.5
SG: 3.9 to 4.2
RI: 1.76 to 1.81
Comments: colored with iron

Almandite ... almandine ... see Garnet

Alunite ... alumstone
hydrous sulfate of aluminum and potassium: $KAl_3(SO_4)_2(OH)_6$
Crystallography: Hexagonal, usually massive crystals are rare
Colors: white, gray, pink
Luster: vitreous to pearly,translucent to transparent Hardness: 3.5 - 4
Specific gravity: 2.6 - 2.9
Fracture: flat conchoidal to uneven, brittle
Cleavage: basal, brittle, conchoidal to uneven

Occurrence: altered orthoclase feldspar rich rocks, massive alunite
Crystal or stone size: massive crystals are rare
Comments: sometimes florescent orange in LW UV; closely resembles limestone and dolomite; a mountain of alunite is in Marysvale Utah

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Amazon Jade ..amazonstone.. see Microcline (Feldspar)

Amazonite ... See Feldspar

Amber... See also Succinite

Amblygonite ... Also Montebrasite, Natromontebrasite
LiAl(PO4)(F,OH)
Crystallography: triclinic, pinacoidal Colors: colorless, yellow, white, light gray green, lilac, gray blue
Luster: glassy
Fracture: uneven to subconchoidal
Hardness: 5.5 to 6
Specific gravity: 3 to 3.1
Cleavage: perfect
Comments: most stones come from pegmatite dikes in Brazil, Main and Burma Lithia; fluorescent in LW weak orange

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Amethyst ... see Quartz

Amianthus ... see Tremolite, Actinolite

Ammonite ... shell replaced by pyrite

Amphibolite ... see hornblende .. a rock

Analcime .. Also Pollucite, Zeolite group, Analcite
NaAlSi2O6.H2O
Crystallography: cubic, tetragonal trisoctahedron (trapezohedron) transparent to translucent
Colors: colorless, white, greenish, reddish
Luster: glassy
Hardness: 5 to 5.5
Fracture: subconchoidal
Specific gravity: 2.3
Cleavage: traces of cubic
Comments: after heating to the point of melt and then cooling it florescences yellow green

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Anatase ... TiO2 ... titanium oxide
crystallography: tetragonal

Colors: blue, light yellow to brown
Luster: adamantine to submetallic
Hardness: 5.5 to 6
S.G.: 3.8 to 3.9
Cleavage: perfect basal
Fracture: subconchoidal
Comments: collector crystal, found in Alpine regions; NC,MA,CO. & France

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Andalusite ...See Kyanite, Sillimanite.^M
Varieties: Chiastolite, Viridine
Al_2SiO_5
Crystallography: orthorhombic
Colors: green, greenish brown w/ reddish tints chiastolite is impure variety showing gray cross on black or gray ground.
Hardness: 7.5
Specific gravity: 3.15
Cleavage: perfect
Refractive index: mean 1.64 v .01
Pleochroism: striking in one direction
Comments: often confused with tourmaline, but has lower DR & higher SG

Andesite ... igneous rock
Essentials: plagioclase, anorthite, biotite
Accessories: magnetite, ilmenite, quartz, hornblende pyroxene, glass
Accidentals: olivine, orthoclase, anorthoclase

Andradine ...see garnet .. andradite
Crystallography: Isometric
Colors : Demantoid is green, Topazolite is yellow, Leuco is colorless Hardness: 6.5
Specific gravity: 3.85
Refractive index: 1.89
Comments: very high dispersion not usually suitable for jewelry, varieties as demantoid, melanite and topazolite usually have gem qualities.

Anglesite ... lead sulfate ... $PbSO_4$
Crystal system: Orthorhombic
Colors: colorless to white, gray, green, brown, black.
Hardness: 2.75 to 3 very soft
Specific gravity: 6.3
Comments: alteration of galena in oxidation areas of lead deposits. Faceted stones from Morocco (colorless 19 ct.) were sold for $50.00 per.ct. (1994)

Anhydrite ... $CaSO_4$

Crystallography: orthorhombic
Colors: colorless, bluish, red - violet Hardness: 3.5
Specific gravity: 2.9 - 2.99
Cleavage: 3 good
Fracture: uneven to splintery
Environment: sedimentary beds, gangue in ore veins and in traprock zeolite occurrences. Crystals are collector items. Sometimes fluorescent. Easily altered to gypsum through hydration.

Annabergite ... hydrated nickel arsenate
$(Ni,Co)_3(AsO_4)_2.8H_2O$
Crystal system: monoclinic
Color: white to green
Luster: silky to glassy
SG: 3.1
Hardness: 2.5 - 3.0
Comments: forms as crust on nickel minerals, sometimes replacing the mineral completely; Best place to see in the US is in Humboldt, CO.

Anorthite ... a variety of feldspar ...see labradorite, oligoclase
sodium calcium alum. silicate
Color: colorless, white, yellowish, green, pink, to reddish
SG: 2.62 - 2.76
Comments: can be found in triclinic crystals or in massive form

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Anorthosite ... intrusive igneous rock
Color: dark gray
Comments: contains plagioclase, anorthite, labradorite - bytownite, orthopyroxene, with some olivine, magnetite, ilmenite, apatite, chromite, and sulfide. It also rarely contains biotite, hornblende and cordierite. Can be found in San Diego,CA.

Anthophyllite ...$(Mg,Fe)_7Si_8O_{22}(OH)_2$... hydrous magnesium iron silicate
Crystal sys.: orthorhombic
Color: gray, light green, light brown
SG: 2.8 - 3.2
Hardness: 5.5 - 6
Cleavage: prismatic
Comments: modification of olivine through hydration crystals are rare. Franklin Co. N.C.

Anthracite ... bituminous coal ... jet Crystallography: organic
Colors: black
Luster: high
Hardness: 2.5 - 4
Specific gravity: 1.3 - 1.35

Cleavage: none
Refractive index: 1.64 - 1.68
Pleochroism: none
Crystal or stone size: massive
Occurrence: world wide: Spain, France, U.S. Comments: when rubbed can become electrically charged.

Antigorite ... see serpentine

Antimony ... see arsenic

Antlerite...$Cu_3(SO_4)(OH)_4$...Sulfate of copper
Crystal: Rhombic bipyramidal
Color: bright to dark green
Luster: glassy
Hardness: 3.5 - 4
SG: 3.9
Fracture: uneven
Cleavage: pinacoidal perfect side, poor front
Comments: Like brochantite is a mineral of the oxidized zones of copper deposits in siliceous rocks that cannot supply an abundance of the CO_2 required for the formation of the carbonate group of copper minerals.

Apache Tears ... see obsidian
Comments: round or simi round, marble like, dark blackish green.

Apatite Crystallography: hexagonal
Colors: yellow, blue, green, violet
Hardness: 5
Specific gravity: 3.18 to 3.21
Cleavage: none
Refractive index: avg. 1.638 v .003
Occurrence: blue from Burma, strong dichroism Comments: yellow shows rare earth absorption bands (584 nm.); very low DR & higher SG distinguish it from danburite

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Aplite ... see orthoclase

Apophyllite Crystallography: tetragonal
Colors: pink
Hardness: 4.5 to 5
Specific gravity: 2.3 to 2.5
Refractive index: avg. 1.536 v. .001
Comments: hydrated potassium-calcium fluosilicate rarely cut, a collector gem.

Aquamarine ... see Beryl Refractive index: 1.75 +/- .006

Aragonite Crystallography: orthorhombic
Colors: colorless various tints
Luster: vitreous
Hardness: 3.5 - 4
Specific gravity: 2.94
Refractive index: 1.53 - 1.685
Occurrence: can form crystals large enough to cut Comments: is the "orient" produced by overlapping of platelets near a pearls surface (pearl RI is 1.52 - 1.69).

Arenite ... clastic sedimentary rock
Color: variable, from white to gray, yellow, green, red to brown.
Comments: composed of quartz sand with other minerals as color: feldspar, mica, calcite, zircon, apatite, olivine, monazite, pyrite, magnetite, gypsum, glauconite.

Arfvedsonite ... hydrous sodium iron mag. alum. silicate
Crystal Sys.: monoclinic
Color: black to greenish black
SG: 3.5
Hardness: 5
Comments: found in alkaline plutocic rocks rich in iron and in rare metamorphic schist.

Argentite ... acanthite
Crystallography: cubic
Colors: black, gray
Luster: metallic
Hardness: 2 to 2.5
Specific gravity: 7.3
Cleavage: poor
Fracture: subconchoidal
Comments:

Argillite ... sedimentary rock
Color: light to dark gray to black
Comments: fine grain, mixture of clay minerals with quartz, feldspar, mica, some carbon, iron oxides, gypsum, & pyrite. Classic marine & glacial deposits.

Arkansas diamond ... see clear quartz Comments: so named because some of the best come from Arkansas

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Arkose ... sedimentary rock
Color: gray, pink or reddish

Comments: coarse grains of feldspar, some quartz, biotite, mica and other minerals derived from igneous and lithic fragments, the binding agent may be silicate, calcitic, or limonitic.

Arsenoferrite ... see skutterudite

Arsenic ...
Crystal system: hexagonal (rare)
Color: black w/ white incrustations
SG: 5.4 - 5.9
Hardness: 3.5
Comments: hydrothermal veins; associated with silver, nickel, cobalt.

Arsenopyrite ... iron arsenic sulfide
Color: silver to whitish gray with pink tints SG: 5.9 - 6.2
Hardness: 5.5 - 6

Asbestos .. see tremolite , actinolite , serpentine
Comments: asbestos is a finely fibrous serpentine; crysotile is a coarser fibrous type.

Artinite ... hydrated magnesium carbonate Crystal system: monoclinic
Color: white to gray
SG: 2.03
Hardness: 2

Astrophyllite ... hydrous potassium iron titanium silicate
Color: golden yellow to yellow brown
SG: 3.3 - 3.4
Hardness: 3.5 - 4.5

Atacamite ... hydrous copper chloride
Crystal sys. orthorhombic
Color: green
SG: 3.76
Hardness: 3 - 3.5

Augelite ... Colors: colorless to brownish
Hardness: 4
Specific gravity: 2.7
Refractive index: 1.574 to 1.588
Comments: aluminum phosphate

Augite ... calcium magnesium iron aluminum silicate..(see pyroxene)

Aurichalcite ... hydrous zinc copper carbonate Color: light blue
SG: 4.2
Hardness: 2 - 2.5

Austinite .. Australite .. moldavite from Australia Colors: bottle green to brown green
Hardness: 5.5
Specific gravity: 2.32 - 2.38
Cleavage: none
Refractive index: 1.48 - 1.5
Comments: tektite formed from rock which has melted after being hit by a meteorite

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Autunite ... hydrated copper uranium phosphate Crystal sys. tetragonal
Color: greenish yellow
SG: 3.2
Hardness: 2 - 2.5

Aventurine .. see quartz

Axinite Crystallography: triclinic
Colors: blue, clove brown, violet
Fracture: conchoidal, brittle
Hardness: 7
Specific gravity : avg. 3.28
Cleavage: perfect
Refractive index: 1.685 + - .011
Pleochroism: strong; olive green, red - brown, yellow - brown
Occurrence: in bladed crystals,U.S.,France,Mexico Comments: occurs in bladed crystals

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Azurite

Babingtonite ... Hydrous calcium iron manganese silicate
Crystal sys: triclinic
Color: black or blue to brown when altered
SG: 3.4
Hardness: 5.5 - 6

Bakerite ... see howlite

Balas ruby ... see spinel

Banded agate...see quartz..chalcedony

Barite ...

Crystallography: orthorhombic
Colors: colorless, yellow, red, green, black
Hardness: 2.5 - 3.5
Specific gravity: 4.48
Occurrence: med. to low temp. hydrothermal veins assoc. with lead, silver, antimony Also deposits in hot springs Crystal or stone size: up to 3.3 ft.
Comments: sometimes fluorescent

Basalt ... A basic igneous rock
Basalt is formed from a lava that solidifies to a fine grained black rock composed of microscopic grains of calcium sodium (plagioclase) feldspar, pyroxene, and olivine, but with no quartz.

Basanite ... see quartz .. also touchstone
Colors: velvet black

Bastite ... bastinite ... hureaulite
Hydrous manganese phosphate
Crystal sys: monoclinic
Color: pink, gray, yellow, reddish brown SG: 3.2
Hardness: 3.5
Comments: pronounced {hoo-ray'o-lite}

Bauxite ... {bawks'-yt}
Crystallography: none, an aggregate
Colors: reddish to brown, white to yellowish Luster: vitreous to pearly
Hardness: 2.5 - 3
Specific gravity: 2.3 - 2.7
Cleavage: perfect
Occurrence: sedimentary ; Surinam, Jamaica, US, world wide.
Comments

Becquerelite ... see gemmite

Benitoite
Crystallography: Hexagonal
Colors: sapphire blue to colorless
Hardness: 6.5
Specific gravity: 3.67
Refractive index: 1.78 + - .047
Comments: Rare stone from San Benito Co. Cal. strong DR and high dispersion

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Bertrandite
Crystallography: orthorhombic

Colors: colorless to pale yellow
Luster: vitreous
Hardness: 6 -7
Specific gravity: 2.6
Cleavage: excellent prismatic
Occurrence : pegmatites US
Crystal or stone size: to 1 cm
Comments: of interest to mineralogists & collectors

Beryl {bair'-ul}...see also aquamarine , emerald, heliodor, morganite
Colors: colorless, gold, yellow-green, yellow, pink, , green (emerald), pale blue to blue green (Aquamarine), golden to yellow (heliodor), pink (Morganite)

Beryllonite ... $NaBePO_4$ ... sodium beryllium phosphate
Crystal: monoclinic
Hardness: 5.5 - 6
Luster: glassy
SG: 2.8
Fracture: conchoidal
Cleavage: good basal, brittle, transparent to translucent
Comments: Fuses with difficulty to a cloudy glass, wet with sulfuric acid and the powdered mineral froths. coloring flame is yellow.

Betafite ... hydrous uranium titanium niobium oxide
Crystal sys: isometric
Color: black, sometimes coated w/greenish brown or yellow surface alteration
SG: 3.7 - 5
Hardness: 5
Comments: occurs in pegmatites, ore of uranium thorium, niobium.

Bindheimite ... see boulangerite

Binnite ... see tetrahedrite tennantite

Biotite ... see mica

Bismuth ... {biz'-muhth}
Crystal sys: hexagonal
Color: A tarnished rose pink
SG: 9.7 - 9.8
Hardness: 2 - 2.5
Comments

Bismuthinite ... bismutite
Crystal sys: orthorhombic
Color: gray
SG: 6.4 - 6.5
Hardness: 2
Comments: rare free growing needles, first named cannizarite because of unbismuthlike needles. Found in NY,CO,Brazil

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Bixbite ... collector mineral (bixbyite) Crystal system: cubic
Color: Black, metallic
H: 6 - 6.5
SG: 4.9 - 5.1
Brittle

Blend ... sphalrite Crystallography: cubic
Colors: brown, yellow, orange, black, transparent to opaque green
Hardness: 3.5
Specific gravity: 3.09
Cleavage: perfect dodecahedral
Refractive index: avg. 2.37
Comments: good color luster and fire but too soft to take a high polish

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Bloodstone...see chalcedony (quartz) Colors : usually green with red spots
Luster: dull to waxy
Hardness: 7 or less
Specific gravity: 2.55 to 2.62
Cleavage: none
Refractive index: 1.535 to 1.539

Boehmite ... see bauxite

Boleite ... hydrated lead copper chloride Crystal sys: tetragonal
Color: dark blue
SG: 5.05
Hardness: 3.5

Bonamite ... see smithsonite H: 5
SG: 4.35
RI: 1.62

Borax {bohr'-ahn} boron, hydrated sodium borate, borax acid
Crystal sys: monoclinic
Color:colorless to white with yellow or blue tint

SG: 1.74
Hardness: 2 - 2.5
Comments

Bornite ... {bohr'-nyt}...copper iron sulfide Crystallography: isometric
Colors: reddish brown, showing purple tarnish
Hardness: 3
Specific gravity: 5 - 5.7
Comments

Boulangerite ... lead antimony sulfide Crystallography: orthorhombic
Colors: dark gray to black
Luster: metallic
Hardness: 2.5 - 3
Specific gravity: 5.7 - 5.9
Occurrence: hydrothermal veins, found with galena,silver, antimony deposits. Crystal or stone size: stubby or tubular prismatic crystals. Comments: dissolves in nitric acid

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Bort ... see diamond ... bortz Comments: diamond unsuitable for gemstones, used in cutting and polishing.

Bournonite ... lead copper antimony sulfide
Crystallography: orthorhombic
Colors: dark gray to black
Luster: metallic
Hardness:2.5 - 3
Specific gravity: 5.7 - 5.9
Cleavage: good
Comments: used as an ore of lead and copper

Bowenite SG:2.59
Avg.RI: 1.55
H: 5.5

Brazilianite Crystallography: monoclinic
Colors: colorless to greenish yellow to transparent or translucent
Hardness: 5.5
Specific gravity: 2.99
Refractive index: avg. 1.612 v. .021
Occurrence : Minas Gerais, & New Hampshire

Breccia ... {brech'-ee-uh} sedimentary rock
Crystallography : none

Colors : variable
Luster : can be polished like marble
Hardness: variable
Occurrence: found in limestone and dolomite Crystal or stone size: massive
Comments

Breithauptite ... see niccolite

Brochantite ... hydrous copper sulfate
Crystallography: monoclinic
Colors : bright green
Hardness: 3.5- 4
Specific gravity: 3.97
Cleavage: perfect
Comments: ore of copper

Bromyrite ... bromargyrite
Crystal system: cubic
Colors: colorless, greenish gray, gray to violet brown
Adamantine luster
H: 1 - 1.5
SG: 5.5

Bronzite ... see enstatite ... hypersthene
Crystallography: orthorhombic
Colors : greenish brown or blackish
Luster: submetallic
Hardness: 5
Specific gravity: 3.2 - 3.5

Brookite ... titanium oxide
Crystallography: orthorhombic
Colors: brown to black sometimes banded
Luster: adamantine
Hardness: 5.5 - 6
Specific gravity: 4.1
Cleavage: imperfect
Comments: ore of titanium

Brownspar ... see calcite

Brucite ... magnesium hydroxide
Crystallography: hexagonal

Colors: colorless, green, blue, pinkish yellow, brown
Luster: pearly
Hardness: 2.5
Specific gravity: 2.4
Occurrence: fracture planes in serpentinized peridotites in asbestos mines
Comments: used for magnesia refractories and a source of metallic magnesium.

Buergerite ... see tourmaline

Bytownite ... see plagioclase feldspar

Cabrerite ... see annabergite

Calamine ... hemimorphite ... smithsonite
hydrated zinc silicate ... ore of zinc

Calaverite ... AuTe2 ... see sylvanite (Au,Ag)Te2

Calciphyre ... calci - silicate rocks
Color: yellow brown w/pink/light green/white & dark red zones
Comments

Calcite ... calcium carbonate
Crystallography: hexagonal
Colors: whitish, red, pink, yellow, blue
Luster: iridescent or pearly
Hardness: 3
Specific gravity: 2.71
Comments: some are fluorescent in UV, red, yellow pink blue

Caledonite ... Cu2Pb5(SO4)3(CO3)(OH)6... carbonate sulfate of lead and copper
Color: light blue to light blue green
Crystal: orthorhombic
Luster: resinous
Hardness: 2.5 - 3
SG: 5.8
Fracture: uneven
Cleavage: 1 good, 1 poor, brittle, translucent
Comments: rare

Californite ... see vesuvianite... hydrous calcium magnesium aluminum silicate. an aggregate combo of idocrase and grossular garnet
Color: apple green

SG: 3.3
Avg.RI: 1.7
H: 5.5 to 7.5
Comments: $450.00 per ct. when cut from crystal.

Calomel ... HgCl ...
Crystal: tetragonal, (minute)
Color: gray to yellowish
Luster: adamantine
Hardness: 1 - 2
SG: 6.5
Fracture: conchoidal
Cleavage: 2 , 1 good, sectile, translucent Comments: Fluorescent red

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Campylite ... see mimetite

Cancrinite ... tectosilicate
Crystallography: hexagonal
Colors: colorless, yellow, white, reddish, violet
Hardness: 5 - 6
Specific gravity: 2.4 - 2.5
Comments: collector item

Cannizarite ... see bismuthinite

Carbonatite ... igneous rock
Color: gray to yellowish
Comments: South Africa; used in the extraction of minerals and rare elements

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Carnallite ... hydrated potassium magnesium chloride
Crystal sys: orthorhombic
Color: colorless to reddish pink
SG: 1.6
Hardness: 2.5
Comments: potassium fertilizer

Carnelian ... see chalcedony
Colors: red to orange
Occurrence: looks like jade and fire opal

Carnotite ... hydrated potassium uranium vanadate
Crystallography: monoclinic
Colors: canary yellow

Hardness: very soft, clumpy powder
Specific gravity: 4.7 - 5
Cleavage: perfect
Occurrence: very common in desert areas of U.S.
Crystal or stone size: crystals are rare
Comments: ore of uranium and vanadium

Cassiterite ... tin oxide
Crystallography: tetragonal
Colors : colorless to dark brown
Luster: adamantine
Hardness: 6.5
Specific gravity: 6.95 to 7
Cleavage: imperfect conchoidal
Refractive index: avg. 2.045 v. .096
Comments: high luster and dispersion, has been used as a diamond substitute

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Celestite ... celestine ... strontium sulfate
Colors: colorless, white, red brown, orange, light blue.
Luster: glassy
H: 3 - 3.5
SG:3.9 - 4
Comments: sometimes fluorescent, geodes from Madagascar can be lined with these blue crystals.

Cerargyrite .. bromyrite .. secondary silver ore
Color: greenish gray to gray
H: 1 - 1.5
SG: 5.5
Comments: composed of 60 to 75 % silver chloride yellow crystals were found in New South Wales, which darken to gray in sunlight.

Cerussite ... lead carbonate
Crystallography: orthorhombic
Colors: colorless, white
Luster: Adamantine
Hardness: 3 - 3.5
Specific gravity: 6.5
Occurrence: Namibia, new Mexico, Rhodesia USSR, Germany, Colorado
Crystal or stone size: some crystals are very large, 50/60 cts, @ $100 per ct.
Comments: ore for lead, bright green fluorescence

Cervantite ... stibnite .. antimony sulfide
Crystal sys: orthorhombic

Color: red (kermesite), yellow
SG: 4.6 -4.7
Hardness: 2
Comments: ore of antimony

Chabazite ... hydrated calcium aluminum silicate
Crystallography: hexagonal
Colors: colorless, white, greenish, reddish
Luster: vitreous
Hardness: 4 - 5
Specific gravity: 2.05
Cleavage: good rhombohedral
Occurrence: world wide, intrusive igneous rocks Comments: collector item

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Chalcanthite ... hydrated copper sulfate
ore of copper
Crystal sys: triclinic
Color: colorless
SG: 2.3
Hardness: 2.5
Comments: major ore of copper in Chile

Chalcedony
types
Crystallography: fine grained quartz
Colors: all
Luster: waxy
Hardness: 6.5 - 7
Specific gravity: 2.6 + - .05
Cleavage: none
Refractive index: 1.535 - 1.539
Crystal or stone size: can be massive
Comments: this is a very general name for all fine grained quartz.look up types under its own name

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Chalcocite ... tobernite ... copper sulfide
Crystal sys; orthorhombic
Color: dull gray, surface altered to black/green
SG: 5.5 - 5.8
Hardness: 2.5 - 3
Comments: ore of copper

Chalcopyrite {kal-koh-py'-rite} copper iron sulfide
Crystallography: tetragonal

Colors: brassy yellow
Luster: metallic
Hardness: 3.5 - 4
Specific gravity: 4.2 - 4.3
Cleavage: none
Occurrence: world wide
Crystal or stone size: massive
Comments

Chalcosine ... see chalcocite

Chalcotrickite ... cuprite ... copper oxide
Crystallography: isometric
Colors: ruby red
Luster: adamantine
Hardness: 3.5 - 4
Specific gravity: 5.8 - 6.2
Crystal or stone size: rare crystals have been cut as gems
Comments: ore of copper

Chert ... see quartz

Chessylite ... see azurite

Chiastolite ... see andalusite

Childrenite ...(Fe,Mn)Al(PO4)(OH)2.H2O... Hydrous iron and manganese aluminum phosphate
Crystal: orthorhmbic
Color: pink to light brown, gray to black
Luster: glassy
Hardness: 4.5
SG: 3.06 - 3.25
Fracture: conchoidal
Cleavage: front and side pinacoid, brittle

Chlorargyrite ... silver chloride
Crystal sys: isometric
Color: gray, tarnish to greenish/purple/brown
SG: 5.5 - 5.6
Hardness: 1 - 1.5
Comments: silver ore, hard to find

Chloritoid ... hydrous iron magnesium aluminum silicate

Crystallography: monoclinic and triclinic
Colors: yellow - green to black
Luster: vitreous to pearly
Hardness: 6.5
Specific gravity: 3.51 - 3.8
Occurrence: found in low grade metamorphic rocks rich in aluminum, iron and manganese
Crystal or stone size: in contact with marbles corundum and quartz.
Comments: collector item

Chondrodite
Crystal system: monoclinic
Colors: yellow to dark reddish brown
Luster: resinous
Hardness: 6 - 6.5
SG: 3.14
Cleavage: poor
Comments: fine crystals are found in Sweden a collector item.

Chromite ... iron chromium oxide
Crystallography: isometric
Colors: black
Luster: submetallic
Hardness: 5.5
Specific gravity: 4.5 - 4.8
Cleavage: none
Crystal or stone size: massive
Comments: ore of chromium, a chromium and iron oxide, in the SPINEL group of minerals. Metallic black chromite generally is associated with serpentinites, peridotites, and related rocks. It forms large, irregular, compact masses in ore deposits and also occurs in stony iron meteorites.

Chrysoberyl...{kris'-uh-bair-ul}... cymophane, alexandrite, cats eye
Crystallography: orthorhombic
Colors: green/red (alexandrite), greenish or brownish yellow to translucent and chatoyant (cat eye) colorless to brown
Hardness: 8.5
Specific gravity: 3.71 - 3.73
Cleavage: distinct in two directions
Refractive index: avg. 1.75 v. .009
Pleochroism: strong in alexandrite
Occurrence: Siberia, Brazil
Crystal or stone size: Alexandrite in Siberia less than 1 ct. Brazilian stones are larger.
Comments

Crysocolla ... see chalcedony SG: 2.1
Avg. RI: 1.5
H: 2

Chrysolite ... see olivine

Chrysotile ... see serpentine ... asbestos

Chrysoprase...see chalcedony
Color : yellowish green
SG: 2.6
Avg.RI: 1.53
H: 7
Comments: confused with jade, poor emerald, serpentine

Cinnabar {sin'-uh-bar} cinnabarite, mercury sulfide
Crystallography: hexagonal
Colors: red, pink
Hardness: 2 - 2.5
Specific gravity: 8.1
Cleavage: perfect
low temp. hydrothermal deposits
Comments

Citrine ... see quartz

Clinochlore...see chlorite...hydrous magnesium iron - aluminium silicate... see penninite
Crystallography: monoclinic
Colors: blue green, yellow, rare white
Luster: pearly
Hardness: 2 - 2.5
Specific gravity: 2.6 - 2.8
Cleavage: perfect basal
Comments: of interest to collectors

Clinoenstatite...see enstatite, hypersthene

Clinozoisite...Hydrous calcium aluminum silicate
Crystal sys: monoclinic
Color: gray, pale green, pink
SG: 3.3 - 3.5
Hardness: 6.5
Comments: Elongated prismatic crystals, poorly terminated

Cobaltite ... cobalt arsenic sulfate
Crystallography: orthorhombic
Colors: gray, violet to purple tint
Luster: metallic
Hardness: 5.5
Specific gravity: 6.3
Cleavage: perfect
Crystal or stone size: 1"
Comments: CoAsS, is the chief ore mineral of cobalt, containing up to 35 percent of the element. A secondary source of arsenic, cobaltite contains up to 10 percent iron and some nickel as impurities. The cubic crystals (ISOMETRIC SYSTEM) are silver white. Luster metallic, streak grayish black. It occurs with other cobalt and nickel minerals and, more commonly, in contact metamorphic zones.

Colemanite ... hydrated calcium borate
Color: white, tinted red to pink by impurities
SG: 2.4
Hardness: 4 - 4.5
Comments: A main ore of boron

Columbite - tantalite group,iron maganese niobium tantalum oxide
Crystal System: orthorhombic
Colors: black
SG: 5.3 - 8.1
Comments: Ore of niobium and tantalum, used in stainless steel

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Conichalcite... hydrous calcium copper arsenate
Crystal sys: Orthorhombic
Color: shades of green
SG: 4.3
Hardness: 4.5
Comments: A secondary mineral occurring in the oxidation of copper

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Copiapite ... hydrated iron sulfate
Crystal sys: triclinic
Color: olive green to yellow or orange
SG: 2.08 - 2.17
Hardness: 2.5
Comments: A secondary mineral that occurs in the upper portions of sulfide deposits, dissolves easily in water.

Copper
Crystal sys: isometric
Color: copper color tinted with green or blackish film

SG: 8.93
Hardness: 2.5 - 3
Comments

Coral ... White, pink, black, red
Crystallography: none, organic
Colors: red, pink, black, white, can be dyed
Hardness: 3.5 - 4
Specific gravity: 2.12
Refractive index: 1.55 - 1.57
Occurrence: warm seas
Comments: Coral has a tree-like form, and a radial fibrous cross section. White is the most common, coral occurs in warm tropical waters having a temp. above 68 F. The Romans believed it had strong healing powers.

Cordierite...{kohr'-dee-uh-ryt}... magnesium aluminum silicate...iolite
Crystallography: orthorhombic
Colors: gray, blue, black, purple
Luster: glassy
Hardness: 7 - 7.5
Specific gravity: 2.61 - 2.66
Cleavage: poor, gem v. distinct
Refractive index: 1.542 - 1.551
Comments

Corundum{kuh-ruhm'-duhm}...sapphire...ruby
Crystallography: Hexagonal
Colors: red = ruby, all other colors = sapphire red - orange = padparadsha sapphire
Hardness: 9
Specific gravity: 3.99
Cleavage: false ,which may be well developed
Refractive index: avg. 1.762 to 1.77 v. .008
Comments

Covellite ... covelline ... copper sulfide
Crystal sys: hexagonal
Color: indigo blue
SG: 4.59 - 4.76
Hardness: 1.5 - 2
Comments: ore of copper

Cristobalite ... silicon oxide
Color: colorless to white or gray

SG: 2.3
Hardness: 7
Comments: only of interest to collectors

Crocidolite SG: 2.66
Avg.RI: 1.54
H: 7

Cryolite ... sodium aluminum fluoride
Crystallography: monoclinic
Colors: white , colorless
Luster: vitreous or pearly
Hardness: 2.5
Specific gravity: 2.95 - 3
Comments: used in pottery glazes and glass

Cubic Zirconia...man made
Colors: all
Hardness: 8.5
Specific gravity: 5.8 + - .2
Refractive index: 2.15 + - .03
Occurrence: man made
Crystal or stone size: up to 2" usual 1" or less
Comments: usually orange or yellow fluor. under UV.

Cummingtonite...hydrous magnesium silicate
Crystal sys: monoclinic
Color: brown
SG: 3.1 - 3.7
Hardness: 5 - 6
Comments: of interest to collectors

Cuprite...{koop'-ryt}... copper oxide
Crystallography: isometric
Colors: dark ruby red
Luster:adamantine
Hardness: 3.5 - 4
Specific gravity: 5.8 - 6.2
Comments: Cuprite, copper oxide is a common and widespread ore mineral formed by oxidation of sulfide minerals in the upper zones of copper veins. It forms octahedral crystals (ISOMETRIC SYSTEM) and granular masses that are various shades of red; parallel, elongated ruby -red needles are called chalcotrichite, and brick - red earthy masses are called tile ore. Cuprite's streak is bright brownish red. Some crystals are cut as gems @ $200.00 per ct.

Cyanite...see kyanite Color: blue
SG: 3.67
Hardness: 6-7 one direction/4-5 in the other Comments: sometimes used as gemstone, also used in the manufacture of porcelain.

Cyanotrichite ... hydrated copper aluminum sulfate
Color: blue
SG: 2.75
Hardness: 1
Comments: rare alteration in copper deposits.

Dacite ... extrusive igneous rock
Colors: medium gray
Occurrence: lava flows, dikes
Crystal or stone size: massive
Comments: no commercial value

Danburite ... calcium borosilicate
Crystallography: orthorhombic
Colors: pale yellow, colorless
Luster: vitreous
Hardness: 7
Specific gravity: 3
Cleavage: poor
Refractive index: avg. 1.633 v. .006
Occurrence: Burma
Crystal or stone size:
Comments: Lower SG / RI distinguish it from topaz.

Datolite...hydrous calcium borosilicate
Crystallography: monoclinic
Colors: colorless to yellow to brown, cloudy nodules in various colors.
Luster: vitreous
Hardness: 5
Specific gravity: 2.99
Refractive index: avg. 1.648 v. .044
Crystal or stone size: to 5 cts. cab.cut @ 250 pc.
Comments: collector stone, ore of boron

Demantoid....garnet...andradite
Crystallography:
Colors: green
Hardness: 6.5 - 7

Specific gravity: 3.85
Refractive index: 1.875 -1.89
Comments: high dispersion, horse tail inclusions

Dendrite ... pyrolusite ...maganese oxide
Crystallography: tetragonal
Colors : black
Luster: submetallic
Hardness: 6 - 6.5
Specific gravity: 4.7 - 5
Comments: can be tree like inclusions

Descloizite ... hydrous lead zinc vanadate
Crystallography: orthorhombic
Colors: orange to reddish brown
Luster: greasy
Hardness: 3.5
Specific gravity: 5.5 - 6.2
Occurrence: massive
Comments: rare ore of vanadium

Diabase ... {dy'-uh-bays} igneous rock Comments

Diamond...(boart, carbonado are industrial types)
Occurrence
Comments

Diaspore ... see bauxite

Diopside... pyroxene group
Crystallography: monoclinic
Colors : pale to dark green
Hardness: 5
Specific gravity: 3.29
Refractive index: avg. 1.69 v. .03
Chatoyant: some 4 ray stars
Comments : Different shade of green from peridot and higher RI lower DR. Enstatite has lower DR

Dioptase ... hydrous copper silicate
Crystallography: hexagonal
Colors: green
Hardness: 5
Specific gravity: 3.3

Cleavage: perfect
Comments: used as cabs in jewelry, rare faceted blue green stones up to 2 cts. @ 500 a piece

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Diorite {dy'-uh-ryt} intrusive igneous rock
Colors: dark gray
Comments

Dolomite {doh'-luh-myt} calcium magnesium carbonate
Crystallography: hexagonal
Colors: colorless, white, pink, yellowish Luster: vitreous
Hardness: 3.5 - 4
Specific gravity: 2.85 - 2.95
Comments

Dumortierite ... aluminum borosilicate
Crystallography: orthorhombic
Colors: blue, violet reddish brown
Luster: vitreous
Hardness: 7
Specific gravity: 3.45
Occurrence: world wide
Comments: used in manufacture of aluminums refractories

Dunite {doo'-nyt} intrusive igneous rock...see olivine
Colors: light green
Comments

Eclogite {ek'-luh-jite}... metamorphic rock
Color: white with red
Comments

Ekanite Colors: green
Luster: glassy
Hardness: 5 - 6.5
Specific gravity: 3.28
Refractive index: 1.597
Occurrence: Ceylon
Crystal or stone size: 1 to 3 cts.
Comments: radioactive, collector gem, @ 150 per ct.

Embrechite ... Migmatite .. ultrametamorphic rock
Color: white w/black
Comments: essentials: quartz, potassic feldspar oligoclase, biotite sometimes: zircon apatite, magnetite.

Rare: muscovite, cordierite, sillimanite, garnet

Embolite ... see cerargyrite .. bromyrite

Emerald...see beryl
Crystal or stone size: usually less than 2 ct. in gem quality.
Comments

Enargite {en-ar'-jite}.. copper arsenic sulfide
Crystal sys: orthorhombic
Color:gray to black
SG: 4.4 - 4.5
Hardness: 3
Comments: Enargite, a fairly rare copper arsenic sulfide mineral, is an important ore of copper and arsenic in the few places where it is abundant, such as Bor, Yugoslavia and Butte, Mont. Enargite forms metallic black, tabular, or prismatic crystals and granular, cleavable masses in vein and replacement deposits of intermediate temperature. Streak is grayish black.

Enstatite
Crystallography: Rhombic
Colors : green, brown, colorless
Hardness: 5.5 - 6
Specific gravity: 3.25
Refractive index: 1.658 - 1.668
Birefringence: .01
Occurrence: south Africa, Burma
Comments:some chatoyant.Absorption line @ 506 nm $100 per ct. for faceted transparent stones

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Eosphorite ... childrenite .. hydrated manganese aluminum phosphate
Crystal sys: monoclinic
Color:pink to brown
SG: 3.1 - 3.2
Hardness: 5
Comments: occurs in granite pegmatites with apatite, manganese phosphates and rose quartz

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Epidote...{ep'-i-doht}
Crystallography: monoclinic
Colors: dark brownish green,yellowish, red, yellow, gray
Hardness:6.5
Specific gravity: 3.25 - 3.45
Cleavage: excellent
Refractive index: avg. 1.75 v. .035
Birefringence: .019 - .045

Pleochroism: strong green, dark brown, yellow
Comments: Color of crystals usually too dark to make good gemstones. strong dichroic. distinctive pistachio green. Epidote is the principal member of a group of silicate minerals that occur most commonly in low grade, calcareous metamorphic rocks and also in igneous rocks, where they have altered from feldspar, pyroxene, and amphibole minerals. A calcium aluminosilicate, epidote forms pistachio green to dark green elongated crystals, disseminated grains, or fibrous or granular masses that have perfect cleavage in one direction. Luster vitreous.

Epsomite ... hydrous magnesium sulfate
Crystal sys: orthorhombic
Color: colorless to white
SG: 1.67
Hardness: 2 - 2.5
Comments: epsom salts

Erythrite ... hydrated cobalt arsenate
Crystallography: monoclinic
Colors: red to gray
Luster: vitreous to pearly
Hardness: 1.5 - 2.5
Specific gravity: 3.07
Cleavage: perfect

Essonite ... see garnet ... hessonite

Euclase
Crystallography: monoclinic
Colors: pale green or blue some yellow, colorless
Luster: vitreous
Hardness: 7.5
Specific gravity: 3.1
Cleavage : very good
Refractive index: avg. 1.665 v. .019
Crystal or stone size:
Comments: appearance & RI almost identical to fibrolite, distinguish by lower SG.

Fauslite... see turquoise
Comments: turquoise which zinc is the colorent

Feldspar
Types: orthoclase, microcline moonstone, labradorite, amazonite, albite, plagioclases, cat's eye, sunstone

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Ferberite ... heubnerite .. iron maganese tungstate

Crystallography: monoclinic
Colors: reddish brown, blackish brown, black
Hardness: 5 - 5.5
Specific gravity: 7.1 - 7.5
Comments: main ore of tungsten

Fergusonite (sp) ... see monazite

Ferroaxinite ... manganaxinite .. hydrous calcium iron manganese borosilicate
Color: reddish brown to yellow, violet and gray sometimes green when incrusted with clorite
SG: 3.25
Hardness: 6.5 - 7
Comments: a rare and unusual gemstone

Ferruginous quartz ... Monazite .. rare earth phosphate
Crystallography: monoclinic
Colors: yellow to brownish red
Luster: vitreous to waxy
Hardness: 5 - 5.5
Specific gravity: 4.8 - 5.5
Comments: ore of cerium and thorium

Fibrolite
Colors: pale blue, greenish
Hardness:7.5
Specific gravity: 3.25
Cleavage : very good
Refractive index: avg. 1.665 v. .019
Crystal or stone size:
Comments: same RI as Euclase

Flint...see quartz, chert, chalcedony, siliceous rock
Color: white, gray, red, black, some zoned
Comments

Flosferri ... see aragonite

Fluorite {flohr'-yt} fluor spar, blue John, Derbyshire spar
Crystallography: isometric
Colors : Purple, blue, green, yellow, pink, colorless
Luster: vitreous
Hardness: 4
Specific gravity: 3.18

Cleavage : perfect octahedral
Refractive index: 1.434
Comments: Fluorite, calcium fluoride, is a major industrial mineral used as a flux in steel making as well as in the preparation of hydrofluoric acid and, in the ceramics industry, in glasses and enamels. Fluorite's vitreous, cubic crystals and cleavable, granular masses have a wide color range (often green, blue, or purple) and may fluoresce under ultraviolet light. Fluorite deposits form under a wide variety of conditions: as veins produced by hydrothermal alteration, as beds and cavities in sedimentary rocks, in hot spring deposits, and in pegmatites.

Fossilized Wood ... Quartz group
subtypes/ trade names: Agatized wood; Petrified wood, (brown, gray, red, white); some opal can be found in this;
Comments: look under quartz

Franklinite {frank'-lin-ite} see magnetite, loadstone
Crystallography: isometric
Colors: black
Hardness: 5.5 - 6.5
Specific gravity: 5.2
Cleavage: none
Comments: Franklinite is a zinc and iron manganese OXIDE MINERAL, that occurs abundantly only at Franklin, N.J., where, associated with zincite and willemite, it has been mined as an ore of zinc and manganese. A member of the SPINEL group, franklinite forms brilliantly metallic, iron black octahedral crystals, rounded grains, and granular masses in strongly altered limestone. Streak is reddish brown.

GGG...cubic..Gadolinium gallium garnet
colorless
Hardness: 6.5 - 7
Specific gravity: 7.02 - 7.05
Cleavage:
Refractive index: 2.03
Occurrence: man made
Crystal or stone size: thumb size

Gabbro...{gab'-roh}.. rock
Comments

Gadolinite...beryllium iron yttrium silicate
Crystal sys: monoclinic
Color: green, brown
SG: 4 - 4.47
Hardness: 6.5 - 7
Comments: ore of yttrium, thorium and rare earth elements

Galena {guh-leen'-uh}.. galenite .. lead sulfate
Crystallography: cubic - hexoctahedral
Colors:gray
Luster: metallic
Hardness: 2.5 - 2.75
Specific gravity: 7.4 - 7.6
Cleavage: perfect cubic
Crystal or stone size: massive
Comments

Garnet see type: almandine, pyrope, hessonite(essonite), grossular, demantoid, topazolite, spessartine (sp), andradite, audradite(sp) Almandine (rhodolite) uvarovite (a rare intensely green stone)
Colors : Green, to red, violet tint, brown tint

Garnierite ... see serpentine

Geode ... hollow rock .. sometimes lined with crystals .. see agate

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Geyserite ... see opal

Glass

Glauberite {glow'-bur-yt} sodium calcium sulfate
Crystallography: monoclinic
Colors: white, light yellow, gray to buff
Luster: glassy
Hardness: 2.5 - 3
Specific gravity: 2.7 - 2.8
Cleavage: perfect basal
Occurrence: in and around salt beds
Crystal or stone size: small 2 to 3 cm
Comments: The EVAPORITE mineral glauberite, a sodium and calcium sulfate, occurs sparingly in the deposits left by evaporation of saline lakes. It forms brittle, tabular, and prismatic crystals with vitreous luster, pale yellow or gray color, good basal cleavage, and slightly salty taste. Glauberite also occurs as isolated crystals in clastic sedimentary rocks, volcanic cavities, and fumaroles.

Glaucodot ... cobalt iron arsenic sulfide
Crystal sys: orthorhombic
Color: white or grayish white often with pink erythrite
SG: 6.04
Hardness: 5
Comments: ore of cobalt

Glauconite ... hydrous potassium aluminum iron magnesium silicate
Crystal sys: monoclinic
Color: light blue green
SG: 2.5 - 2.8
Hardness: 2 - 2.25
Comments: because of potassium content it is used in textile, sugar and brewing.

Glaucophane ... hydrous sodium magnesium aluminum silicate
crystal sys: monoclinic
Color: pale blue gray to dark blue and black
SG: 3.08 - 3.3
Hardness: 6 - 6.5
Comments: of interest to petrologist as a means of defining the metamorphic conditions in which the surrounding rock formed.

Gneiss...{nys}...rock .. less mica than schist otherwise much the same
Crystal or stone size: massive
Comments

Goethite...{guh'-tyt}... hydrogen iron oxide
Crystallography: orthorhombic
Colors: black to brown to yellow
Luster: adamantine to metallic to silky
Hardness: 5 - 5.5
Specific gravity: 3.3 - 4.3
Cleavage: side pinacoid
Comments: The widespread iron ore mineral goethite, an iron hydroxide is a common weathering product. It usually forms stalactitic masses with concentric or radiating internal structure. Color is yellowish to dark brown. Streak yellow. Cleavage perfect. Goethite is often associated with and indistinguishable from limonite in the gossan of sulfide mineral deposits, in tropical laterite, and in bog deposits

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Gold
Crystal sys: isometric
Color: yellow
SG:15.3 - 19.3
Hardness: 2.5 - 3
Comments,

Granite..{gran'-it}... coarse grained plutonic rock
Color: light gray, white, pink or black and yellow brown
Comments

Granodiorite Comments: Granodiorite is a plutonic rock composed mainly of coarse plagioclase, QUARTZ, and a little potassium FELDSPAR. Hornblende (see AMPHIBOLE) and biotite (see MICA) may constitute about 20 percent of the rock, with small amounts of other accessory minerals. Granodiorite is intermediate between QUARTZ MONZONITE and quartz DIORITE. Batholiths in the Sierra Nevada containing large amounts of granodiorite often show intrusive relationships. They probably formed from the melting or transformation of sedimentary rocks in deep zones of mountain belts.

Granophyre ... igneous rock
Color: reddish to pink
Comments: potassic feldspar, quartz. with: biotite, amphibole, sodic pyroxene, magnetite, ilmenite, muscovite, apatite, zircon, molybdenite, topaz, fluorite, etc.

Graphite ... carbon
Crystallography: hexagonal
Colors: black
Luster: submatallic
Hardness: 1 - 2
Specific gravity: 2.3
Cleavage: perfect basal
Crystal or stone size: rare tiny crystals in marble.
Comments: greasy feel

Graywacke...{gray'-wak}
Comments: Graywackes are SANDSTONES composed of a mixture of abundant mineral and rock fragments, together with a fine grained clay matrix that constitutes from 15 to 50 percent of the rock. Graywackes vary widely in their mineral composition and may include fragments of biotite, chlorite, feldspar, hornblende, magnetite, pyroxene, quartz, and serpentine. Their color, as the name implies, is various shadings of gray. Graywacke beds, probably formed by DENSITY CURRENTS, are thin and graded, and they are generally found in geosynclinal areas of thick sediment accumulation. They date from nearly all geological ages, from the Precambrian Time to the Pleistocene Epoch.

Greenockite ... cadmium sulfide
Crystal sys: hexagonal
Color: yellow
SG: 4.9
Hardness: 3 - 3.5
Comments: ore of cadmium

Grossularite ... grossular ...garnet Occurrence: metamorphosed limestone

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Gummite ... a mixture of several uranium oxides silicates, and salts
Crystallography: none

Colors: orange red to gray, yellow
Luster: greasy to waxy
Hardness: 2.5 - 5
Specific gravity: 3.9 - 6.4
Cleavage: none
Comments: ore of uranium

Gypsum {jip'-suhm} alabaster .. hydrous calcium sulfate
Crystallography: monoclinic
Colors: white and light tints may be dyed
Luster: glassy to greasy to silky
Hardness: 2
Specific gravity: 2.3
Cleavage: one direction perfect
Occurrence: world wide
Crystal or stone size: massive
Comments: Gypsum, a hydrated calcium SULFATE MINERAL, is used as a raw material in plaster of Paris, as fertilizer, as an ornamental stone (alabaster and satin spar), and as optical material (selenite). Common gypsum is found as prismatic, curved, or twisting monoclinic crystals of vitreous luster and as earthy, foliated, or granular masses; alabaster as fine grained masses; selenite as colorless, transparent crystals or foliated masses; and satin spar as pearly, fibrous masses. Gypsum is soft clear, white, or tinted, and has perfect cleavage in one direction. It occurs with halite and other evaporite minerals in extensive beds, often alternating with limestone and shale, deposited in seas or playa lakes.

Hackmanite .. see sodalite
Color: light pink to light yellow
Comments: this variety of sodalite, when exposed to SW UV causes yellow an colorless to change to bright orange for a very short time.

Halite ... {hay'-lite}...salt
Crystallography:isometric
Colors: white, tinted blue, reddish
Luster: glassy
Hardness: 2.5
Specific gravity: 2.1 - 2.6
Cleavage: perfect cubic
Crystal or stone size:
Comments: Halite, sodium chloride (NaCl), is the most abundant of the EVAPORITE minerals. As rock salt, it is a major source of sodium and chlorine; as table salt, it is used to flavor food and is an essential dietary constituent Halite forms glassy, colorless, bluish or variously tinted cubic crystals and masses exhibiting perfect cubic cleavage Halite occurs with anhydrite, gypsum, and other evaporites, often in extensive beds left behind by evaporation of enclosed, salt water bodies (playas). When such deposits are buried and deformed, a plug or SALT DOME may be extruded through the overlying sediments.

water soluble sometimes red fluorescent.

Hambergite
Colors: colorless
Hardness: 7.5
Specific gravity: 2.35
Refractive index: avg. 1.587 v. .072
Comments: strong double refraction, collector stone @ $100 to $300 per ct. for outstanding faceted stones.

Harmotome ... hydrated barium potassium aluminum silicate
Crystal sys: monoclinic
Color: white, gray, yellow, red or brown
SG: 2.4 - 2.5
Hardness: 4.5
Comments: collector item

Hauerite ... manganese sulfide
Crystal sys: isometric
Color: blackish brown
SG: 3.5
Hardness: 3.5 - 4.5
Comments: scientific interest

Hausmannite ... manganese oxide
Crystal sys: tetragonal
Color: blackish
SG: 4.7 - 4.8
Hardness: 5 - 5.5
Comments: manganese ore

Hauyne ... sodium calcium aluminum silicate sulfate
Color: blue, white, green
SG: 2.44 - 2.5
Hardness: 5.5 - 6
Comments: found in lapis, collector stone when it can be found large enough to cut. rare $ 2000 to $ 3000 per ct. blue

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Hedenbergite ... calcium iron silicate
Crystal sys: monoclinic brown to light green
SG: 3.58 - 3.6
Hardness: 5 -6
Comments: collector item

Heliodore ... see beryl

Heliolite .. see feldspar
Color: brownish orange

Hematite...{hee'-muh-tite}...haematite
Crystallography: hexagonal
Colors: metallic black, reddish
Luster: high
Hardness: 5.5-6.5
Specific gravity: avg. 5.1
Cleavage: none
Refractive index:
Occurrence: iron ore
Crystal or stone size:
Comments: The widespread iron oxide hematite is the most important ore mineral of IRON. Other uses include polishing compounds and paint pigments. Varying in color from reddish brown to black, it forms brilliantly metallic, tabular crystals as well as compact, fibrous kidney shaped or granular masses and CONCRETIONS. Streak is cherry red to brownish. Present in rocks of all types as an alteration product of earlier iron minerals, hematite is particularly abundant in the sedimentary rocks known as RED BEDS. It is usually slightly magnetic.

Hemimorphite {hem-i-mohr'-fyt} calamine hydrated zinc silicate
Crystallography: orthorhombic
Colors: white stained
Luster: glassy
Hardness: 4.5 - 5
Specific gravity: 3.4 - 3.5
Cleavage: prismatic
Crystal or stone size: 2 - 3 cm.
Comments: The hydrated zinc silicate mineral hemimorphite, formerly called calamine, is an important ore of zinc. It forms rounded aggregates of white or tinted sheaf like crystals with perfect cleavage in one direction. Luster is vitreous. An alteration product of sphalerite, it occurs with other zinc minerals, particularly smithsonite, from which it is distinguished by its strong pyroelectricity. Fluoresces bright orange in LW UV.

Herderite ... calcium beryllium phosphate
Crystal sys: monoclinic
Color: yellow, greenish white, purple
SG: 2.9 - 3
Hardness: 5 - 5.5
Comments: collector item

Heubnerite ... see ferberite

Heulandite ... hydrated sodium calcium aluminum silicate
Crystal sys: monoclinic
Color: yellow, green, reddish orange
SG: 2.2
Hardness: 3.5 - 4
Comments: collector item

Hexagonite ... tremolite .. see actinolite

Hiddenite...spodumene...kunzite
Colors: light red to purple, colorless to yellow
Hardness: 6.5
Specific gravity: 3.18
Cleavage: perfect in two directions
Refractive index: avg.1.665
Birefringence:
Pleochroism: strong in colorless, red to violet colors in the dichroscope and to the eye as the stone is turned. Hiddenite shows blue green and yellow green. The yellow type shows differences in depth of color as you turn the stone.
Comments: biaxial +;

Hornblende
Crystallography: monoclinic
Colors: green (adenine); blue green (parasite) to black
Luster: glassy
Hardness: 5 - 6
Specific gravity: 3 - 3.4
Cleavage: prismatic
Occurrence: A mineral of metamorphic and igneous rocks, often replacing pyroxene (uralite),also in solid crystalline aggregates.
Crystal or stone size: often several in. long
Comments: Fusible to a black glass.

Hornfels...{hohrn'-felz} rock
Comments: Hornfels is a fine grained, dense to granular METAMORPHIC ROCK formed mainly from sedimentary rocks and volcanic tuffs in the zones of contact metamorphism surrounding igneous intrusions. Hornfels can form at temperatures ranging from 200 deg to 800 deg C (1,392 deg to 1,472 deg F), depending on the depth and pressure, which respectively, cannot exceed 10 km (6 mi) and 3,000 bars. Recrystallization is as thorough as that of SCHIST but, because uniform pressures prevail during contact metamorphism, foliation does not occur. The texture is a mosaic of equal sized small grains. Mineralogic varieties are indicated by prefixing the term hornfels with the names of essential

constituents, for example, biotite hornfels.

Hyacinth ... see zircon

Hyalite ... see opal

Hypersthene...Magnesium iron silicate..bronzite
Crystallography: orthorhombic
Colors: brown to black
Luster: bronze
Hardness: 5 - 6
Specific gravity: 3.4 - 3.9
Cleavage: perfect in one direction
Refractive index: 1.69 - 1.705
Crystal or stone size: good crystals are rare Comments: difficult to distinguish from augite. rock forming mineral. same as but with more iron than enstatite.

Idocrase...{y'-duh-krays}...vesuvianite .. Californite
Crystallography: aggregate of tetragonal xtals
Colors : yellow, green, brown
Luster: similar to jade
Hardness: 6.5 (Californite: 5.5)
Specific gravity: 3.38 (Californite: 3.3)
Cleavage: none
Refractive index: avg. 1.7 v. .015
Crystal or stone size: crystals very small aggregate massive
Comments: Californite resembles jade. Idocrase, or vesuvianite, is a calcium aluminosilicate mineral commonly found in altered limestones. It forms prismatic crystals (tetragonal system) and columnar, granular, or massive aggregates that are usually brown or green. Luster is vitreous to resinous, Transparent crystals sometimes are cut as gemstones, and californite, a compact, green, jadelike variety found in California, is an ornamental stone.

Ilmenite...{il'-muhn-yt}...iron titanium oxide
Color: dark brown to black
SG: 4.5 - 5
Hardness: 5 - 6
Comments: The iron and titanium oxide mineral ilmenite is present in small amounts in many igneous rocks and placer sands and is the principal titanium ore. Ilmenite forms iron black, thick tabular or acute rhombohedral crystals (hexagonal system), as well as thin plates, compact masses and embedded grains. Luster metallic to dull.

Iron pyrite ...see pyrite

Iolite...(see cordierite)...dichroite

Ison glass...see mica

Jadeite
Crystallography: monoclinic
Colors: green, white, brown, mauve, black orange red, yellow
Luster: waxy
Hardness: 6.5 - 7
Specific gravity: 3.33 v. .04
Cleavage: two directions perfect, but the aggregate structure does not easily cleave in ant direction.
Refractive index: avg. 1.66 - 1.68 v. .012
Crystal or stone size: massive
Comments

Jasper
Subtypes / trade names: Agate (name used by some, Quartz group), Egyptian; Riband; Basanite; Blood; Nunkirchner; Plasma; Silex; also see quartz
Crystallography: none
Colors: all
Hardness: 7
Specific gravity: 2.55
Refractive index: avg.1.65
Crystal or stone size: massive
Comments: Jasper is an opaque and fine grained quartz. Colored red, yellow, brown, or off white to gray by impurities, jasper has long been used as an ornamental stone because it takes a fine polish. The color of a streak made on a black jasper touchstone can determine with good accuracy the gold content of gold ores.

Jet... coal
Crystallography: amorphous
Colors: black
Luster: glassy dull
Hardness: 2.5
Specific gravity: 1.33
Refractive index:avg. 1.66
Crystal or stone size:
Comments: hot point test produces coal odor

Kaolinite
Crystallography: monoclinic
Colors: white
Hardness: 2 - 2.5

Specific gravity: 2.6
Cleavage: can be cut and shaped
Occurrence: A mineral derived from aluminum silicates in the soil that has altered from feldspar in granite and pegmatite. Clay beds.
Crystal or stone size: compact masses, dull and earthy white, stained red brown to black. Clay like
Comments

Kernite...see hematite

Kimberlite...{kim-bur-lite}

Kornerupine... also cat's eye
Crystallography: orthorhombic
Colors: green, brownish green, yellow
Hardness: 6.5
Specific gravity: 3.32
Refractive index: avg. 1.675
Birefringence: .013
Occurrence: Sri Lanka, Burma, Kenya
Crystal or stone size:
Comments: strongly dichroic;confused w/tourmaline biaxial -

Kunzite ...(see spodumene)

Kyanite
Crystallography: triclinic
Colors: blue, some green, colorless
Hardness: 4 in one direction to 7 in the other
Specific gravity: 3.69
Cleavage: easy in one direction
Refractive index: avg. 1.72 v. .019
Pleochroism: strong; colorless, dark blue violet and blue.
Occurrence: can be found in NC
Crystal or stone size:
Comments: biaxial - The aluminum SILICATE MINERAL kyanite (derived from the Greek kyanos, meaning "blue") is used in the manufacture of spark plugs, porcelain, and other refractories; it has the same chemical composition as ANDALUSITE and SILLIMANITE. Its long bladed, usually blue crystals are distinctive. Luster is vitreous to pearly. Cleavage is perfect in one direction. Kyanite occurs in GNEISSES, SCHISTS, and granite PEGMATITES; it is an indicator of deep-seated, regional metamorphism of clay rich sediments.

Labradorite...(see feldspar)
Crystallography: triclinic

Colors: white, yellow, reddish, gray to black
Luster: glassy
Hardness: 6 - 6.5
Specific gravity: 2.6 - 2.8
Cleavage: good in two directions
Occurrence: labradorite (sp) found in Labrador
Crystal or stone size: not common except albite (cleavelandite), moonstone
Comments: bluish to whitish internal flashes in moonstone and labradotite

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Lamprophyre...{lam'-proh-fire}
Comments: Lamprophyre is a dark-colored igneous rock composed of large crystals (phenocrysts) of iron and magnesium-rich minerals, such as hornblende (see AMPHIBOLE), biotite (see MICA), or PYROXENE, set in a fine grained, dark-colored groundmass. Lamprophyres commonly occur as dikes or sills. Most of them contain less than 46% silica by weight and are high in sodium and potassium. Lamprophyric magma is commonly rich in volatile compounds such as water and carbon dioxide.

Latite...{lay'-tite}
Comments: Latite is a medium colored igneous rock composed of large crystals of plagioclase and potassium feldspar set in a fine grained groundmass. Latites commonly occur as dikes or sills. Chemically, latite is a fine grained equivalent of monzonite.

Lapis lazuli...{lap'-is laz'-u-lee} lazurite, lazulite, scorzalite
Crystallography: monoclinic
Colors: blue
Luster: waxy
Hardness: 5.5
Specific gravity: 2.8
Cleavage: poor
Refractive index: 1.5
Crystal or stone size: massive

Lazulite...hydrous magnesium aluminum phosphate
Crystal sys: monoclinic
Color: blue
SG: 3 - 3.1
Hardness: 5 - 6
Comments: ornamental stone

Lazurite ... sodium calcium aluminum silicate sulfate
Crystal sys: tetragonal
Color: blue, white, gray, pink
SG: 2.55 - 2.74
Hardness: 5 - 6.6

Comments: collector item

Leadhillite...sulfate & carbonate of lead... Pb4(SO4)(CO3)2(HO)2
Crystal: monoclinic (looks like hexagonal)
Color: white tinged with yellow, blue, or green Luster: pearly to adamantine
Cleavage: prominent, almost micaceous
Hardness: 2.5
SG: 6.3 - 6.4
Fracture: conchoidal
Translucent to transparent
Comments: fluoresces orange

Legrandite ...see adamite

Lepidocrocite...see hematite

Lepidolite...basic fluosilicate of lithium, potassium, and aluminum

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Leucite...potassium aluminum silicate
Colors: colorless
Hardness: 6
Refractive index: 1.504 - 1.509
Crystal or stone size:
Comments: some color caused by thin repeated twinning laminate

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Lepidocrocite ... hydrous iron oxide
Color: red, brown
SG: 4
Hardness: 5 - 5.5
Comments: iron ore

Lepidolite...hydrous potassium lithium aluminum
Ver: zinnwaldite, silver gray to brown silicate
Color: pink to lilac
SG: 2.8 - 2.9
Hardness: 2.5 - 4
Comments: ore of lithium

Leucite...potassium aluminum silicate
Color: white
SG: 2.5
Hardness: 5.5 - 6
Comments: fertilizer

Libethenite...copper phosphate... Cu2(OH)PO4
Crystal system: rhombic bipyramidal
Color: dark olive green
Luster: resinous
Hardness: 4
SG: 3.6 - 3.8
Fracture: subconchoidal
Cleavage: 2 good
Comments: Like olivenite, brochantite, and malachite, (likely associations), is one of the secondary minerals formed in the alteration through weathering of sulfide ore minerals.

Lignite ... coal
Color: black

Limonite...{ly'-muh-nite}...stalactites...goethite
Crystallography: orthorhombic or amorphous
Colors: brown black to ocher yellow
Luster: glassy to dull
Hardness: 5.5
Specific gravity: 2.7 - 4.4
Cleavage: none
Crystal or stone size:
Comments

Limestone...rock... calcium carbonate (calcite) in a very fine granular structure
Color: gray
Hardness: 3
SG: approx 2.7
Cleavage: brittle
Comments: Limestone is easy to scratch acid will dissolve. some limestone was chemically precipitated, other in beds of accumulated lime removed from seawater by living organisms. Beds of clean limestone can only form father out in the sea and in deeper water beyond the distance that stream borne clay particles and sand can travel. Often remains of the organic life of the sea of the period of the lime deposition are included in the beds. These are fossils.

Linarite...hydrous lead copper sulfate
Color:blue
Crystal sys: monoclinic
SG: 5.35
H: 2.5
Comments: crystals to 4 in.

Lindgrenite...see powellite

Lintonite...(sp) local name in Michigan
Color: green to grayish green
Hardness: 5 - 5.5
Comments: sometimes confused with jade

Liroconite...hydrated copper aluminum arsenate... $Cu_2Al(AsO_4)(OH)_4.4H_2O$
Crystal system: monoclinic - prismatic
Color: sky blue to greenish blue
Luster: glassy
Hardness: 2 - 2.5
SG: 3
Streak: pale blue
Cleavage: 2, poor, brittle.
Comments: translucent. Blowpipe turns it deep blue, then blackens, fusing to a black bead. Soluble in acid.

Lithiophilite...isomorphous series of lithium, iron, and manganese phosphate $LiMnPO_4$ (Triphylite $LiFePO_4$)
Crystal system: orthorhombic
Color: gray blue to gray blue green (triphylite), pink to greenish brown (lithiophilite)
Luster: glassy
Hardness: 4.5 - 5
SG: 3.4 - 3.6
Cleavage: 1 fair, 2 imperfect
Fracture: uneven to small conchoidal
Comments: Brittle, transparent to translucent. Fuse on charcoal to black bead. Triphylite bead magnetic.

Lithophysae...see cristobalite & tridymite (polymorphs of quartz)

Loadstone ... see magnetite
Color:black to dark brown

Loellingite...$FeAs_2$... diarsenide of iron
Crystal system: orthorhombic - bioyramidal
Color: tin white
Luster: metallic
Hardness: 5 - 5.5
SG: 6.2 - 8.6
Cleavage: basal
Varieties: nickelin, cobaltian loellingite
Comments: sometimes found with cobalt and nickel. Arsenic approx. 68 %; when heated gives garlic odor

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Luzonite... see enargite

Magma... melted rock well below the surface of the earth; called lava when it reaches the surface.

Magnesite ... magnesium carbonate
Crystal sys: hexagonal
Color: white, yellow, gray
SG: 3
Hardness: 3.5 - 4.5
Comments: The carbonate mineral magnesite is a source of magnesia, used in the manufacture of refractory brick and various chemicals and pharmaceuticals. Color is white (gray-to-brown with impurities), Luster is vitreous. A compact, earthy form occurs when carbonic acid alters rocks containing serpentine or peridotite; a cleavable (rhombohedral) aggregate form occurs when metamorphism alters magnesium rich rocks, or when magnesium solutions replace limestone rocks. Major deposits are in Manchuria, Austria, Washington, and Nevada.

Magnetite ... iron oxide
Color: black
SG: 5.2
Hardness: 5.5 - 6.5
Comments: ore of iron, strongly magnetic

Malachite...copper carbonate

Malacolite ... see diopside & hedenbergite

Manganapatite...see apatite

Manganite...manganese oxide... MnO(OH)
Crystal system: monoclinic - prismatic
Color: steel gray to black
Luster: submatilic
Hardness: 4
SG: 4.2 - 4.4
Streak: reddish brown
Cleavage: perfect side, poor prismatic and basal
Comments: Formed at higher temps than other manganese oxides, in veins.

Manganocolumbites...see columbite & tantalite

Manganotantalites...see columbite & tantalite

Marble...forms in regional metamorphism from another single mineral sedimentary rock, like sandstone

is a rock in which no major change can take place other than a growth and cementation of the individual crystal units. Marble forms from limestone and dolomite.
Color: multi colored depending on containts
Hardness: 3 - 4.5

Marcasite Crystallography: orthorhombic
Colors: silver black
Luster: metallic
Hardness:6
Specific gravity: 4.9

Margarite ... hydrous calcium aluminum silicate
Color: pink, white or grat aggregates
SG: 2.99 - 3.1
Hardness: 3.5 - 4.5
Comments: can be found in NC, PENN, collector item

Marialite...sodium & calcium aluminum silicate, with chlorine, carbonate, and sulfate; sodium and calcium mutally replace each other to any amount, making a series which have been named marialite for the NaCl rich end member and meionite for the CaCO end
Crystal system: tetragonal
Color: colorless - white, violet, pink, gray
Luster: glassy
Hardness: 5.5 - 6
SG: 2.5 - 2.7
Comments: fluorescent orange to bright yellow, less often red.

Marl
Comments: A sedimentary rock, marl is a white, gray, or brownish earthy mixture of fin grained calcium carbonate and clay. Formed in both marine and freshwater environments marl commonly contains fossil shells. It is used as a fertilizer and in the manufacture of insulation, portland cement, and bricks. Some marl, such as the potassium rich glauconite, or green sand, marl of the Atlantic coasts of Europe and the United States, is used in water softeners.

Marmolite...see serpentine

Marshite...see calomel

Martite...see magnetite

Massicot... PbO...Litharge...PbO lead oxide
Crystal system: rhombic
Color: yellow to red
Luster: greasy to dull

Hardness: 2
SG: 9.7
Cleavage: several
Comments: association with galena

Melanite ... see andradite

Melanterite...see chalcanthite

Meneghinite...see jamesonite

Mercury ... Hg
Color: silver
SG: 13.6
Hardness: soft heavy liquid
Comments (there are a lot of them...)

Mesolite ... see natrolite

Meteorite ... see iron and pyrrhotite

Miargyrite...antimony sulfide ...AgSbS2
Crystal system: monoclinic
Color: black to gray
Luster: metallic
Hardness: 2 - 2.5
SG: 5.1 - 5.3
Streak: cherry red
Cleavage: 3 poor
Fracture: subconchoidal
Comments: rare, never forming large crystals. Silver ore.

Mica group...{my'-kuh}...muscovite...biotite...phlogopite
Crystallography: monoclinic prismatic
Colors: colorless, light yellow, amber, rose, green, gray, black
Luster: glassy
Hardness: 2 - 2.5
Specific gravity: 2.8 - 3
Cleavage: perfect basal
Crystal or stone size: common flat transparent used as windows in stoves; plates are flexible.
Comments

Micaceous hematite

Comments: see hematite; hematite with mica.

Mica schist...conglomerate rock containing a large amount of mica (see mica)

Microcline...(see feldspar)...green feldspar...amazonstone
Crystallography: triclinic
Colors: light cream, yellow, brown, green to black.
Luster: resinous
Hardness: 6
Specific gravity: 2.5 - 2.6
Cleavage: two directions good
Occurrence: pegmatite dikes
Crystal or stone size: inches to feet
Comments: gemstones and scouring powder

Microlite...hydrous sodium calcium tantalum oxide
Crystal sys: isometric
Color: brown, colorless, yellow
SG:4.2 - 6.4
Hardness: 5 - 5.5
Comments: VA,MA,CN, collector item

Migmatite...anatexite...ultrametamorphic rock
Colors: dark to light gray
Occurrence: Precambrian shields
Uses: building stone, sometimes as polished slabs for ornamental purposes.

Millerite ... nickel sulfide
Crystal sys: hexagonal
Color: brassy yellow
SG: 5.2 - 5.6
Hardness: 3 - 3.5
Comments: The nickel sulfide mineral millerite (NiS) is a minor ore of nickel. It forms slender to capillary, brass to bronze yellow crystals, often in radiating needles, interwoven hairs, or tufted coatings. Luster metallic, streak greenish black. A low temperature mineral, millerite occurs as a lining in cavities, geodes, and carbonate veins; as an alteration, or weathering, product of other nickel minerals; and as inclusions in other minerals.

Mimetite...{mim'-uh-tyt}...mimetesite...lead arsenate chloride
Crystallography: monoclinic
Colors: colorless, yellow brown to orange
Luster: resinous to adamantine
Hardness: 3.5

Specific gravity: 7.1
Cleavage: none
Crystal or stone size: small long crystals Comments: The lead arsenate mineral mimetite is a minor ore of lead, occurring in the oxidation zone of lead veins. Its name is derived from its ability to "mimic" pyromorphite, a similar but more common mineral in which the arsenic is replaced by phosphorus. Mimetite forms crusts and prismatic or barrel shaped crystals (hexagonal system) that are pale or orange yellow to brown. Luster, resinous; and its an ore of lead.

Minium...see massicot

Mispickel...arsenopyrite
Crystallography: monoclinic
Colors: sliver white
Luster: metallic
Hardness: 5.5 - 6
Specific gravity: 5.9 - 6.2
Cleavage: prismatic
Crystal or stone size:
Comments: garlic smell with hammer blow, ore of arsenic

Moldavite...tektites from Czechoslovakia
Colors: gray, black, green
Luster: glassy
Hardness: 5
Specific gravity: 2.35
Refractive index: 1.49
Crystal or stone size:
Comments: volcanic glass

Molybdenite...{muh-lib'-duh-nyt}... molybdate
Crystallography: hexagonal
Colors: bluish gray
Luster: greasy
Hardness: 1 - 1.5
Specific gravity: 4.7
Cleavage: perfect along plates
Occurrence: tabular crystals with hex outline interwoven masses common
Comments: The chief ore of molybdenum is the molybdenum sulfide mineral molybdenite. Usually found in foliated or granular masses and scales, molybdenite occasionally forms lead gray, six sided tabular or prismatic crystals. Its luster is metallic. Because of its softness and perfect basal cleavage, it has a greasy feel and is useful in making special lubricants. Its streak (greenish or bluish gray). SG (4.7) distinguish it from graphite (dark black and 2.23), which has similar physical properties. Widespread but rarely abundant, molybdenite occurs in acid igneous rocks, such as granite in contact metamorphic

deposits; in pegmatite; and in high temperature quartz veins. The world's most important deposit is at Climax, Colorado.

Monazite...{mahn'-uh-zyt}
Comments: The chief ore of thorium and the rare earths is the phosphate mineral monazite. It commonly forms small flattened or elongated crystals (monoclinic system) that are a resinous, reddish to yellowish brown. Hardness is 5 -5.5, streak is white, and specific gravity is 4.6-5.4. Monazite occurs as an accessory mineral in granites, gneisses, and pegmatites and as rounded grains in the sands formed from their weathering. The thorium-rich varieties are radioactive and have been used in geologic dating.

Monzonite...{mahn'-zuh-nyt} rock
Comments: The coarse-grained plutonic rock monzonite, which results from deep igneous or metamorphic processes, contains approximately equal amounts of potassium and plagioclase feldspars and little or no quartz. Dark minerals, such as pyroxene and hornblende, make up 30 to 40 percent of the rock. Monzonite is intermediate between syenite and diorite.

Moonstone...see albite, orthoclase (plagioclase feldspar)

Morganite...see beryl...mortor
Colors: rose pink to red, light pink to colorless
Hardness: 7.5
Specific gravity: 2.8
Refractive index: avg. 1.59 v. .008

Mossottite...see aragonite

Mottramite...(Zn,Cu)Pb(VO4)(OH)... lead zinc - copper ...Descloizite...(Cu,Zn)Pb(VO4)(OH)
Crystal system: rhombic
Color: yellow brown to cherry red, brown, green, or black
Luster: greasy
Hardness: 3.5
SG: 5.9 mottramite... 6.2 descloizite
Streak: yellow orange to brown red
Fracture: small conchoidal
Cleavage: none
Comments: associated with wulfenite and vanadinite

Muscovite...var. fuchsite, alurgite, mica ...hydrous potassium aluminum
Crystallography: monoclinic
Colors: silver white, yellow, gray, brown
Luster: glassy
Hardness: 2 - 2.5
Specific gravity: 2.76 - 2.88

Cleavage: perfect along plates
Crystal or stone size: tabular crystals w/pseudo -hex outline, up to 30 - 50 sq. yds.
Comments: usually scaly laminae masses

Mylonite...{my'-luh-nyt}
Comments: Ductile, as opposed to brittle, processes dominate the formation of the metamorphic rock mylonite in deep seated fault zones. Mylonite is commonly foliated and may contain fine grained quartz, feldspar, and micas surrounding much larger feldspar or sometimes quartz grains or other minerals that have been greatly flattened and drawn out in the foliation. Mylonite zones, which may vary in width from a few millimeters to several kilometers, occur in the central portions of recent mountain chains and in the roots of old mountain chains.

Nantokite...see calomel

Naphtheline...(sp) Nepheline, igneous rock .. nephelin w/ olivine augite, titnite, perovskite, melilite noselite, sodalite, or hauyne.
Crystallography: none
Colors: light gray, pin, green
Hardness: ver.
Specific gravity: ver.
Crystal or stone size: massive
Comments: Nepheline, the most common of the group, is a white to gray mineral that is distinguished from the feldspars, which it resembles, by its poorer cleavage and slightly greasy luster. It occurs as grains or large masses in many alkaline igneous rocks ranging from magnesium rich nepheline basalts to granitelike but quartz free nepheline syenites. It is also found in some metamorphic rocks, particularly the nepheline gneisses of Ontario, Canada.

Natrolite...hydrated sodium aluminum silicate
Crystallography: orthorhombic
Colors: white
Luster: vitreous to pearly
Hardness: 5 - 5.5
Specific gravity: 2.2 - 2.26
Crystal or stone size: 3 ft. x 6 in. in Canada
Comments: found with asbestos, collector mineral

Nephrite ... tremolite ... actinolite...(jade)
Crystallography: monoclinic
Colors: green, white, black
Hardness: 6.5
Specific gravity: 2.96
Refractive index: 1.62
Comments: usually classed with jadeite as jade.

Neptunite ... sodium potassium iron titanium silicate
Color: dark brown to black
SG: 3.23
Hardness: 5-6
Comments: collector item

Niccolite ... nickeline .. nickel arsenide
Crystallography: hexagonal
Colors: pink bronze, pale green film
Luster: metallic
Hardness: 5 - 5.5
Specific gravity: 7.78
Cleavage: none
Crystal or stone size: rare small crystals
Comments: ore of nickel

Nicholsonite...see aragonite

Nickeline ... see niccolite

Niter... potassium nitrate (saltpeter) ...KNO3
Color: white
Luster: glassy
Hardness: 2
SG: 2.1
Comments: found in caves, short fibers on rock surface and floors.

Norbergite

Obsidian...volcanic glass
Crystallography: none
Colors: black
Luster: glassy
Hardness: 5
Specific gravity: 2.35
Cleavage: none
Refractive index: 1.49
Occurrence: lava flows
Crystal or stone size: can be massive
Comments

Octahedrite ... see anatase

Odontolite ... very similar to turquoise
Colors: blue green
Hardness: 5
Specific gravity: 3.1
Refractive index: 1.6
Crystal or stone size:
Comments: can be confused with turquoise

Oligoclase...(see feldspar)

Olivine...olivenite... magnesium iron silicate ...forsterite...fayalite ...gem variety peridot

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Omphacite...calcium magnesium iron aluminum silicate
Crystal sys: monoclinic
Color: light green
SG: 3.29 - 3.37
Hardness: 5-6
Comments: collector crystal usual found in quartz

Onyx
Colors: white, usually dyed to any color
Hardness: 7
Specific gravity: 2.6
Refractive index: 1.535 + - .004
Crystal or stone size: massive
Comments: used for carvings, building stone

Opal ... black, fire, white, water

Ophiolite... see serpentine

Orpiment... arsenic sulfide
Color: golden yellow to orange
SG: 3.48
Hardness: 1.5 - 2
Comments: ore of arsenic, used in hide tanning

Orthite....(Allanite)
Orthoclase...orthose...(see feldspar)...moonstone ...plagioclase...albite...adularia
Colors: colorless with floating blue sheen, light yellow, white, see below
Hardness: 6 - 6.5
Specific gravity: 2.56
Cleavage: perfect in two directions

Refractive index: 1.52 - 1.526
Crystal or stone size:
Comments: 4 ray star in green, brown, orange, brown and black. It may be completely transparent, and the sheen can be either silvery white or a soft but distinct blue. The blue or white sheen is called adularscent, and is caused by the presence of tiny crystals of albite arranged in layers within the host microline. The adularscent sheen resembles a cloud of light that appears within the gem when it is turned at the right angle to the eye. Moonstones come mainly from India, Sri Lanka, Burma, Canada, Brazil, and others.

Painite
Colors: dark red
Hardness: 8
Specific gravity: 4.01
Refractive index: 1.8 +- .029
Pleochroism: pale brown orange to ruby red
Comments: uniaxial (-)

Pargasite... see hornblend

Pearl...white, pink, bronze, black, gray, blue... freshwater ... conch is pink, clam is black. Biwa (fresh water), Mabe (dome), baroque (odd shape)
Colors: white to cream, Australian is silver white, venezuelan is translucent

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Pectolite

Pegmatite...{peg'-muh-tyt} ...igneous rock

Penninite ... see chlorite ... pennine

Pentlandite ...{pent'-luhnd-yt} see pyrrhotite
Comments: The nickel and iron isometric sulfide mineral pentlandite is the principal ore of nickel. Forming light bronze yellow, granular aggregates in basic igneous rock, it is nearly always intimately associated with and hard to distinguish from pyrrhotite. Hardness is 3.5, luster is metallic, streak is light brown, and specific gravity is 4.6-5.0. At nickel mines in Sudbury, Ontario, and elsewhere, the pentlandite pyrrhotite aggregate is crushed, and the pyrrhotite is magnetically separated from the nonmagnetic pentlandite.

Periclase... see brucite

Peridot ...(see olivine) Occurrence: green type from Red Sea, Arizona Burma, etc.

Peridotite...pyroxenite
Colors: green, blue, black

Occurrence: world wide
Comments: a rock, a dunite

Perlite...A glass froth which swells with heat or water found in old obsidian flows. A man product is sold as perlite.

Petalite ... lithium aluminum silicate
Crystallography: monoclinic
Colors: colorless, white
Luster: vitreous to pearly
Hardness: 6 - 6.5
Specific gravity: 2.41
Cleavage: perfect
Crystal or stone size:
Comments: ore of liyhium

Phacolite ... see chabazite

Phenacite...phenakite
Crystallography: hexagonal
Colors: colorless to white
Luster: glassy
Hardness: 7.5 to 8
Specific gravity: 2.96 to 3
Fracture: conchoidal
Cleavage: poor
Refractive index: avg. 1.662 v. .016
Occurrence: a mineral of pegmatites and high temperature veins.
Comments: bright silvery appearance.

Phlogopite... potassium, magnesium, aluminum silicate ...$K(Mg,Fe)_3(AlSi_3)O_{10}(F,OH)_2$
Crystal system: monoclinic - prismatic
Color: light to dark brown
Luster: pearly to metallic
Hardness: 2.5 - 3
SG: 2.7
Cleavage: perfect basal, yielding thin, flexible and elastic plates
Comments: translucent, 6 or twelve ray star not uncommon. Unlike muscovite makes a cloudy solution if boiled in strong sulfuric acid.

Phonolite ... igneous rock
Crystallography: none
Colors: light gray, green, brown, pink

Luster: greasy
Hardness: Varies
Occurrence: in US, COL, SD, MONT.
Crystal or stone size: massive
Comments: building stone

Phosgenite...chlorocarbonate of lead... $Pb_2(CO_3)Cl_2$
Crystal system: tetragonal trapezohedral (4 2 2)
Color: colorless, white, yellowish brown to gray
Luster: adamantine
Hardness: 2.5 - 2.75
SG: 6 - 6.1
Fracture: conchoidal
Cleavage: good prismatic, poor basal
Comments: slightly sectile, transparent to translucent, fluoresces a brilliant orange yellow

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Phosphophyllite ... hydrated zinc iron manganese phosphate
Crystallography: monoclinic
Colors: blue green
Luster: vitreous
Hardness: 3 - 3.5
Specific gravity: 3 - 3.1
Crystal or stone size: long prismatic or thick tabular crystals are rare up to 4 in.; massive
Comments: sometimes faceted into gems for collectors

Phosphuranylite

Phyllite

Picrolite...see serpentine

Pinite...see spodumene

Pisanite...see chalcanthite

Pisolitic ... see bauxite

Pitchblende ... see uraninite

Platinum
Color: silver gray
SG: 14 - 19
Hardness: 4 - 4.5

Comments

Plagioclase...see feldspar

Polybasite ... silver copper antimony sulfide
Crystallography: monoclinic
Colors: iron black
Luster: metallic
Hardness: 2 - 3
Specific gravity: 6 - 6.2
Crystal or stone size: small, collector
Comments: ore of silver

Polycrase... see monazite

Polyhalite

Porphyry ... igneous rock .. diorite
Crystallography: none
Colors: gray, green, reddish to bluish Hardness: varies
Specific gravity: varies
Comments: facing on buildings, marble like.

Powellite

Prehnite...{pray'-nyt}
Crystallography: orthorhombic
Colors: pale greenish yellow, yellow, white
Luster: glassy
Hardness: 6
Specific gravity: 2.87
Cleavage: basal
Refractive index: avg. 1.63 v. .03
Occurrence: N.J., CN, Mass., Quebec
Crystal or stone size: crystals usually small, stone massive.
Comments: The calcium-aluminum silicate mineral prehnite, which may be pale to dark green, gray, white, yellow, or colorless, is sometimes cut and sold as Cape emerald. Often associated with zeolite minerals, it usually lines the cavities of basaltic rocks. Prehnite frequently forms lamellar or rounded masses; tabular or prismatic crystals (orthorhombic system) are found more rarely. Ornamental stone that sometimes is confused with jade.

Proustite...{proost'-yt}...silver arsenic sulfide
Crystallography: hexagonal

Colors: dark red
Luster: adamantine
Hardness: 2 - 2.5
Specific gravity: 5.57
Cleavage: good rhombohedral
Refractive index:
Crystal or stone size: up to 6 in.
Comments: The silver arsenic sulfide mineral proustite, or light ruby silver, is a minor ore of silver. Scarlet to vermilion in color and streak, proustite forms compact masses and prismatic, rhombohedral, or scalenohedral crystals (hexagonal system) often associated with PYRARGYRITE, or dark ruby silver, in silver veins. luster is adamantine to submetallic. Prized mineral for collectors.

Psilomelane...{sy-loh-mel'-ayn}...romanechite .. hydrous barium manganese oxide
Crystallography: orthorhombic
Colors: brown, black
Luster: submetallic
Hardness: 5 - 7
Specific gravity: 3.7 - 4.7
Crystal or stone size: masses never in crystals
Comments: Psilomelane, a basic oxide mineral of barium and manganese, is, after pyrolusite, the most important manganese ore. It forms iron-black to steel-gray concretionary or earthy masses that have a submetallic or dull luster, streak brownish black. Formed by the weathering and alteration of manganese carbonates, psilomelane frequently is associated with pyrolusite and other secondary manganese oxides and with clay and hydrated iron oxides. Greasy feel.

Pumice...{puhm'-is}... igneous rock
Crystallography: none
Colors: gray, yellowish, red
Specific gravity: v. sometimes less than water
Occurrence: material expelled by volcanos
Crystal or stone size: massive
Comments: Pumice is a frothy volcanic glass, usually light in color and high in silica. It occasionally contains some crystals of quartz and feldspar. The froth, which forms during an eruption of a gas rich magma because of the decrease in confining pressure, is similar to the bubbles formed in carbonated beverages when their containers are opened. The bubbles make pumice so light that it will float on water. Pumice, which may float for weeks before it becomes waterlogged and sinks, has been found floating as many as 6,400 km (4,000 mi) from its source. Pumice is used primarily for abrasives, polishing compounds, insulators, and lightweight aggregates and in stucco, plaster, and cement. very porous, may float

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Purpurite ... manganese iron phosphate
Crystal sys: orthorhombic
Color: purple to red with brown to black surface alteration

SG: 3.4
Hardness: 4 - 4.5
Comments: SD,CA collector item

Pycnite... see topaz

Pyralspite ... see garnet

Pyrargyrite... silver antimony sulfide
Crystallography: hexagonal
Colors: black w/dark red tints
Luster: submetallic
Hardness: 2.5
Specific gravity: 5.85
Crystal or stone size: masses or disseminated grains
Comments: purple red streak, minor silver ore

Pyrite...{py'-ryt}
Crystallography: cubic
Colors: brassy yellow
Luster: metallic
Hardness: 6
Specific gravity: 4.9 - 5.02
Cleavage: none
Comments

Pyrochlore ... see microlite

Pyrolusite ...manganese oxide... polianite Crystallography: tetragonal
Colors: black
Luster: greasy
Hardness: 6 - 6.5
Specific gravity: 4.7 - 5
Crystal or stone size: aggregates and masses
Comments: earthy ver. very soft and greasy ore of manganese

Pyromorphite ... lead phosphate chloride
Crystallography: hexagonal
Colors: green brown, colorless
Luster: resinous to adamantine
Hardness: 3.5 - 4
Specific gravity: 6.7
Cleavage: none

Occurrence: PENN., IN US
Crystal or stone size: aggregates and masses
Comments: minor ore of lead

Pyrope ...see garnet
...magnesium aluminum silicate
Crystallography: isometric
Colors: red, best is blood red
Luster: vitreous
Hardness: 7.5
Specific gravity: 3.7 - 3.9
Cleavage: none but splinters
Refractive index: 1.73 - 1.76
Crystal or stone size: gem, up to 20 cts

Pyrophanite...see Ilmenite

Pyrophyllite...{py-roh-fy'-lyt} hydrous aluminum silicate... var. agalmatolite, pagodite
Crystallography: monoclinic
Colors: yellow, white, pale green, brown
Luster: pearly to greasy
Hardness: 1 - 2
Specific gravity: 2.8
Occurrence: NC, SC, AR, GA. IN US
Crystal or stone size: massive, used for carving
Comments: flexible but not elastic. Pyrophyllite a hydrous aluminum silicate mineral, often resembles talc in its appearance, properties, and uses. It forms foliated, radiating, or fibrous aggregates and compact to granular masses that have a greasy feel and are pale colored. Mohs hardness is 1 to 2, luster is pearly to dull and glistening, and specific gravity is 2.65 to 2.90. Pyrophyllite is the main component of some schists and also occurs in hydrothermal veins with quartz and micas.

Pyroxenite ... igneous rock .. var. websterite, bronzitite
Contains: pyroxene with some or all of olivine, hornblende, chromite magnetite, ilmenite sulfide biotite, garnet, apatite.
Crystallography: none
Colors: dark green, brown, black
Crystal or stone size: massive, coarse grain
Comments: building stone

Pyroxmangite ... see rhodonite

Pyrrhotite ... ferrous sulfide
Crystallography: pseudohexagonal

Colors: bronze
Luster: metallic
Hardness: 4
Specific gravity: 4.6 - 4.7
Cleavage: none
Crystal or stone size: massive
Comments: magnetic

Quartz
Subtypes

Quartzite ... metamorphism of sandstone
Colors: brown, yellow, gray, reddish, white
Hardness: ver. see quartz
Specific gravity: ver.
Cleavage: none
Occurrence: world wide
Crystal or stone size: massive
Comments: very small grains of quartz firmly together

Radelerz ... see bournonite

Rammelsbergite... see loellingite

Realgar ... arsenic sulfide
Crystallography: monoclinic
Colors: orange red
Luster: resinous
Hardness: 1.5 - 2
Specific gravity: 3.4 - 3.5
Cleavage: perfect
Crystal or stone size: crystals common
Comments: could be mistaken for cinnabar ore of arsenic, very unstable

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Rhodochrosite...{roh-duh-kroh'-syt}...manganese carbonate
Crystallography: hexagonal
Colors: pink, gray, brown
Luster: vitreous to pearly
Hardness: 3.5 - 4
Specific gravity: 3.4 - 3.6
Cleavage: perfect rhombohedral
Refractive index: 1.597 - 1.817
Crystal or stone size: massive

Comments: ornamental stone, crystals rare. The manganese carbonate mineral rhodochrosite is a minor ore of manganese used mainly as a decorative stone and gemstone. Typically displaying shiny rose-red, intricately banded surfaces, it forms granular to compact cleavable masses, crusts, or columns. Streak is white. It occurs in moderate to low-temperature hydrothermal ore veins, particularly of silver, lead, zinc, and copper, as well as in high temperature metamorphic deposits.

Rhodonite...{roh'-duh-nyt}...manganese silicate
Crystallography: triclinic
Colors: violet red to flesh red
Hardness: 5.5 - 7
Specific gravity: 3.3 - 3.68
Cleavage: two directions perfect
Refractive index: 1.72 - 1.744
Crystal or stone size: massive
Comments: ornamental stone usually with black inclusions. The manganese, iron, and calcium silicate mineral rhodonite is valued not only as a rose-red ornamental stone but also as a major ore of manganese in India. Usually associated with rhodochrosite and other manganese minerals, it forms large, rounded, tabular crystals (triclinic system) or cleavable, compact masses. luster is vitreous, streak is white.

Rhodolite ...see garnet
Colors: violet red to brownish red violet
Specific gravity: 3.84
Refractive index: 1.76
Comments: a cross between almandite & pyrope

Rhyolite ... a volcanic rock
Colors: shades of gray, yellow, pale to deep red
Luster: glassy
Hardness: 6 - 6.5
Specific gravity: v.
Occurrence: volcanic
Crystal or stone size: massive
Comments: it may contain many minerals, biotite quartz, hornblende, opal, feldspar, magnetite. Rhyolite is a light-colored, fine grained volcanic rock with a very high (more than 70%) silica content. It often contains phenocrysts of quartz and feldspar in a glassy matrix. Iron and magnesium minerals are rare or absent. Similar to the coarser grained granites in mineralogy and chemistry, rhyolite tends to be very viscous because of its high silica content, and upon eruption it generally forms steep-sided domes and plugs. Gas rich rhyolite, however, erupts violently to form welded tuffs, or ignimbrites, and may spread out over great distances.

Richterite ... hydrous sodium magnesium silicate
Color: purple red to yellow
SG: 2.97 - 3.46

Hardness: 5-6
Comments: in crystal form a collector item

Rockbridgeite... see dufrenite

Rosolite
Crystallography: monoclinic
Colors: deep rose to pink
Luster: glassy
Hardness: 3.5
Specific gravity: 3.5 - 3.7
Cleavage: easy
Refractive index: unable to find info
Occurrence: now found in cobalt mines in Morocco.
Crystal or stone size: small, rare
Comments: collector gem, too soft and rare for jewelry.

Rubellite ... see red tourmaline

Ruby ... red corundum

Rutilated quartz ...see rutile and quartz

Rutile...{roo'-teel}...titanium oxide
Comments: synth. is common. A minor ore mineral of titanium, is the most stable of three naturally occurring forms of titanium oxide see OXIDE MINERALS). Rutile forms prismatic or needlelike crystals (tetragonal system), most commonly red-brown in color, streak is pale brown, luster is adamantine to metallic, Widespread in small amounts, rutile occurs in intermediate basic igneous rocks as a high-temperature accessory mineral, in gneiss and schist, and in high-temperature veins and pegmatite dikes. Because it is highly resistant to chemical and physical weathering, it is common in placer deposits.

Safflorite ... see loellingite

Salt...sodium chloride...NaCl...see halite
Comments

Samarium...{suh-mair'-ee-uhm}
Comments

Sanidine ...potassium aluminum silicate...see feldspar
Color: white to gray to yellow
SG: 2.53 - 2.56

Comments: volcanic rock

Sapphire

Satin spar ... see gypsum

Scapolite ...{skap'-oh-lyt}
Crystallography: tetragonal
Colors: pale yellow, colorless, pink chatoyant violet chatoyant
Hardness: 6
Specific gravity: 2.7
Refractive index: avg, 1.57 v. .021
Occurrence: pale yellow from Brazil, chatoyant types are from Burma.
Comments: Scapolite, a member of the feldspathoid group of minerals (sodium and calcium aluminosilicates), consists of a mixture of the minerals marialite and meionite. It occurs in calcium-rich metamorphic rocks, particularly schists, gneisses, and marbles. The name refers to the typical shaftlike shape of the prismatic, white crystals (tetragonal system). Hardness is 5 to 6, luster is vitreous, and specific gravity is 2.5 to 2.8. Some scapolite fluoresces yellow under ultraviolet light.

Scheelite ...{sheel'-yt}
Crystallography: tetragonal
Colors: colorless, yellow, brown, green, white
Luster: adamantine
Hardness: 5
Specific gravity: 6.12
Refractive index: 1.918 - 1.934
Crystal or stone size: massive
Comments: ore of tungsten, collector gem fluoresces strongly light blue under SW UV. Scheelite, calcium tungstate, is an ore mineral of tungsten. It forms pyramidal and tabular crystals (tetragonal system) and columnar or granular masses that vary in color from white through pale yellow. streak is white, luster is glossy, The fact that it fluoresces bright blue white under ultraviolet light enables prospectors to search for it at night, using portable "black" lights. It occurs in veins or pegmatites associated with granite or gneiss, and in contact metamorphic deposits.

Schist...(sp) shist...{shist} a rock
Comments

Schorl... see tourmaline

Scolecite... hydrated calcium aluminum silicate
Crystallography: monoclinic
Colors: colorless, white
Luster: silky

Hardness: 5 - 5.5
Specific gravity: 2.26 - 2.4
Comments: collector item

Scorodite

Selenite ... see gypsum

Sepiolite ... meerschaum
Color: white
SG: 2
Hardness: 2 - 2.5
Comments: used in making pipes

Serpentine...verd...williamsite... bowenite
Crystallography: monoclinic
Colors: yellowish green, green, black, white sometimes dyed
Luster: greasy
Hardness: 2.5 - 4; will.=4; bow.=5 - 5.5
Specific gravity: 2.57; bowenite = 2.8
Refractive index: normal 1.55 - 1.56...extreme 1.49 - 1.57
Crystal or stone size: massive
Comments: used as jade sub. counters, walls The hydrous magnesium silicate mineral serpentine forms from the alteration of olivine and pyroxene in the presence of abundant water. Asbestos, its most fibrous form, is used as an insulating material. Serpentinite, the massive form of serpentine, may be cut and polished for ornamental stone. Serpentinite rocks are found associated with alpine peridotites and ophiolite sequences and are thought to be segments of altered mantle material that have been thrust upward into the Earth's crust.

Siderite ... {sid'-ur-ite}...iron carbonate
Crystallography: hexagonal
Colors:yellow, brown, black
Luster: vitreous
Hardness: 3.5 - 4
Specific gravity: 3.7 - 3.9
Occurrence: The iron carbonate mineral siderite was formerly a major ore. It forms gray-to-brown rhombohedral crystals (hexagonal system) in silver-ore veins, compact concretions called clay ironstone in clay or shale deposits, and impure earthy material stratified with coal deposits called black-band ore. streak is white. Although black-band siderite ore has been mined, the most important ore deposits have been siderite replacements in limestones. good clear crystals are rare.
Comments: crystals are of collector value

Sillimanite...{sil'-uh-muhn-yt}...fibrolite

Crystallography: orthorhombic
Colors: gray, green, white, brown, grayish blue
Hardness: 6 - 7
Specific gravity: 3.24
Refractive index: 1.64 - 1.68
Birefringence: .02
Crystal or stone size: massive
Comments: The aluminum silicate mineral sillimanite, used in the manufacture of spark-plug porcelain and other refractories, has the same chemical formula, as andalusite and kyanite. Also called fibrolite because of its long, needlelike crystals (orthorhombic system) and fibrous masses, sillimanite has a vitreous luster and is brown to grayish. Sillimanite forms by the alteration of mica minerals in clayey sediments. Also an ornamental stone sub. for jade.

Silver...Ag
Color: silver
SG: 10 - 12
Hardness: 2.5 - 3
Comments

Simpsonite ... see microlite

Skutterudite...cobalt arsenide
Color: silverlike
SG: 6.5 - 6.8
Hardness: 6
Comments: cobalt, nickel, and arsenic ore

Smaltite ... skutterudite ... cobalt arsenide
Crystallography: isometric
Colors: gray to black
Luster: metallic
Hardness: 6
Specific gravity: 6.5 - 6.8
Comments: ore of cobalt, nickel, and arsenic

Smithite... see miargyrite

Smithsonite ... zinc carbonate
Crystallography: hexagonal
Colors: white, yellow, light green, blue
Luster: greasy
Hardness: 5
Specific gravity: 4.3

Cleavage: perfect rhombohedral
Refractive index: 1.62 - 1.85
Birefringence: large
Comments: The zinc carbonate mineral smithsonite is an ore of zinc, formed by oxidation of sphalerite. It occurs as rounded, crystalline crusts and granular or honeycombed masses that have a vitreous luster and are typically dirty brown or gray in color, and less often white or of a greenish or bluish hue. Streak is white. It is found with galena and sphalerite in veins and beds, especially in limestone regions.: uniaxial neg. sign.

Soapstone ... see pyrophyllite, talc, steatite

Sodalite ... sodium aluminum silicate chloride
Crystallography: isometric
Colors: blue, white, gray with green tints
Luster: vitreous
Hardness: 5.5 - 6
Specific gravity: 2.27 - 2.33
Cleavage: poor
Refractive index: 1.48
Comments: used as sub. for lapis. Sodalite, a relatively rare sodium aluminosilicate, is one of the feldspathoid minerals. (Lazulite, a blue variety containing sulfur, is the principal component of lapis lazuli.) Sodalite forms dodecahedral crystals, embedded grains, and concentric nodules. Gray, greenish, yellowish, or white in color, it has a vitreous luster. It occurs with other feldspathoids in igneous rocks that have crystallized from sodium-rich magma.

Soddyite... see gummite

Soumansite... see wardite

Spessartite...see garnet... spessartine
Crystallography: cubic
Colors: Red to brown, orange, pink
Hardness: 6.5 - 7.5
Specific gravity: 4.2
Cleavage: none
Refractive index: 1.79 - 1.81
Crystal or stone size: up to 10 cts.
Comments: transparent are cut for gemstones

Sphalerite...{sfal'-ur-yt}...zinc iron sulfide
Crystallography: isometric
Colors: yellow, reddish brown, black (marmatite) pink, green, colorless
Luster: adamantine or resinous some iron rich varieties have submatallic luster

Hardness: 3.5 - 4
Specific gravity: 3.9 - 4.2
Cleavage: perfect
Comments: Sphalerite (ZnS), a common and widely distributed zinc sulfide mineral, is the major ore of zinc. Found in a variety of crystal forms as well as in cleavable, granular, or foliated masses, it ranges from colorless to brown and black in color, darkening as the amount of iron impurities increases. Streak is brownish, luster is resinous to adamantine, Sphalerite, usually in association with the lead sulfide galena, occurs in contact metamorphic deposits, in replacement deposits within limestone and dolomite, and in veins. Much is fluor. in UV

Sphene
Crystallography: monoclinic
Colors: yellow, green, brown
Hardness: 5.5
Specific gravity: 3.53
Refractive index: avg. 1.96 v. .12
Pleochroism: strong
Comments: rare, large DR. dispersion higher than diamond. Sphene, also called titanite, is a titanium and calcium silicate mineral. When transparent and of good color, it is faceted to produce a brilliant, multicolored gem. Sphene forms wedge-shaped crystals (monoclinic system) of various forms and granular masses that range in color from brown to black through gray and green to yellow and red. Hardness is 5 to 5.5, luster is adamantine to resinous, and specific gravity is 3.4 to 3.6. Sphene occurs as an accessory mineral in igneous rocks, notably nepheline syenites, and in gneisses, schists, and marbles.

Spinel...{spuh-nel'}...Ceyonite... gahnosspinel.(shades of blue); Balas Ruby is red spinel, flame, black, purple, yellow, greenish blue
Comments: The magnesium aluminate mineral spinel is used as a GEM when transparent and finely colored. Ruby colored spinel has been confused with RUBY, the Black Prince's Ruby in the British Imperial State Crown being a famous example. The different colors of the mineral, caused by impurities, include various reds, yellow, blue, green, brown, and black, luster is vitreous. Gem spinels occur as crystals and pebbles in placer deposits, where they accumulate because they resist weathering. Common spinel occurs in metamorphic rocks and as an accessory mineral of some basic igneous rocks.

Spodumene
Subtypes: Hiddenite (yellow - green, green);Kunzite (pink-violet, violet)
Crystallography: Monoclinic
Luster: vitreous to glassy
Hardness: 7
Specific gravity: 3.18
Cleavage: easy in two directions
Refractive index: avg. 1.67 v. .015
Pleochroism: distinct
Crystal or stone size: usually long crystals

Comments: true green hiddenite very rare

Staurolite ..{stohr'-uh-lyt} hydrous iron magnesium aluminum silicate .. Greek cross .. St.Andrew's cross
Crystallography: orthorhombic
Colors: gray to black brownish
Luster: vitreous to resinous
Hardness: 7 - 7.5
Specific gravity: 3.73
Occurrence: associated with garnet & kyanite
Comments: The iron and magnesium aluminum silicate mineral staurolite forms well-developed, brown, prismatic crystals Twinned, cruciform pairs, in which one crystal penetrates another, are called fairy crosses and are worn as charms. The crystals often have a rough surface and subvitreous to resinous luster. Staurolite is typical of regional metamorphism, but less so of contact metamorphism. It is often associated with garnet and kyanite in crystalline schists and other altered clay-rich sediments. occurs in 90 & 60 degree angles.

Seatite ... see talc .. soapstone .. pipe stone

Stephanite ... silver antimony sulfide
Crystallography: orthorhombic
Colors: black
Luster: metallic
Hardness: 2 - 2.5
Specific gravity: 6.3
Comments: minor ore of silver

Stibnite ... antimony sulfide
Crystallography: orthorhombic
Colors: gray, red (kermesite), yellow
Luster: metallic iridescent
Hardness: 2
Specific gravity: 4.6 - 4.7
Cleavage: perfect lengthwise
Occurrence: Japan, US, Romania, China world wide
Crystal or stone size: up to 18" long Comments: ore of antimony

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Stilbite ... hydrated sodium calcium aluminum silicate
Crystallography: monoclinic
Colors: white, gray, reddish brown
Hardness: 3.5 - 4
Specific gravity: 2.1
Occurrence: US, Scotland, Canada, Brazil

Comments: collector item

Strontianite ... strontium carbonate
Crystallography: orthorhombic
Colors: white, pink, gray, green
Luster: glassy
Hardness: 3.5 - 4
Specific gravity: 3.7
Cleavage: good prismatic
Occurrence: Germany, US, Scotland
Crystal or stone size: compact fibrous masses
Comments: ore of strontium, fireworks, glass

Strontium Titanate ... man made ..strontianite is natural
Crystallography: cubic (man made)
Colors: all, colorless
Hardness: 5.5
Specific gravity: 5.13
Refractive index: 2.41
Crystal or stone size: no more than 2.5 x 10 cm
Comments: mfg. in 50's

Sulphur
Crystallography: orthorhombic
Colors: yellow to brown to black
Hardness: 1
Specific gravity: 2 - 2.1
Cleavage: poor
Occurrence: crystals come from Sicily
Comments: ore, mineral, S, sulfuric acid

Syenite ... igneous rock {sy'-uh-nyt}
Colors: gray, pinkish, violet
Crystal or stone size: massive
Comments: Syenite is a coarse-grained, intrusive igneous rock that is composed largely of sodium- or potassium-rich feldspar and of a ferromagnesian mineral. The feldspar commonly is orthoclase, albite, perthite, or, more rarely, microcline, and the dark-colored ferromagnesian mineral usually is biotite mica, hornblende, or a pyroxene; some examples of syenite also contain feldspathoid minerals. Syenite is in many respects similar to GRANITE; a major difference is the relative lack (less than 5%) or absence of quartz in syenite. Granite is much more commonly found in the field than is syenite.

Sylvanite...{sil'-vuh-nyt} silver gold telluride
Crystallography: monoclinic

Colors: silvery white
Luster: metallic
Hardness: 1.5 - 2
Specific gravity: 8 - 8.3
Cleavage: perfect
Comments: Sylvanite is a rare gold and silver telluride mineral. It forms brilliantly metallic prismatic or tabular crystals (monoclinic system), as well as imperfectly columnar to granular, cleavable masses. Hardness is 1.5 to 2, color and streak are steel gray to silver white, and specific gravity is 8.1. Sylvanite and the other tellurides (calaverite and krennerite) are mined from igneous rocks in the near-surface, low-temperature veins at Cripple Creek, Colo., and in the deeper-seated deposits at Kalgoorlie, Australia.

Sylvite...{sil'-vyt}...potassium chloride
Crystallography: isometric
Colors: colorless, white, blue, yellowish red, purple
Luster: vitreous
Hardness: 2
Specific gravity: 1.99
Comments: fertilizer. The potassium chloride evaporite mineral sylvite (KCl) is mined as a source of potassium. It forms gray, white, or tinted cubic crystals (isometric system) and cleavable granular masses. Luster is vitreous, Sylvite occurs in basinlike bedded salt deposits.

Taaffeite
Crystallography: hexagonal
Colors: pale red violet
Hardness: 8
Specific gravity: 3.61
Refractive index: 1.719 - 1.723
Comments: neg. optic sign, collector gem

Talc ... soapstone .. steatite ... hydrous magnesium silicate
Crystallography: monoclinic
Colors: white, greenish white, gray, brownish
Luster: greasy
Hardness: 1 to 2.5
Specific gravity: 2.58 - 2.83
Refractive index: 1.54 - 1.59
Crystal or stone size: massive
Comments: used for carving, can be cut with knife. Talc is a common, extremely soft, basic magnesium silicate mineral; compact aggregates are known as soapstone (steatite) in reference to their soapy feel. Talc occurs as translucent, foliated or granular masses that vary in color from pale to dark green, with one perfect cleavage. Hardness is 1 (talc is a standard of hardness), streak is white, luster is pearly, and specific gravity is 2.7 to 2.8. Talc crystallizes in the monoclinic system. A low-grade metamorphic mineral, it forms when water and silica or carbon dioxide are added to extensively altered olivine- or

pyroxene rich igneous rocks and when water and silica are added to altered carbonate rocks (with the release of carbon dioxide). Talc is also found in crystalline schists. In most instances, talc is found associated with carbonate minerals, particularly dolomite, and is associated frequently with tremolite, forsterite, and serpentine.

Tanzanite... see zoisite

Tarbuttite ... hydrous zinc phosphate
Color: white, pink, yellow, and green
SG: 4.1
Hardness: 3.7
Comments: collector item

Tetrahedrite - tennantite group .. copper iron sulfide
Color: purplish red or dark blue
SG: 4.5 - 5.2
Hardness: 3 - 4.5
Comments: associated with copper, silver, lead, zinc silver ore.

Thomsonite ... hydrated sodium calcium aluminum silicate
Crystallography: orthorhombic
Hardness: 5 - 5.5
SG: 2.3 - 2.4
RI: 1.515 - 1.54
Colors: white with brown impurities
Crystal or stone size: crystals are rare
Comments: usually cut in cabochon

Thorianite ... thorium uranium oxide
Color: gray to black
SG: 9.7 - 9.8
Hardness: 6.5
Comments: ore of thorium and uranium

Thulite ...see zoisite

Tincalconite ... see borax

Topaz ...an aluminum silicate mineral
Topaz occurs in high-temperature veins, in pegmatites, and in granites and rhyolites, where it is one of the last minerals to form. Luster is vitreous. It has perfect cleavage in one direction. Common topaz is widespread, and fine gem material comes from Saxony, the Ural Mountains, Brazil, Japan, Mexico, and the Cairngorm Mountains in Scotland.

Topazolite... see andradite

Tourmaline ... {tur'-muh-leen}

Subnames: Achroite (colorless); Rubelite (pink to red); Dravite (yellow brown to dark brown; Verelite (green); Indigolite /Indicolite (blue); Siberite (Lilac to violet blue); Schorl (black)

Trachyte...{trak'-yt}

Trachytes are volcanic rocks of intermediate silica and high alkali content. The lava flows from which they originate are usually quite viscous, and consequently they occur as short, thick flows, as tuffs, or as small dikes and sills. Feldspars are the major minerals found in trachytes. Either quartz or feldspathoids, but never both, may also occur, along with alkali-rich mafic minerals such as aegirine, augite, hornblende, and biotite. The lath shaped feldspar crystals are often aligned with the flow direction of the magma, giving rise to the typical trachytic texture. Trachytes are mineralogically and chemically similar to the coarser-grained syenites.

Tremolite ... hydrous calcium magnesium silicate asbestos
Color: white to greenish
SG: 2.9
Hardness: 5 -6
Comments: asbestiform, serpentine, chrysotile forms used as asbestos

---

Troilite... see pyrrhotite

Troostite... see willemite

Tsavorite ...grossular...see garnet

Colors: green
Occurrence: Kenya
Crystal or stone size: over 1 ct. rare
Comments: collector gem being found more and more in the trade.

Tungstite... tungsten oxide + water... $WO_3.H_2O$
Color: yellow earth colors
Crystal system: orthorhombic
Hardness: 2.5
SG: 5.5
Comments: rare

Turnerite... see monazite

Turquoise ...hydrous aluminum phosphate + copper... $CuAl_6(PO_4)_4(OH)_8.4H_2O$

Ulexite... hydrous sodium calcium borate... $NaCaB_5O_9.8H_2O$

Crystal system: triclinic
Color: white
Luster: silky
Hardness: 2.5
SG: 1.6
Comments: desert borax deposits

Uralite ... see hornblende

Uranium ... Uraninite UO_2... uranium dioxide
crystal: cubic
Color: black to gray, greenish
Luster: submetallic to greasy
Hardness: 5 - 6
Comments on Actinide elements

Uranophane... hydrated calcium uranium silicate... $CaU_2Si_2O_{11}.7H_2O$
Crystal system: rhombic
Color: yellow to orange
Luster: glassy
Hardness: 2 - 3
SG: 3.8 - 3.9
Cleavage: pinacoidal
Comments: fluorescent weak yellow green

Uranotile... see uranophane

Uvarovite ...see garnet... $Ca_3Cr_2Si_3O_{12}$
Crystal: cubic
Colors: emerald green
Luster: vitreous
Hardness: 6.5 - 7.5
Specific gravity: 3.56 - 4.32
Cleavage: none
Refractive index: 1.81
Occurrence: with olivine and chromite in peridotite of plutonic rocks and in serpentinite of hydrothermal metamorphic rocks.
Comments: collector stone

Vanadinite...{vuh-nay'-duh-nyt} lead vanadate chloride... $Pb_5(VO_4)_3Cl$
Crystal sys: hexagonal
Color: red to yellow, brown to orange
SG: 6.8 - 7.1

Hardness: 2.75 - 3
Comments: The uncommon lead vanadate mineral vanadinite is an ore of vanadium and a minor source of lead. It forms brown, yellow, or red barrel-shaped prismatic crystals (hexagonal system) in oxidized zones of lead deposits. Streak is white or pale yellow.

Variscite ... hydrated phosphate of aluminum and strengite iron...Utahlite...vermiculite
Crystallography: orthorhombic
Colors:pale green to emerald green, bluish green, green, colorless,
Luster: vitreous, waxy
Hardness: 4 - 4.5
Specific gravity: 2.57
Cleavage: good in one direction
Refractive index: 1.56 - 1.59
Occurrence: West U.S.A. World wide
Crystal or stone size: usually nodules, sometimes confused with turquoise but it has a more green color and is lighter than turq. Comments: The name is from Variscia an ancient district in Germany where the mineral was first found. Crystals are rare but are cut as gemstones for collectors.

Vesuvianite...hydrous calcium magnesium aluminum silicate... $Ca_{10}Mg_2Al_4(SiO_4)_5(Si_2O_7)_2(OH)_4$
Crystal: ditetragonal
Color: brown, olive green, yellow, red, blue
SG: 3.27 - 3.45
Hardness: 6.5
Comments: crystals ejected by Vesuvius.

Vivianite ... hydrated iron phosphate... $Fe_3(PO_4)_2.8H_2O$
Crystal: monoclinic
Color: blue to greenish black
SG: 2.6 - 2.7
Hardness: 1.5 - 2
Comments: used as a coloring agent

Volborthite ... hydrated copper vanadate
Color: olive green
SG: 3.5 - 3.8
Hardness: 3
Comments: collector item

Wardite... hydrous sodium calcium aluminum phosphate... $NaAl_3(PO_4)_2(OH)_4.2H_2O$
Crystal system: tetragonal
Color: bluish green to white
Luster: glassy
Hardness: 5

SG: 2.8 - 2.9
Fracture: conchoidal
Cleavage: good basal
Comments: Named for Henry A. Ward

Wavellite ...{way'-vuh-lyt}... Al3(OH)3(PO4)2.5H2O...hydrous aluminum phosphate
Color: white to green, yellow to brown
SG: 2.4.
Luster: glassy
Hardness:3.25 to 4
Comments: The secondary, hydrated, aluminum phosphate mineral wavellite is widespread in small amounts associated with limonite and phosphate-rock deposits and with low-grade metamorphism. It forms white to green rounded crystalline aggregates. Luster is vitreous to resinous or pearly, streak is white,

---

Whewellite ... calcium oxalate
Color: white to colorless
SG: 2.23
Hardness: 2.5 (unless you have one, then they are very hard.)
Comments: one of the main components of kidney stones and urinary precipitates

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Willemite ... zinc silicate often with manganse and iron... Zn2SiO4
Crystallography: hexagonal
Colors: yellow, green, red, brown, white, colorless.
Luster: resinous to vitreous
Hardness: 5.5
Specific gravity: 3.9 - 4.2
Cleavage: good in three directions
Occurrence: associated w/calcite, franklinite, zincite
Comments: strong fluorescent

Witherite ... barium carbonite... BaCO3
Crystal: orthorhombic
Color: colorless to gray, light yellowish, to white
SG: 4.28
Luster: glassy
Fracture: uneven, brittle
Hardness: 3 - 3.75
Comments: barium ore

Wollastonite... calcium silicate... CaSiO3
Crystal system: triclinic
Color: white to colorless, pink or gray

Luster: glassy to silky
Hardness: 4.5 - 5
SG: 2.8 - 2.9
Fracture: splintery
Cleavage: perfect pinacoidal on base
Comments: often yellow to orange fluorescent used in the mfg. of refractories

---

Wulfenite {wul'-fen-yt} stolzite, iron manganese tungstate... $PbMoO_4$... wolframite
Crystal sys: tetragonal
Color: reddish brown, blackish brown, yellow
SG: 6.5 -7
Hardness: 2.75 - 3
Comments: ore of tungsten. The lead molybdate mineral wulfenite is a minor ore of lead and molybdenum that occurs in the oxidized zone of lead deposits. It forms brilliant yellow, orange, and reddish, square, tabular crystals (tetragonal system) and granular masses. Streak is white, luster is resinous to adamantine.

Xenotime ... see monazite

YAG ... yttrium aluminum garnet
Crystallography: cubic
Colors: all
Hardness: 8+
Specific gravity: 4.55
Refractive index: 1.83
Crystal or stone size: max. 4 x 20 centimeters
Comments: man made

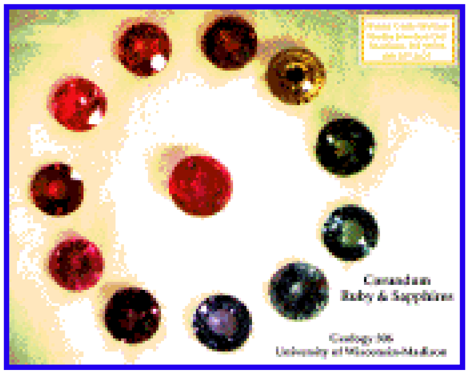
Zincite...{zink'-yt}...zinc oxide
Crystallography: hexagonal
Colors: deep red to orange, yellow or brown
Hardness: 4
Specific gravity: 5.4 - 5.7
Cleavage: perfect in one direction
Refractive index:
Occurrence: usually found with willemite and franklinite
Comments: ore of zinc tinted with maganese. The zinc oxide mineral zincite (ZnO) is an important zinc ore found at Sterling Hill and Franklin, N.J., although it is rare elsewhere. It forms coarse grains and foliated masses that are orange yellow to deep red in color.

Zircon...{zur'-kahn}

Zoisite

The above is extracted from the GEMSTONE program

Corundum



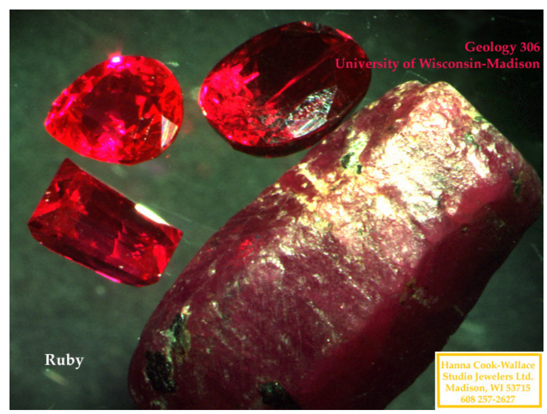
Quick Links:

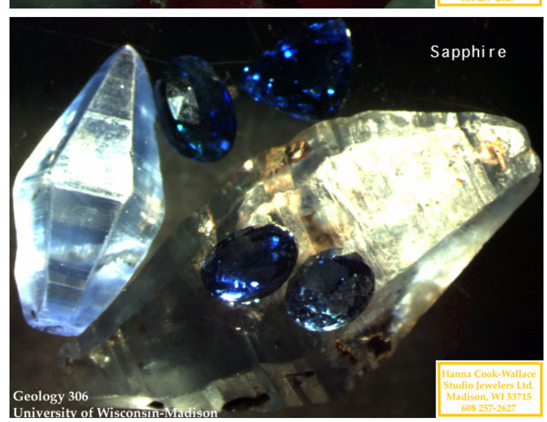
- What is corundum?
- Where is corundum formed and found?
- How are crystals cut?
- Star rubies and sapphires
- Natural versus synthetic?
- Treatments

Basic Data on Corundum

COMPOSITION	Al2O3
HARDNESS	9 (1/400 the hardness of a diamond)
CRYSTAL SYSTEM	Hexagonal*
INCLUSIONS	Common (minerals and glass)
SPECIFIC GRAVITY	High (around 4.0)

*Note: some texts list the crystal system of ruby as trigonal. Trigonal is more simply considered a subdivision of the hexagonal crystal system.





Ruby:

COLOR	Red (ruby is Latin for red), may also be pinkish or brownish-red;
	(absorbs blue, transmits and fluoresces red)
PLEOCHROISM	Strong
IMPURITIES	Red: Cr+++ (< 1%), Brown: Fe+++

Buying rubies: what to consider?

Sapphires:

Physical characteristics: composition, structure etc. same as for a ruby.

Color (other than ruby red) 

The blue color is due to charge transfer involving Fe-Ti (see lecture on color in minerals for details!.

Different concentrations of various impurities produce a range of colors from quite pale, due to low concentrations, to quite deep blue. Other colors include: purple and pink, yellow, orange, green, etc.

Origin of Rubies and Sapphires (Corundum):

- Primary origin: metamorphic rocks and volcanic rocks (basalts)
- Secondary origin: alluvial

Rubies and sapphires are found in Burma, Thailand, Sri Lanka

Cutting:

Cutting refers to the proportions and finish of a gem, regardless of the shape or size. In other words, did the cutter do a good job? Are the facets (polished faces) placed symmetrically? Are they smooth, or do they have minute pits and lines? Are the facet junctions crisp, and do the facets meet correctly? Is the pavillion (the bottom) of the stone of sufficient depth that you see bright reflections across the entire face of the stone? A stone that is shallow "leaks" light out the bottom and is not brilliant. This is called "windowing"--you can see right through the stone, like through a window.

More details on the importance of refractive index and critical angle are provided in the first lecture

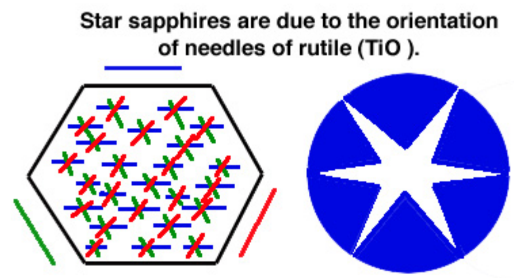
Crystals normally cut with table of cabochon perpendicular to long axis of crystal (long axis is axis about which crystal has hexagonal symmetry) results in best color (because it is pleochroic).

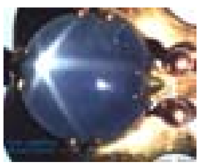
- normally use a mixed cut on the crown
- brilliant and step cut on the pavillion

Clarity:

Undesirable inclusions

While many cut rubies and sapphires contain inclusions, gems that have eye-visible inclusions are less desirable than "eye-clean" stones. In some cases, inclusions can make the stone more vulnerable to breakage.



 **Desirable inclusions:**

Give rise to asterism (star stones): 'silk'-like texture due to fine rutile needles throughout the crystal. The light reflects from the fibers -> 6- pointed star.

NOTE: There are 3 special orientations in which rutile crystals occur. These are parallel to hexagonal faces and thus at 60 degrees. Note that the chemical formula of rutile is TiO_2, and Ti is one of the elements responsible for color in some sapphires.

Another example of a star Ruby

Star sapphiresare also due to oriented rutile needles

star can change positions depending on where the light hits

- off-center
- almost centered
- centered

Natural versus synthetic

Rubies and sapphire are commonly synthesized by the Verneuil method

It is possible to synthesize both clear crystals and stars. The first synthetic rubies appeared on the market in 1908.

Usually, a single crystal or boule is grown from a melt by one of several methods.

An example of a synthetically created ruby.

How do I tell if the stone is synthetic?

- **Natural origin** may be proved by inclusions (e.g., natural gaseous and fluid bubbles) and spectroscopic measurements.
- **Synthetic origin** may be indicated by
  - the presence of flux inclusions and non-natural gas inclusions
  - synthetic corundum may contain a visible seed crystal (esp. in older gems)
  - whispy white veils
  - strain cracks, curved striae etc...

Treatments:

Heat Treatment of Corundum

Heat treatment of gemstones to is done to improve their appearance.

Heat treatment may change the color of corundum for a variety of reasons.

In some cases, heating the stone causes changes in the oxidation state of impurites. An especially important example involves reduction of Fe (conversion of Fe+++ to Fe++). Fe++ causes color in a variety of sapphires via charge transfer (see lecture on color in minerals).

Conversely, stones that are too deeply blue may be lightened by oxidation of Fe (converstion of Fe++ to Fe+++)

In some cases, heat treatment will improve the depth of color because heat causes dissolution of inclusions and diffusion of impurites (especially Ti from rutile inclusions) into the surrounding corundum. Because fine inclusions cause some stones to look cloudy, heat treatment that dissolves the inclusions may also improve the clarity of the stone.

Heat treatment may also remove local color concentrations (remove patches of color) because heat allows the color-causing impurity (Cr, in the case of ruby) to more evenly distribute through the crystal. (however, this may require such long times that it is impractical)

The conditions for heat treatment vary,

depending upon the individual stone. Some typical values and conditions are listed here

How do I tell if a stone has been heat treated?

Detection of heat and diffusion treatment is possible because these treatments modify natural inclusions. This may involve rupture of gas or fluid inclusions or partial dissolution of mineral inclusions. For gems that contained needles, the needle margins may become diffuse.

Themelis states that "glass-appearing" inclusions may be found on rubies that have been heat-treated with borax-based substances.

Diffusion Treatment of Corundum

Why? Color enhancement can be achieved through addition of the color-causing impurity to the surface of the faceted gemstone. For Ruby, this involves heating the stone to very close to its melting point in the presence of a chromium source (chromium oxide powder: Cr2O3). Chromium enters into the structure of the corundum (diffuses into the corundum). This is a slow process, so chromium enrichment only occurs in the surface layer. This is sufficient to produce a strong color enhancement that is difficult to detect by eye.

Diffusion treatment for sapphires is similar to that for any corundum variety. To enhance the blue color Fe and Ti oxide powders are placed in contact with the faceted gem and Fe and Ti diffuse into the surface of the stone.

Note that diffusion treatement is done to faceted stones and is probably not obvious by inspection under normal viewing conditions!!

Some specifics for conditions for sapphire and ruby treatments are given in this table.

How do I tell if a stone has been diffusion treated?

There are several ways you can determine if your stone has been treated. Diffusion treatment will result in concentration of color at facet junctions, and will modify the refractive index of the gemstone.

An excellent, simple, non-destructive method is as follows:

Place the faceted gem in methylene iodide. Note that color concentrations are apparent at facet junctions (where the gemstone is thin). This color concentration tells us that the deeply colored layer is quite thin!

This is how these gemstones look under normal viewing conditions!

To demonstrate that the layer is thin, we polished off a part of the girdle region, exposing the pale, untreated interior.

some other comments and information

[Gallery of corundum and sapphire images!]

Previous Lecture: Color in Minerals
Next Lecture: Beryl

Other Tools

Index
Mineral Reference
Glossary

Olivine, Cordierite & Feldspar

Quick Links
Olivine
Cordierite
Feldspar

Olivine (Peridot)

What is olivine (peridot)?
Where is it found?

What is olivine?

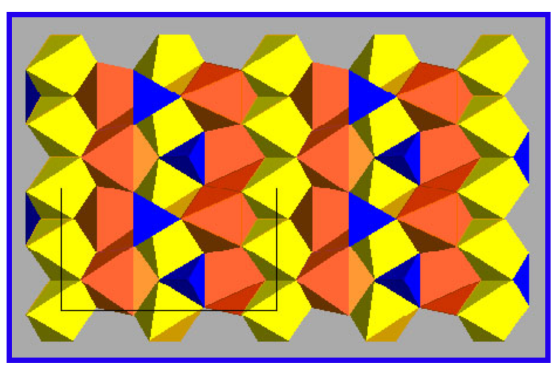
COMPOSITION	Mg2SiO4-Fe2SiO4
HARDNESS	6.5-7
CRYSTAL SYSTEM	Orthorhombic
COLOR	Yellow/pale green-black
FRACTURE	conchoidal
INCLUSIONS	Commonly gas bubbles or other minerals

Learn more about how to identify olivine

Olivine Images

Mg2SiO4	**	MgFeSiO4		Fe2SiO4
pale green	**	brown-green		black

**most common color and composition (yellow-green)



See a movie illustrating the olivine structure!

Therefore, the depth of color depends on Fe content

Olivine is a silicate mineral where the silicate tetrahedra are embedded in a sea of cations (Mg or Fe)

Origin:

Olivine is obtained from many geographic localities

Geological

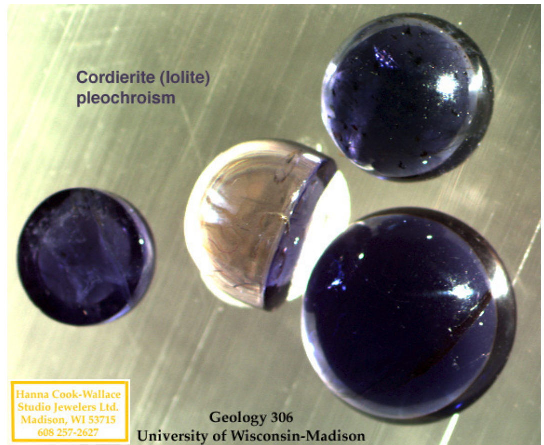
- Olivine is found in many different rocks:
  - Basalts and "peridotitic" (peridot-rich) rocks
    - rocks that contain little quartz
  - Mantle rocks
    - the mantle is composed mostly of olivine
    - "dunite" is a rock made almost entirely of olivine
  - Volcanic rocks, like those found at Kilbourne Hole
  - Xenoliths (lumps of rock ripped up from a source area and carried up in magma)
- Olivine has a high melting point and is an early crystallizing mineral
  - Mg-rich crystals crystallize first, then Fe-rich ones. Consequently, they tend to have Mg-rich (pale colored) cores and Fe-rich (browner) rims (i.e., they are color zoned). crystals are commonly zoned

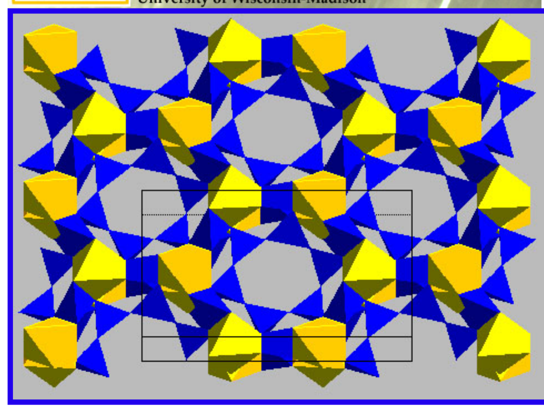
Cordierite (Iolite)

What is cordierite?
Where is it found?

What is cordierite?

COMPOSITION	Mg-Al(Fe) silicate
HARDNESS	7-7.5
CRYSTAL SYSTEM	Orthorhombic
PLEOCHROISM	Strong
FRACTURE	Conchoidal
COLOR	Blue (resembles quartz and amethyst)
SPECIFIC GRAVITY	2.58-2.66
INCLUSIONS	Many!





Learn more about how to identify cordierite

- one of the most diagnostic properties of cordierite is that it is VERY pleochroic
  - the color is purple from one side, and clear when rotated to another side

  Cordierite is a RING silicate, similar to beryl
- "Bloodshot Iolite" contains many small inclusions
- it is also known as iolite and dichroite

See a movie illustrating the cordierite structure!

Where is it found?

Cordierite is found in contact and regionally metamorphosed rocks in localities like Burma, Brazil, Sri Lanka, India etc.

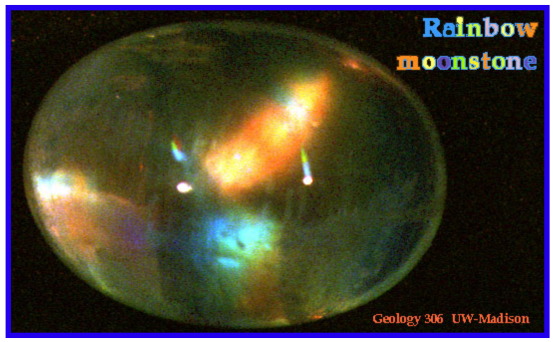
Feldspar

What are feldspars?
Where are they formed?
Characteristics that make feldspars interesting as gems

Feldspars are the most abundant minerals in the Earth''s crust. They are silicate minerals and are referred to as framework silicates because the tetrahedra (of Si and Al four coordinated by oxygen) are linked together in three dimensions to make a framework. Note the tetrahedra are connected through sharing of all oxygen atoms in the coordination polyhedra (see movies below).

Plagioclase feldspars - sodium, calcium, aluminum silicates

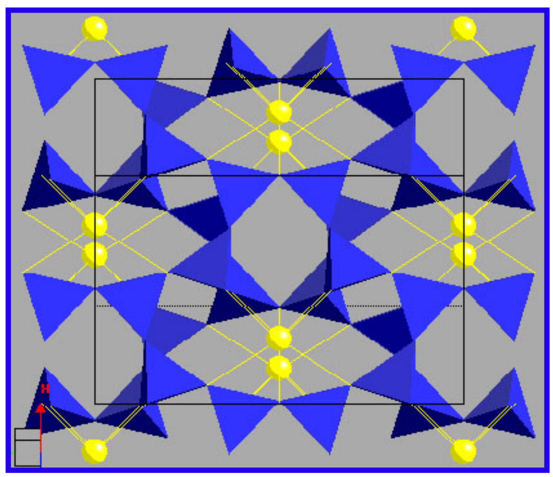
Learn more about how to identify plagioclase



Alkali feldspars - sodium, potassium, aluminum silicates

Learn more about how to identify microcline
Learn more about how to identify orthoclase

Images of feldspar



Feldspars are very important rock-forming minerals and they are covered in more detail in other geology courses. Further information about their structures, compositions, and microstructures can be found here.

Potassium(K) Sodium(Na) aluminosilicate = alkali feldspar.

Examples include moonstone, amazonite, orthoclase

Other terms used for potassium-rich feldspars include: sanidine, orthoclase, microcline

Albite is a term used for sodium-rich feldspar.

Sodium(Na) Calcium(Ca) aluminosilicate = plagioclase.

See a movie on an albite structure!
See a movie on an anorthite structure!
See a movie on a sanidine structure!

One example is the mineral labradorite

HARDNESS	6-6.5
CRYSTAL SYSTEM	Monoclinic or triclinic
CLEAVAGE	2 good cleavages at 90 degrees
SPECIFIC GRAVITY	2.56-2.76

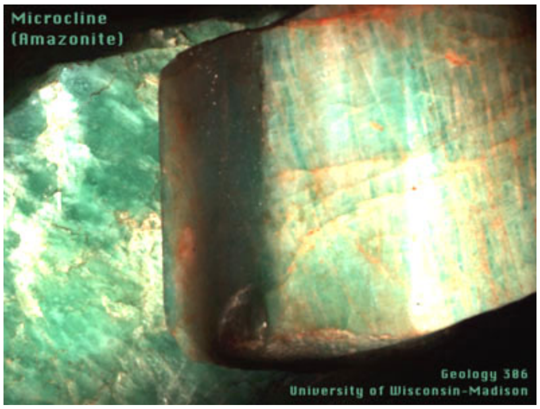
Where are feldspars formed?

- They can be found in lots of different rock types
- Feldspars make up 50-60 % of crustal rocks
    - large crystals in rocks cooled slowly deep in the earth
    - common in igneous rocks
- Feldspars are very important and interesting minerals but less important gems. If you want to learn more about these common rock-forming minerals, there is lots of additional information here.

Other interesting characteristics

Alkali feldspars

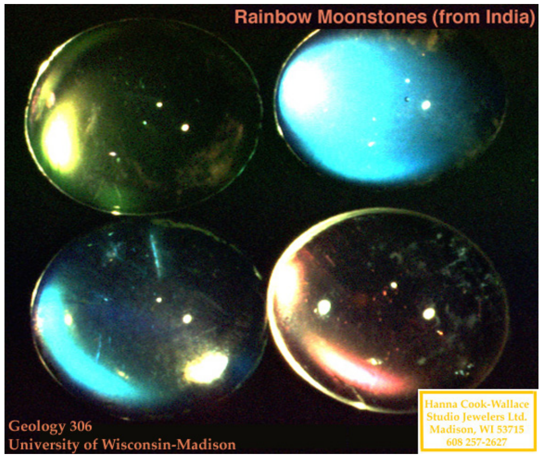
- Gem quality orthoclase: yellow stones colored by Fe impurities
    - Microcline
        - Amazonite is a light green-blue form of microcline



- Moonstone is normally set as a cabachon in rings, pins, and pendants ; it exhibits "adularescence" or "schiller"

Plagioclase feldspars

- commonly twinned, twin planes produce parallel striations on mineral's surface
- gem varieties: Labradorite: - dark grey color, irridescent - play of color is referred to as 'labradorescence'.
- some wavelengths are amplified, and some are cancelled
- the net result is that different spacings and orientations produce rainbow-like effects
- irridescence is mostly blue, but often with rainbow-like appearance
- rainbow moonstones
- Sunstone and Aventurine have inclusions of Cu in the feldspar



Previous Lecture: Zoisite and Quartz
Next Lecture: Pyroxenes (and Amphiboles), Tourmaline and Garnet

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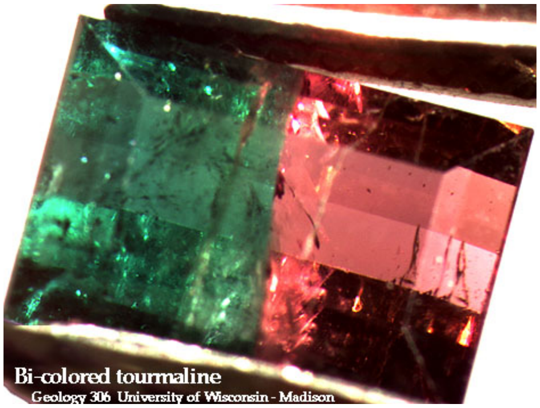
Pyroxenes (and amphiboles), Tourmaline, & Garnet

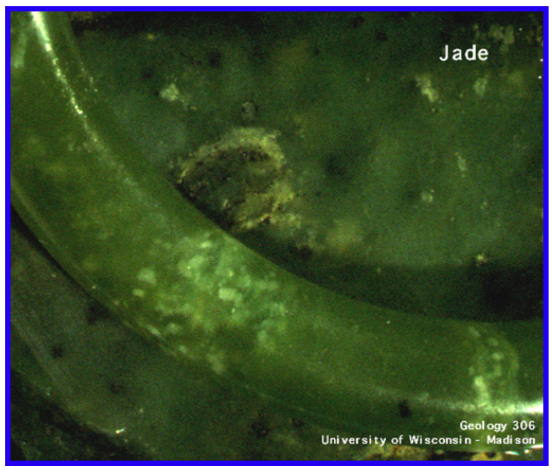


Quick Links

Pyroxene
Tourmaline
Garnet

Pyroxenes (and Amphiboles)

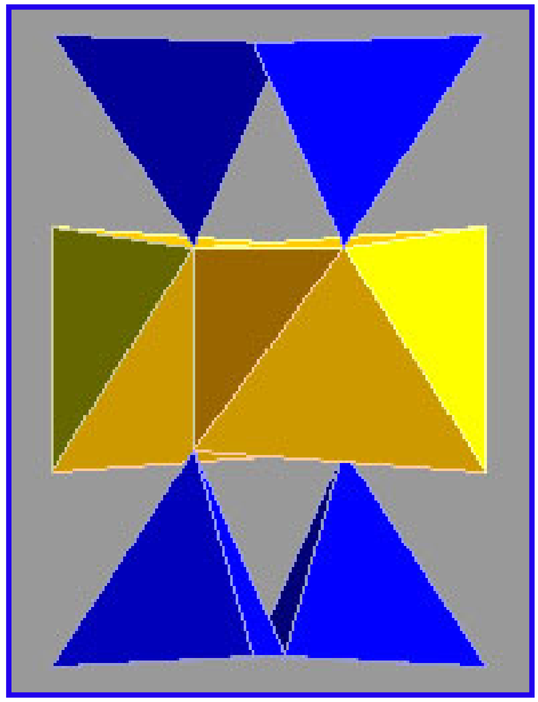
What are they?
Where are they found?
Varieties, etc.



Pyroxene images

What are pyroxenes?

- silicate minerals
- simplest formula: $MgSiO_3$.
- silica tetrahedra form single chains
- not resistant to physical and chemical processes at the Earth's surface
  - break down to clay !!
  - (found in alluvial deposits ???)
  - even more facinating information on pyroxenes and amphiboles
- Hardness 6.5 - 7.0
- S.G.: 3.18
- Their cleavages are at 90 degrees!



[See a movie on a pyroxene I-beam structure!]

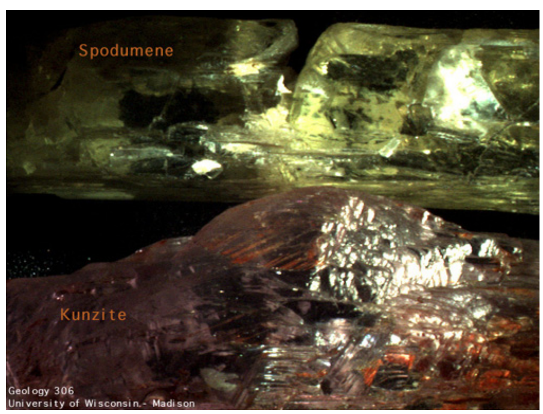
Where are they found?

- Pyroxenes are found in many rocks, often those crystallized from a melt (sometimes in metamorphic rocks)
- it may constitute ~ 100 % of some rocks

  but it's not as common in rocks in the Earth's crust as feldspars

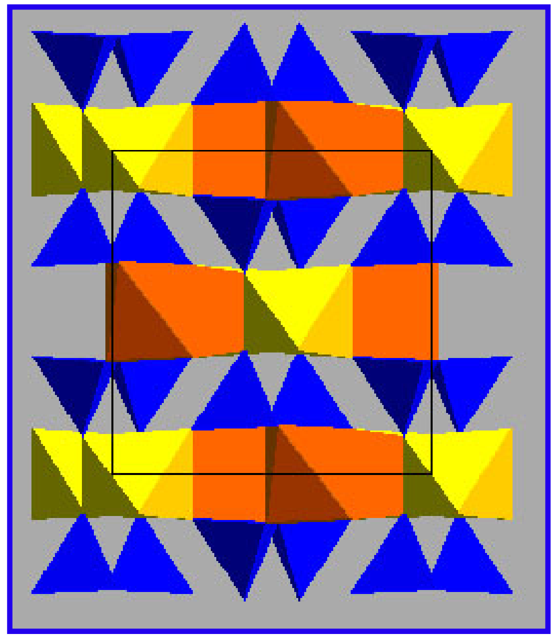
Varieties

Spodumene or Kunzite



- a Lithium (Li)-bearing pyroxene

  (Li is the lightest metal)
- color is light pink / purple
- some crystals are very large: Etta Mine in South Dakota mined a crystal that was 47' long and 90 tons! But gems are *usually* smaller.
- usually found in pegmatites
- irradiation causes them to go to yellow - green (unstable color)



See a movie on a diopside structure!

Diopside (Calcic magnesian monoclinc pyroxene)

- it's a common mineral, less commonly used in jewelry
- asterism in diopside
- a close-up of the "star"

Augite (Calcic clinopyroxene)

- is another common pyroxene, whose composition is similar to diopside.

Hiddenite:

- Chromium (Cr) - rich pyroxene
- strongly pleochroic !!
- good cleavages makes gems difficult to cut

Jade (Jadeite)

- often used for carvings
- sometimes jade is not actually jadeite but a mineral known as nephrite, which is an amphibole
- sodium (Na) - Aluminum (Al) silicate
- H= 6.5-7.0
- S.G.: 3.4
- monoclinic
- almost never found as large crystals !
    - small, interlocking crystals
    - cleavage are at 90 degrees and

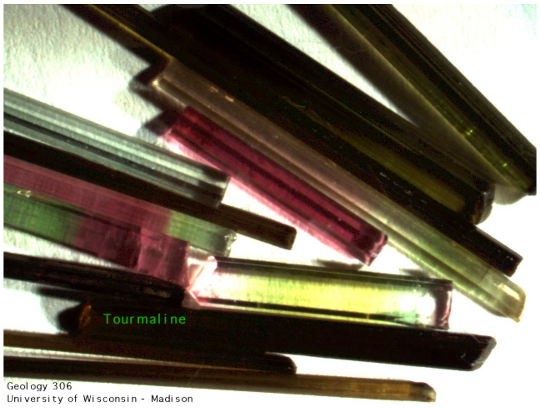
are not seen in massive form

- the color is due to the presence of Cr+++ - deep green color
  - Fe produces a paler green color
- formed by high pressure metamorphism of Na-rich rocks
- famous localities include North Burma, Guatemala, Japan

Nephrite

- nephrite is an amphibole not a pyroxene
  - amphiboles are double chain silicates
- unlike pyroxenes, amphiboles are HYDROUS minerals (contain hydrogen)
- Used for carvings in places like China (for more than 2000 yrs) and Central America (over 7000 yrs)
- Cleavages are at 60 degrees (not apparent in massive varieties)
- Composition: calcium (Ca) magnesium (Mg) silicate
- Green color is due to Fe
  - greatly resembles jadeite in color and structure
  - composed of many tiny interlocking crystals
- Hardness 6-6.5
  - harder than steel, thus used in neolithic tools
- S.G.: 2.95
- "New Jade" = serpentine H = 5.5-6.0, S. G. = 2.5
- "Styrian Jade" = chlorite

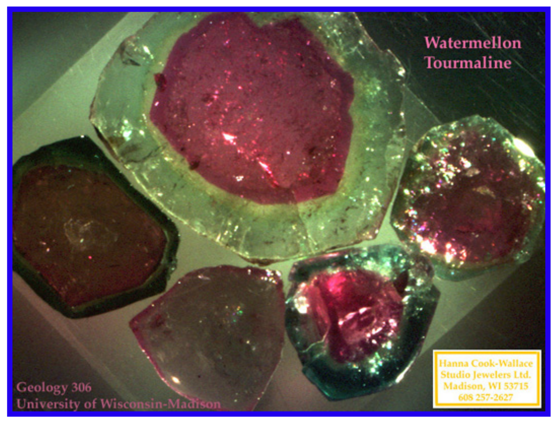
Tourmaline



What is tourmaline?
Where is it found?
Other neat facts

What is tourmaline?

COMPOSITION	See below
HARDNESS	7-7.5
CRYSTAL SYSTEM	Hexagonal
COLOR	MANY!!!
SPECIFIC GRAVITY	3-3.25
FRACTURE	Conchoidal
CRYSTAL GROWTH	Prismatic with triangular cross sections

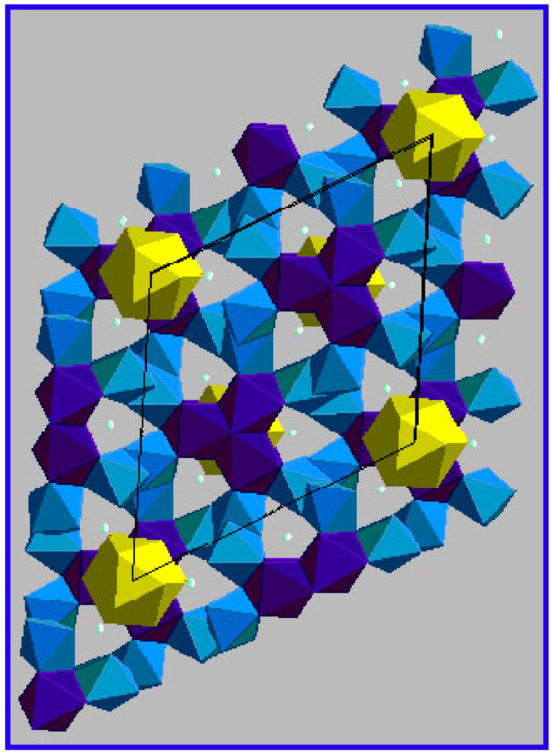


Tourmaline Images

- Tourmaline is a complex Boron (B) bearing mineral
- Note that the ends of tourmaline crystals have different shapes.
- Tourmaline has some interesting properties: it's pyroelectric and piezoelectric:
  - pyroelectric: crystal + heat - develops charge:
  - Causes crystals to collect dust in display cases
  - Piezoelectric
  - apply pressure to opposite ends of the crystal - develops charge at opposite ends
- Structure:
  - (Na,Ca)(Li,Mg,Al)3(Al,Fe,Mn)6(BO3)3

(Si6O18)(OH)4

- **Note:** This gemstone displays a tremendous rangeof color!
  - often many colors in a single crystal
  - From blue to aqua, aqua to green, green to red, and red to colorless



See a movie on a tourmaline structure!

Where is it found?

Geological:

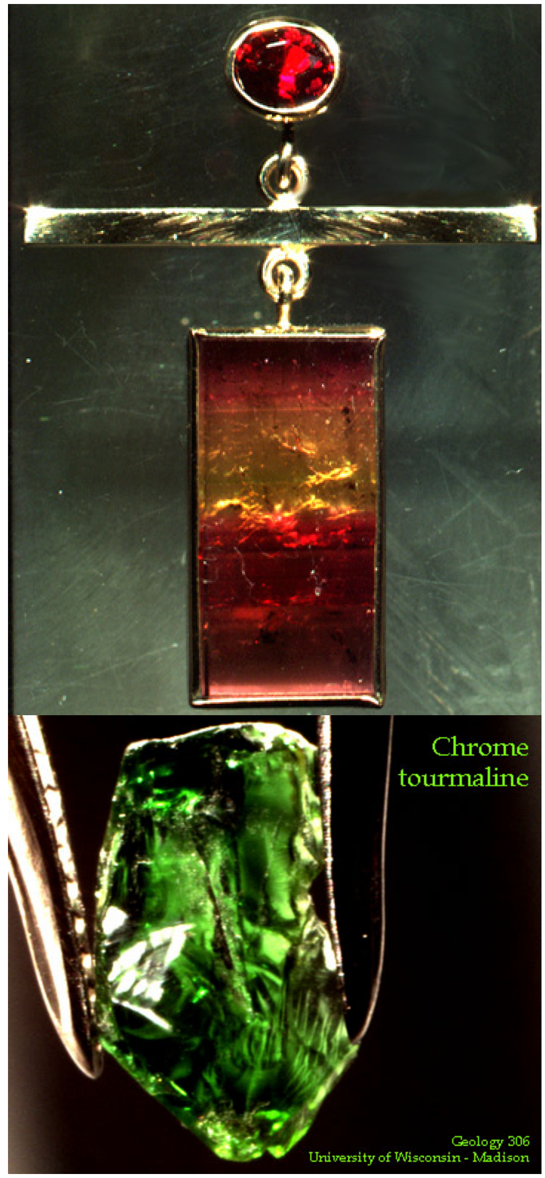
- normally found in pegmatites and igneous and metamorphic rocks

Geographical:

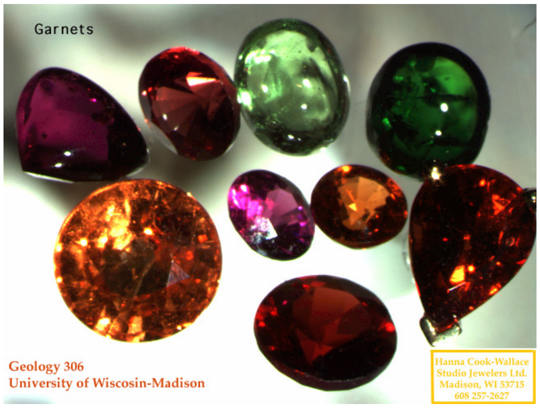
- Elba, Brazil, Ural Mountains, many US localities (inc. Wisconsin)

Other neat facts:

- strongly pleochroic; strongest color seen along prism length
- tourmalines are often color zoned along length of prisms
- you can also find cats eye tourmaline
- famous color zoning is known as "Watermelon tourmaline"
    - as a faceted gem
    - picture of an "inside-out" Watermelon tourmaline
    - Varieties:
        - Elbaite: pink - green
        - Schorl: black
        - Dravite: brown
        - Verdelite : green
        - Rubellite: pink - red
        - Achroite: white
        - Indicolite: blue
- Synthesis: limited and generally unsatisfactory
- Treatments: turn dark shades to a paler color using heat
    - gentle heat only otherwise crystals lose water and the structure is destroyed
    - heat makes crystals more brittle and facet junctions abrade
- Irradiation: to produce popular pink and red, sometimes yellow or orange
    - effect is probably due to change in oxidation state of Fe or Mn**.**
- Chatoyant tourmaline:
    - the tubes are parallel to length and sometimes filled with oil or epoxy



Garnet:

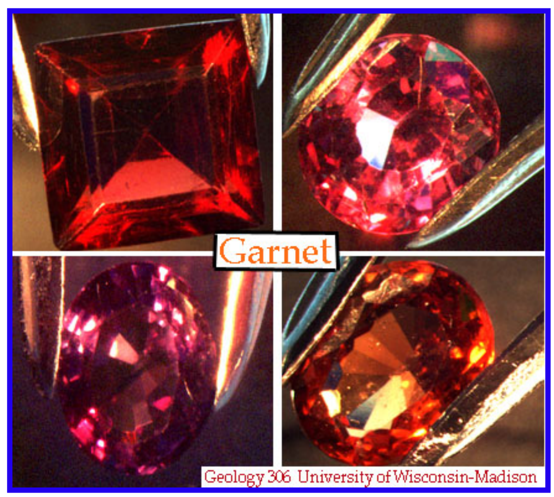


What are garnets?
What are their compositions and characteristics?
Where are they found?

What are garnets?

- Garnets are silicate minerals with diverse compositions. All garnets have almost identical atomic structures.
- generalized chemical formula of garnets is X3Y2 (SiO4)3,
  - X indicating a divalent cation, such as iron(Fe2+), magnesium (Mg2+), calcium (Ca2+) or manganese (Mn2+)
  - Y is a trivalent cation, such as aluminum (Al3+), iron (Fe3+), or chromium (Cr3+).
  - The SiO4 indicates silica tetrahedrons--a silicon ion surrounded by four oxygen ions.
  - The other atoms are packed between the tetrahedrons.
- Garnets belong to the isometric crystal and commonly grown in a distinctive well developed crystal form is known as a dodecahedra (triangular-shaped faces)
- hardness: 6.5 - 7.5
- S.G. 3.58 - 4.32

  Because the atoms are tightly packed, garnets are relatively hard and dense.
- Graph of R.I. vs. S.G. for Garnets



Garnet Images

The structure is illustrated in this movie

Composition and names of varieties

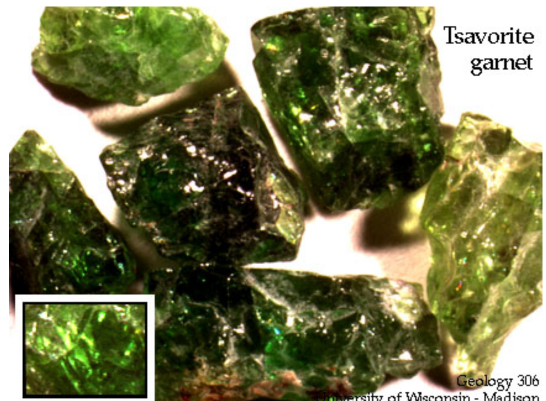
All physical properties vary with composition. There are two broad groups: Ca-garnets and Al-garnets.

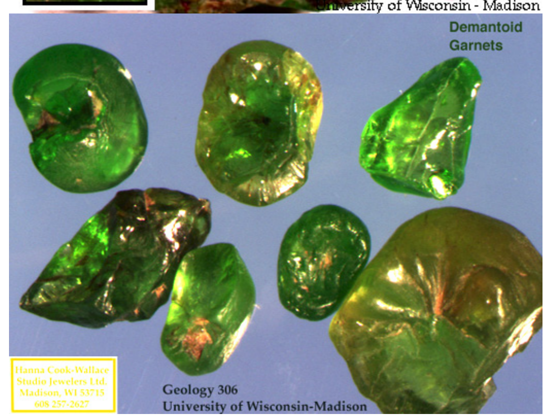
- Ca + a bunch of stuff (Ugrandite)
- Al + a bunch of stuff (Pyralspite)

Most have compositions that involve complex mixtures of cations

- Because of the compositonal variability, garnets may have almost any color!

Examples:





- Demantoid (= Cr-andradite): rare, vivid green garnet color (quite valuable)
  - colored by Cr / V (thus, Ca<Al,V) : it has more fire than diamond! (but it's much softer)
  - sometimes chatoyant
  - may contain "horsetail" inclusions (mostly from Urals)
- Tsavorite: a green grossular
  - rough
- Spessartine and hessonite: orange colored garnets (Fe, Mn,Al)
  - hessonite is a variety of Grossular: green-yellow-brown
- Pyrope: brown-red ("cape ruby")
  - Czechoslovakian source for much garnet used in 18th and 19th centuries
- Almandine: violet-red
- Uvarovite: emerald-green garnet
- Rhodolite: purple
- Malaia and color change garnets (V and Cr impurities)

  garnet viewed in fluorescentlight versus

  garnet viewed in incandescent light

- purple, pink, and orange! garnets

Where are they found?

Geological:

- found in a wide variety of rocks - igneous, metamorphic, and sedimentary
  - Iron-rich almandine, the most common garnet, is widespread in metamorphic rocks such as schists and gneisses and in granitic igneous rocks.
  - The magnesium garnet, favored by high pressures of formation, is found in magnesium rich metamorphic rocks formed at great depth and may be an important mineral in the mantle of the Earth.
  - Spessartine is found in manganese-rich gneisses and in coarse grained, igneous rocks (pegmatites).
  - The ugrandites are rarer than the pyralspites.
  - Grossular, containing calcium and aluminum, is found in clay rich limestones that have been metamorphosed to marble and in contact metamorphic deposits, (skarns), formed when an igneous rock intrudes and reacts with limestone.
  - The calcium-iron garnet andradite and the rare calcium-chromium garnet uvarovite are also usually found in skarns.
- also formed by regional metamorphism, especially of sedimentary rocks.

Other information:

- Garnets have been prized as gems for over 5000 yrs.
    - in Roman times they were used for carving
    - Garnets were especially popular in the 19th Century; The dark red, Victorian garnet jewelry was made from pyrope garnets mined in Bohemia, now a part of Czechoslovakia. Examples of their use in a a variety of jewelry
- some garnet folklore
- YAG and GGG - diamond simulants!
- Garnets are also used as abrasives

Previous Lecture: Olivine, Cordierite and Feldspar

Next Lecture: Precious Stones: Lapis, Turquoise, Malachite and Azurite

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Quartz & Zoisite

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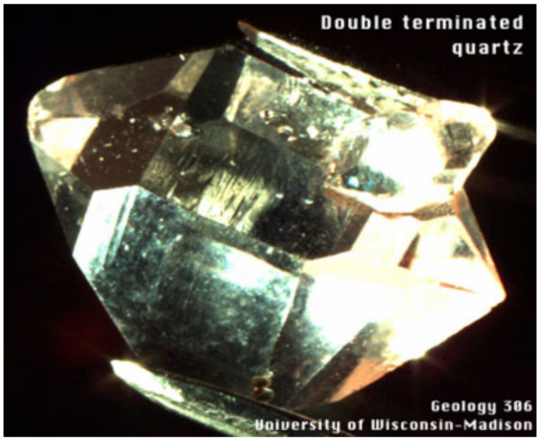
Quartz
Zoisite

Quartz



What is quartz?
Varieties of quartz
Where is it found?
Synthesis
Treatments

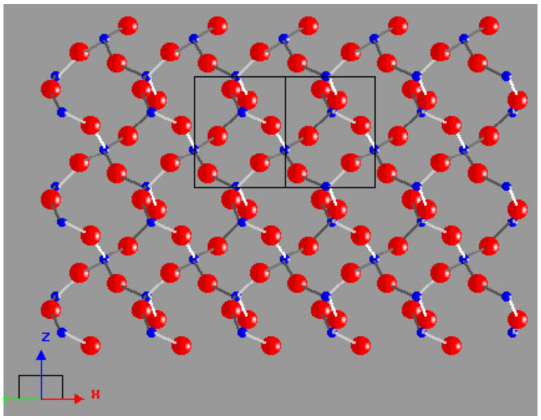
What is Quartz?

COMPOSITION	Pure SiO2
HARDNESS	7
CRYSTAL SYSTEM	Hexagonal
COLOR	Many
FRACTURE	conchoidal
SPECIFIC GRAVITY	2.6
REFRACTIVE INDEX	Low (glass-like appearance, which doesn't make it a good gem)

Quartz has no cleavage and fails by brittle, conchoidal fracture; the fracture surfaces have vitreous luster.

Quartz in thin section

Quartz images.



Movie showing quartz structure

Varieties

SiO_2 exists in several forms, the most common of which is low-temperature (alpha) quartz.

Quartz: pure SiO2 is colorless, not normally used as a gem.

sometimes carved (quartz crystal)
used in optical devices, etc. (like radio frequency oscilltors)
can be doubly terminated

The most common gem varieties of quartz are amethyst and citrine.

Amethyst

comes in different shades of purple (due to Fe impurity, commonly with zoned distribution):

- light purple
- purple
- blue-purple
- reddish purple

it is also set as a cabachon
radiation damage and iron (Fe) impurity are necessary to produce amethyst color

Fe - O charge transfer gives color: O-- <=> Fe4+
Fe3+ in Si site -> Fe4+

Other comments

Citrine

transparent, shades of orange
Citrine
yellow-orange-brown
color may be zoned
the color is due to the presence of Fe, which is also the impurity present in amethyst.

The term "ametrine" refers to bi-colored citrine/amethyst (junction is a peach color).

Smoky quartz

smoky quartz is Al+++- bearing quartz that has been exposed to radiation (natural and unnatural)
it removes an electron from O-- (i.e., a color center effect)
if there is sufficient Al and radiation, the crystal can turn completely black! ("morian")
Heat treatement restores clarity
Also sometimes faceted

Rose quartz

has rose-pink color
the color is often due to the element Titanium (Ti)
used for beads etc.
sometimes you can find star rose quartz which has inclusions
often massive (aggregates of crystals, not single crystals)

Green quartz

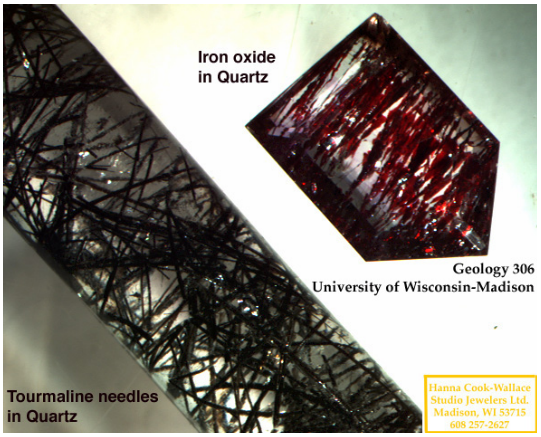
Milky quartz

milky appearance due to inclusions (often of fluid)
often associated with gold deposits - used as a gem mainly if gold present

Rutilated quartz is (normally) clear quartz that contains fine, often oriented, rutile crystals.

Rutilated quartz
common in jewelry
The term "venus hair"refers to fine red rutile needles
Note the orientations of the rutile needles

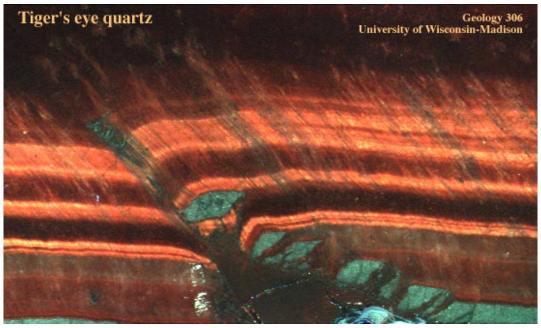
Tourmaline and other inclusions



examples of quartz containing tourmaline and Fe-oxide
fine tourmaline needles
a second example of green tourmaline in quartz
other inclusions can involve minerals (possibly rutile) and open tubes, for example:
at low magnificationthese features make interesting patterns,
the three dimensional natureof these needles is quite apparent

Chatoyant quartz

due to the presence of needles of asbestos etc. Form when prexisting minerals are replaced by quartz ('fossilized')
(tiger's eye): brown/yellow, and red
if needles retain their green asbestos color: "hawk's eye"; "falcon's eye"... etc.



Other fibrous varieties, including agate and chrysophrase are discussed in later lectures

Adventurine: green quartz containing platy inclusions of mica; can be used as a substitute for jade; used in beads etc.

Quartz can also contain inclusions of trapped fluid that may contain mineral precipitates and gas bubbles ('fluid inclusions') [Note the bubble of liquid and gas in this image is round. The black line is marker to draw your attention to the appropriate region).]. These tell us about the fluids present when the quartz formed. For example, fluids may be quite saline, indicating quartz grew from salt-rich solutions.

Where does it come from ?

- Quartz is a very common mineral in most igneous, metamorphic, and sedimentary rocks. It has also been found in some lunar rocks and meteorites.
- Quartz forms in rocks of igneous origin (melts) only after other silicates have incorporated most other available cations.
- Rocks that are more than about 47 percent (by weight) silicon dioxide contain quartz. The quartz content increases as the weight percentage SiO2 increases.
- Quartz can be dissolved in hot water or steam and is thus transported from place to place in the Earth, being deposited by cooling of the transporting fluid or by release of pressure.
- Because quartz is relatively resistant to mechanical abrasion, it is abundant in stream sediments, on beaches, and in wind-blown sands. Quartzite and sandstone are mostly quartz because this is the most abundant mineral that survives processes occurring at the Earth's surface.

Synthesis

- Quartz was first synthesized in 1845 via a hydothermal method > 1 lb. crystals
- Amethyst can be synthesized; distinguished mostly by "twinning"

Twinning produces many separate crystals of a mineral in rotated orientation, but orderly arrangement.

Doped quartz (quartz containing an impurity such as cobalt (Co) may be synthesized to achieve bright colored materials.

Heat Treatment: Citrine and amethyst:

Primitive methods can be employed like using a wheelbarrow to immerse crystals in sand within a fire to heat them to a high enough temperature to modify the oxidation state of the Fe.

- before
- during
- after

Quartz has some interesting properties

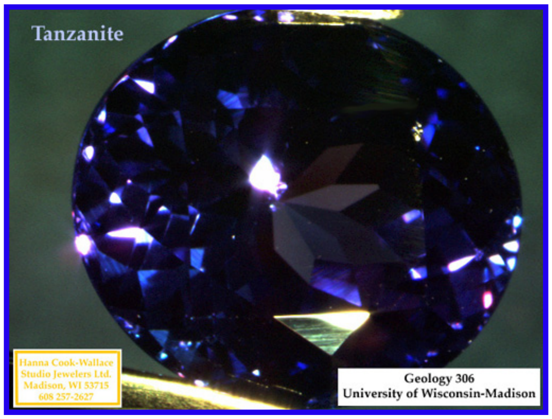
Piezoelectricity
some other comments

Zoisite (Variety Tanzanite)

What is it?
Where is it found?

What is it ?

- Tanzanite is the important gem variety of zoisite (zoisite is also refered to as epidote)
- Color is variable. Gem varieties are often sapphire blue or violet blue. However, other colors occur, like the red variety (thulite), and a green variety.
- Hardness: 6.5-7 (note this hardness is less than normally desirable for a gem used in jewelry subject to abrasion by dirt and dust)
- Crystal system: orthorhombic
- Composition: Ca-Al-silicate (tanzanite color is attributed to a Vanadium (V) as an impurity
- strongly pleochroic
- View an uncut crystal.



View some images of tanzanite

Where is it found?

- The variety of zoisite known as tanzanite was discovered in Tanzania in 1967
  - it occurs in pegmatite veins (inclusions suggest hydrocarbon-rich fluids)

Other:

- usually heat treated at 400 - 500 C to remove brown tints, deepen blue
- some cats eye varieties due to channels or needles
  - best orientation for color not same for chatoyancy

Previous Lecture: Chrysoberyl, Rutile and Spinel
Next Lecture: Olivine, Cordierite and Feldspar

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Where do gems form?

&

Where are they found?

Gems form in many different environments in the Earth. We will examine the most common and important environments and formation processes in this lecture.

It is important to distinguish where gems are **formed** from where they are **found**.

Almost all gems are formed below the Earth's surface.

- Some are brought to the surface through mining
- Some are brought to the surface through earth processes (faulting, folding, large scale uplift, volcanism). These processes can move rock up from more than 400 km below the surface.

Formation Environments:

In the following sections we will examine how gems form. We will start with examples at or near the Earth's surface and move down into the mantle.

Quick Links

Formation environments:

- Water near Earth's surface
- Hydrothermal deposits
- Pegmatites
- Magmatic gems
- Metamorphic gems
- Gems of the mantle

Do you have a way to **play the movies properly?** If not, click here.

1. Formation from water near the Earth's surface

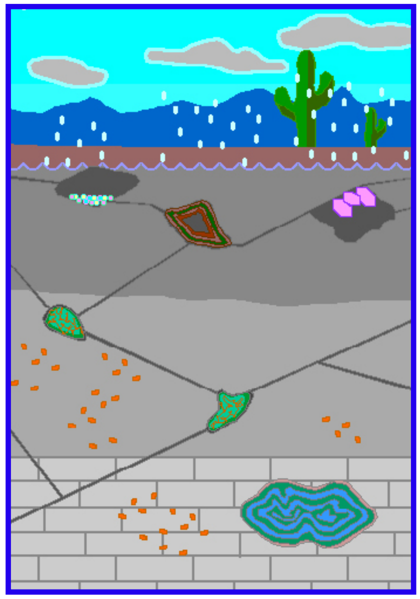
Water near the Earth's surface interacts with minerals and dissolves them. The ability of these solutions to maintain elements in solution varies with physical conditions. If the solution conditions change (for example if the solution cools or evaporates), minerals will precipitate. A similar, familiar processes is formation of salt crystals by evaporation of sea water.

The mineral that forms is determined by what the dissolved elements are. If the water has interacted with silica-rich rocks (e.g., sandstone), silica-rich minerals will form:

- Silica (SiO_2)-based minerals: amethyst (quartz); agate ; and the formation of opal. Of these, only opal is non-crystalline (ordered blobs of gel less than a micron in diameter).

If the water has interacted with copper-rich rocks, copper minerals will form:

- Cu-bearing minerals: malachite and azurite; or turquoise.



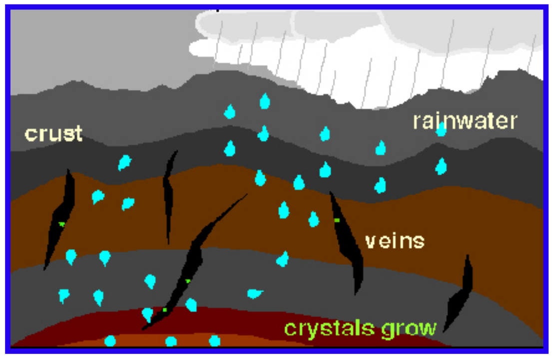
This movie shows formation of agate, amethyst, opal, turquoise, and malachite/azurite. Note the importance of alternating wet periods (when solutions are dilute and can dissolve a large amount of silica, copper, etc.) and dry periods (when solutions evaporate and minerals precipitate).

Here is some additional explanatory text for this movie!

2. Hydrothermal deposits

The formation of gems by **hydrothermal** processes is not dissimilar to formation of gems from water near the Earth's surface

The solutions involve rain water and/or water derived from cooling magma bodies< Gems crystallize from solution when it encounters open spaces such as cracks. As a result, 'veins' of minerals fill preexisting cracks.



This process is illustrated in this movie.

Minerals such as beryl (e.g., emerald), tourmaline need unusual elements, and some of these, like beryllium (for beryl) or boron (for tourmaline) are derived from cooling molten rock (magma).

Here is some additional explanation of this movie.

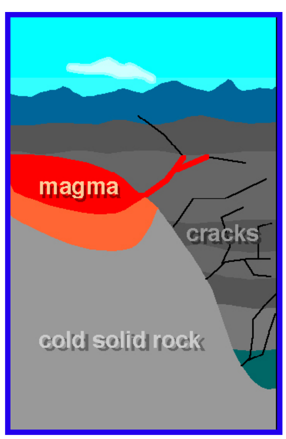
3. Pegmatites

Pegmatites are unusual magma bodies.

As the main magma body cools, water originally present in low concentrations becomes concentrated in the molten rock because it does not get incorporated into most minerals that crystallize. Consequently, the last, uncrystallized fraction is water rich. It is also rich in other weird elements that also do not like to go into ordinary minerals.

When this water-rich magma (also rich in silica and unusual elements) is expelled in the final stages of crystallization of the magma, it solidifies to form a **pegmatite**.

The high water content of the magma makes it possible for the crystals to grow quickly, so pegmatite crystals are often large. Of course, this is important for gem specimens!



This movie shows formation of crystals such as

When the pegmatite magma is rich in beryllium, crystals of beryl form.

If magmas are rich in boron, tourmaline will crystallize.

You should note that beryllium and boron are extremely rare elements in most rocks and it is only because the above process efficiently concentrates these unusual elements that crystallization of boron and beryllium-rich minerals can occur.

More information on pegmatites.

4. Magmatic gems

Some gems crystallize in magmas or in gas bubbles (holes) in volcanic rocks. Examples include: zircon, topaz, ruby, etc.

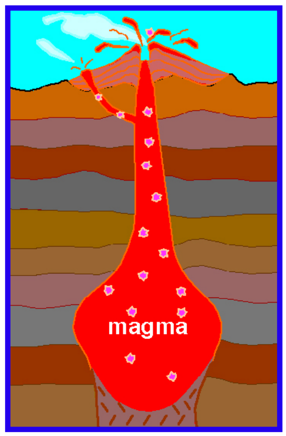
5. Metamorphic gems

Metamorphic rocks are rocks changed by heat, pressure, and interaction with solutions. There are a number of types of metamorphic environments:

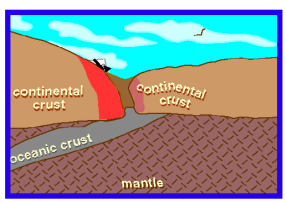
- Plate tectonics creates metamorphic environments characterized by high temperature and high pressure - produce jadeite (jade). In extremely rare cases, pressures in metamorphic rocks may be high enough that diamonds form.

emeralds and tourmaline in pegmatite bodies associated with cooling intrusive (magmatic) rocks

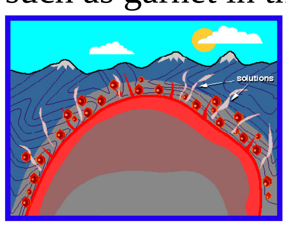
Here is some additional information about this movie.



This movie shows formation of crystals such as ruby or zircon (pink crystals) and topaz in open cavities (e.g., holes made by gas bubbles) in volcanic rocks.



This movie shows metamorphism of rocks resulting from continent-continent collision associated with a subduction zone. Note the formation of large crustals such as garnet in the deformed, heated zone.



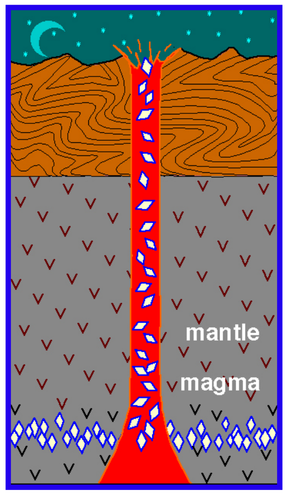
This movies illustrates the process of contact

- Regionally metamorphosed rocks: large volumes of rock that are buried and changed in response to increases in pressure and temperature. Minerals found in these rocks might include gems such as garnet and cordierite.

metamorphism. This is the process by which the minerals in rocks change in response to proximity to a hot intrusive body. For example, a limestone intruded by a magma undergoes significant change in crystal size, mineral content, and chemistry (due to addition of solutions released from the cooling magma). These rocks contain gems such as garnet.

6. Gems formed in the mantle

- The most abundant upper mantle mineral is olivine (peridot). Slabs of mantle material are brought to the surface through tectonic activity and volcanism.
- **Deep mantle gems.** Rocks such as kimberlites are eruptive volcanics that come from quite deep in the mantle and carry with them diamonds. Diamonds are made from carbon. The stable form of carbon at the Earth's surface is graphite. High pressures and temperatures are required to convert graphite to diamond. Thus, almost all diamonds formed about 100 miles below the Earth's surface. Dates suggest that their formation was restricted to in the first few billion years of Earth history.



This movie shows that diamonds do not form in the kimberlite magma but are carried up to the surface by the magma.

Rarely, diamonds are formed in very high temperature and pressure metamorphic rocks.

Alluvial Gem Deposits:

After rock is brought to the surface, gems may be released from the rock by weathering (some minerals dissolve, others are transformed to clay minerals, and some others survive unchanged). The minerals that survive unchanged may be washed into streams, etc., where they are concentrated by river / ocean processes.

- Gems retrieved from alluvial deposits are often rounded due to rolling around in rivers and oceans.
- Gems are often those minerals that are resistant to chemical weathering. They are commonly concentrated in stream beds and beach sands in what are known as **alluvial deposits**.
- Gems often have quite a high specific gravity (density) compared to other minerals so that they are easily trapped in depressions in stream beds. This causes them to become concentrated and makes it easier to mine them. Other valuable and durable things are also concentrated by these processes. Gold is a well known example.

In summary, gems are not always found where they were formed, nor are they formed where they're found!

Previous Lecture: What is a Gem?

Next Lecture: What is a Crystal?

OTHER TOOLS:

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Chrysoberyl, Spinel, & Rutile

Quick Links

Chysoberyl
Spinel
Rutile

what is chrysoberyl?
where is it found?
what are its unique characteristics?

Chrysoberyl

What is chrysoberyl?

COMPOSITION	BeAl2O4
HARDNESS	8.5 (3rd hardest gem!)
CRYSTAL SYSTEM	Orthorhombic
COLOR	Yellow, green and brown
VARIETIES	Yellow-green gems
	Cats eye
	Alexandrite
IMPURITIES	Fe (produces the yellow color)
	Cr (responsible for the alexandrite effect)
SPECFIC GRAVITY	3.68-3.78
FRACTURE	Conchoidal

Chrysoberyl Images

Remember:

- chrysoberyl is NOT the same as beryl
- it is among the world's rarest gems
- uncut crystals are commonly found in the shape of "cyclic twins"
    - drawing

Geological Origin

Chrysoberyl is found in Be- and Cr-rich environments (not unlike beryl)

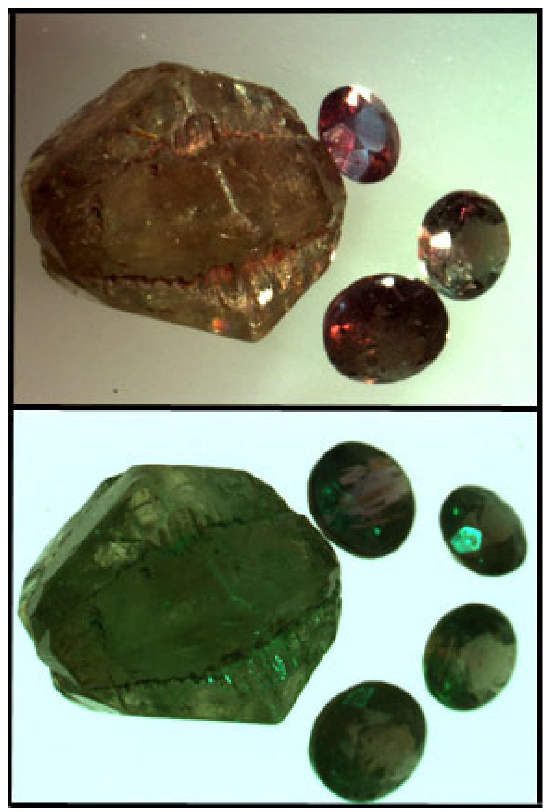
- pegmatites
- gem gravels

Chrysoberyl is recovered from several localities

Unusual properties

Color change

Chrysoberyl displays the "Alexandrite Effect" where the stone looks green in daylight (rich in blue light) and red in candle light (rich in red light). (Comparision of the two together.) This effect is most obvious in thick stones, and is due to the substitution of Cr+++ for Al+++.



Brilliant green to blood red are the most desirable colors for gemstones.

Chrysoberyl can be synthesized.

Other gems which show the color change phenomenon:

- Corundum (containing ~20 % Cr)
- Ruby
- Spinel

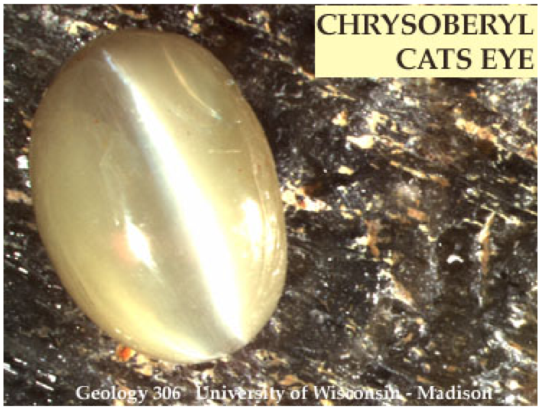
Chatoyant Chrysoberyl:

"Cat's Eye"

- due to the presence of inclusions (needle-shaped) or tube-like cavities
- needles are parallel to the base of the

cabochon and perpendicular to long axis of cut gem

- also called "cymophane" (Greek for waving light)
- note the silky sheen and similarity to star sapphires etc.
- as the stone is turned, the band of light moves, like a cat's eye (note: Tiger's eye is quartz that has replaced fibrous asbestos)
- most cat's eye chrysoberyl comes from Brazil.



Spinel

What is spinel?
Where is it found?

What is Spinel?

spinels are oxide minerals:

COMPOSITION	[Metal][Metal]2O4
	Ex: MgAl2O4, FeAl2O4
HARDNESS	8
CRYSTAL SYSTEM	Cubic
COLOR	Red, pink, green, blue, yellow, violet...
GROWTH HABIT	Octahedral crystals
SPECIFIC GRAVITY	approx. 3.6

Spinel Images

uncut spinels

Commonly, gem spinels are red and closely resemble rubies:

- Black Prince's Ruby
- Timur Ruby

Where is it found?

Spinel is a metamorphic mineral

- gems are often found in limestones
- found in gem gravels, very often along with ruby (another source of confusion)

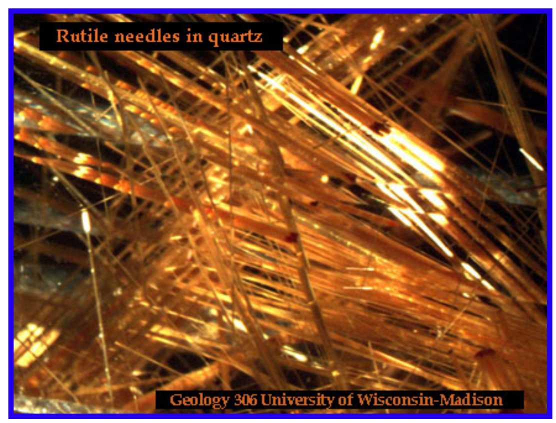
Geographically, you can find spinel in Burma, Sri Lanka and Thailand.
It is commonly synthesized by the Verneuil method

Rutile

What is rutile?
Where is it found?

What is Rutile?

COMPOSITION	TiO_2
HARDNESS	6.5
CRYSTAL SYSTEM	Tetragonal
COLOR	Usually red-brown (due to Fe impurity)
SPECIFIC GRAVITY	4.2



Rutile Images

- rutile's natural color is usually so dark that it is rarely encountered as a cut gem
- natural rutile is important in gemology because of its presence as fine inclusions, often as needle like crystals, in gems. If the needles are very fine, this results phenomena described as 'asterism' and chatoyancy.
- Rutile can be synthesized as a diamond simulant
- it displays exceptional fire
  - it is too high to be a good diamond simulant
  - six times the fire of a diamond

Where is it found ?

- in many rock types as a minor constituent
- it can be found at Graves Mountain, USA

Previous Lecture: Zircon
Next Lecture: Quartz

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Pearls and Other Organic Gems

Pearls

What are pearls? How are cultured pearls different from natural pearls?

Pearls are known to have been used in jewelry for over 6000 years!

PHYSICAL CHARACTERISTICS:

- hardness: 2.5 - 4.5
- S.G.: 2.70 (fresh-water up to 2.74)
- Size: from microscopic to many centimeter diameter (rare)
- Luster - typical pearly luster is termed "orient"
- a variety of colors, depending upon the type of mollusc and the water composition (polluted water produces unusual colors!)
  - bodycolor: underlying color: white-yellow (cream), black
  - overtone: "float" (resembles a filmy lacquer): pink / green / blue
- composition:
  - ~ 86 % calcium carbonate ($CaCO_3$)
  - 2 - 4 % water
  - ~ 10 % conchiolin (an organic binding agent)

View some images of pearls and organic gems

History of culturing of pearls:
Care of Pearls!

Together, the conchiolin and $CaCO_3$ are referred to as **nacre**.
Nacre consists of a series of alternating layersof conchiolin and crystals of $CaCO_3$. The $CaCO_3$ is in the crystal form known as aragonite. The typical irridescence of the pearl is due to the series of nacre layers. This is referred to as 'orient'(iridescent effect due to overlapping nacreous plates)

How to buy pearls

Summary: what makes a pearl a pearl?

- they must have outer nacre (mostly aragonite) layer to be considered a true pearl
- thus only pearls from mollusks with a nacreous mother of pearl lining are "true" pearls

Formation

Pearls are produced by a variety of organisms, commonly sea molluscs. They are also produced by fresh water mussels, and occassionally, by snails. Some examples of pearl-producing oysters (you don't have to remember these) are:

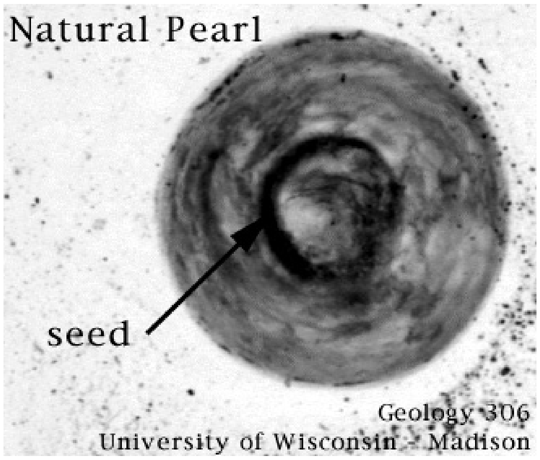
- Akoya pearl oysters (Pinctada fucata)
- Black Lip Pearl shell (Pinctada margaritifera)
- Freshwater mussel (Hydriopsis schlegeli)
- Large winged pearl shell (Pteria penguin)
- Abalone (Notohaliotis discus)
- Golden Lip pearl shell or white lip pearl shell (Pinctada maxima)

Reference: Mikimoto Pearl Museum, Toba.

Natural Pearls:

Concentric layers of $CaCO_3$ are deposited around an irritant. This may be a piece of mantle lobe or some other material.

Only the mantle lobe can secrete nacre. When a piece of mantle lobe is introduced by some accident into the tissue of the oyster, the oyster forms a bag known as a "pearl sac". It is this sac that secretes the nacre around the irritant to make the pearl.

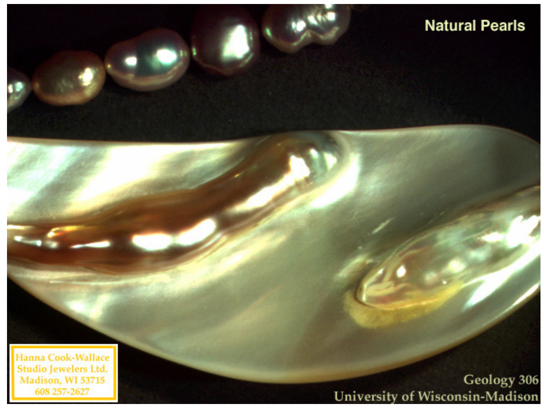


Thus, pearls are calcareous concretions

Some natural pearls have quite unusual shapes. These are often called "baroque" pearls.

Both saltwater and freshwater pearls consist of the same material and can form in "baroque" shapes. Unless you are quite familiar with the typical characteristics ("look") of pearls from certain specific sources, it would be very difficult to know whether a given pearl was saltwater or freshwater in origin.

Probably the most common freshwater pearl on the market is the Chinese freshwater baroque, some of which are crinkily and look like crisped rice. These have been very popular in recent years because they cost dramatically less than Akoya cultured pearls.



Blister Pearls:

Blister pearls form on the inside of the mother of pearl shell

Cultured Pearls:

Oysters and mussels are induced to make pearls. The result are termed "cultured pearls".

Maybe 90% of the pearls sold are cultured

If you break a pearl open you will see that it consists of a bead covered by a thin layer of nacre.

The culturing process involves inserting a small piece of mantle lobe and a bead made from mother of pearl shell into the tissues of a pearl-producing mollusk.

The mollusk treats the bead as an irritant and the mantle lobe tissue begins to deposit a nacreous coating over it.

Here is a description and some photographs to illustrate the process. The photographs were taken at the Mikimoto Pearl Museum, Toba, Japan:

- Oysters are raised in a tank, allowed to attach to fibers, then grown in sea water for two to three years. Growing oysters are suspended in cages hung from rafts. They feed on plankton. Healthy oysters are selected for pearl cultivation.

- The bead is prepared. Mikimoto use Pig toe clam shells, from the Mississippi River. Small balls are prepared from pieces of these shells. An example of a mother of pearl bead.

- Living oysters are wedged open and a piece of mantle lobe harvested from an other oyster, plus a bead, are inserted into the soft tissue. This image shows insertion of mantle tissue and bead. Here is a labelled version of this image, showing the important components.
- This image shows the oyster source of mantle tissue, the cut up pieces of mantle tissue, and the mother of pearl beads. A labelled version of this image is given here.
- Oysters are then returned to the sea, where they are suspended in cages 7 - 10 feet below the surface. They are maintained and harvested after some time. The culture period used to be ~ 3.5 yrs, producing ~ 1mm layer on the bead, but now the culture period may take less than 2 yrs.

The commercial production method is

now known as the Mise-Nishikawa method

Typical results:

(you do not need to memorize these numbers)

- 5% high quality pearls (hanadama)
- 28% marketable pearls
- 17% unmarketable pearls
- 5% uncoated nuclei
- 50% of oysters containing nuclei will die.

Source: Mikimoto.

Selection and presentation of pearls: Pearls are selected for their size and color (hue). Careful color grading is extremely important.

Pearls are then drilled from both sides, often at a place that is slightly flawed. They are then sorted, threated, and marketed.

Mabe pearls:

Mabe pearls are cultured blister pearls. These are produced by inserting a half bead against the shell of the mollusk, after a layer of nacre has been deposited over the bead, the whole formation is cut out and the nacreous dome cemented onto a mother of pearl bed.

Biwa pearls:

> Biwa pearls are produced at lake Biwa, Japan using freshwater clams. They are irregular in shape but have good color and luster. Instead of a bead a small square of mother of pearl in inserted into the clam. These pearls require three years to produce good results.

Natural or Cultured?

Distinction between these can often be made if the pearl is drilled because the size and nature of the seed can be determined. For cultured pearls, you should see a mm or so beneath the surface.

The term "candling" refers to examination of pearls in strong light. This may reveal the mother of pearl bead.

If the pearl is undrilled, an excellent method to distinguish cultured from natural pearls is to X-ray them.

Because the size of the seed differs, natural pearls ar less dense than most cultured pearls.

Information comparing Japanese and Chinese pearls

Use

The majority are strung as necklaces. Some are used in rings. Rejects are used in medicines as a source of calcium.

Preservation and damage

Conchiolin is prone to drying. If this occurs, the pearl becomes dull, the surface cracks and finally peels.

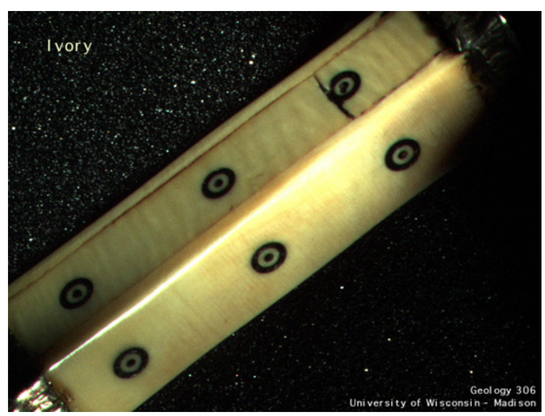
Pearls are damaged by excess humidty, dryness, acids, perspiration, cosmetics, hair sprays, and other chemicals.

Treatments

Pearls can also be dyed
Pearls are sometimes bleached to lighten their color

Conch "Pearls"

> Conch "pearls": because they lack nacre, these are not considered real pearls. They are often orange or pink in color. They form as concretions in conch shells.



Other organic gems

Coral, amber (which may include a variety of inclusions and cracks) and the tagua nut, which is used in place of ivory

---

Previous Lecture: Precious Stones: Agate and Opal

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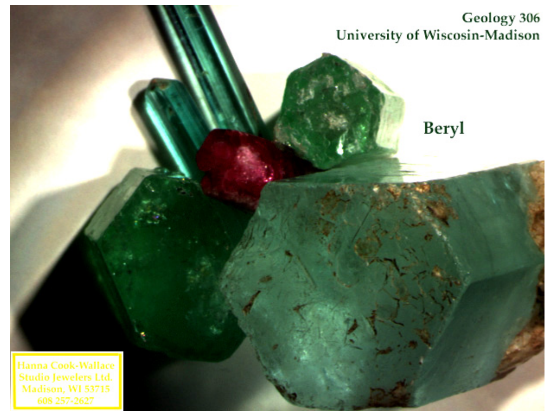
Beryl

Quick Links

- What is Beryl?
- What varieties exist?
- Flaws / cuts
- Geographic sources
- Synthetics
- Treatments

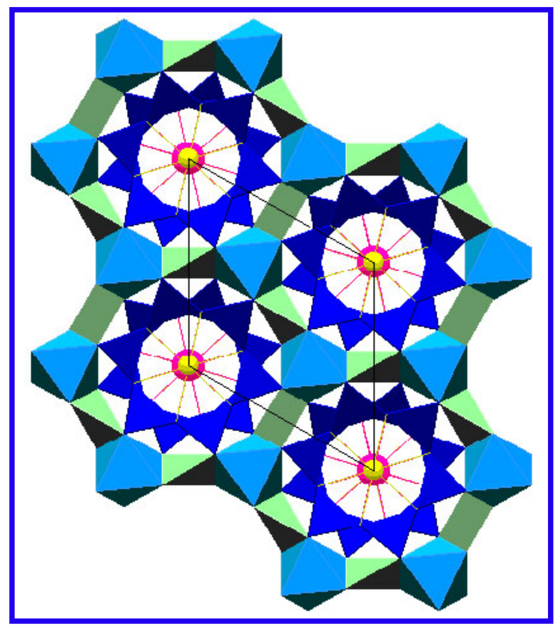


What is Beryl?

It's a silicate mineral with an unusual composition:

- Beryl contains the element beryllium.
- It is a ring silicate - the silicate tetrahedra are linked to form rings!
- Beryl commonly grows as elongate crystals with hexagonal cross sections.

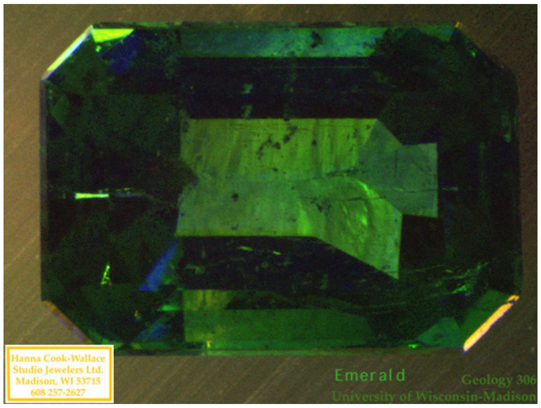
COMPOSITION	Be3Al2Si6O18
HARDNESS	7.5-8.0
CRYSTAL SYSTEM	Hexagonal
COLOR	Various
PLEOCHROISM	Prominent
IMPURITIES	Various
FRACTURE	Conchoidal
SPECIFIC GRAVITY	2.36-2.91



See a movie on a beryl structure!

Varieties:

Emerald:

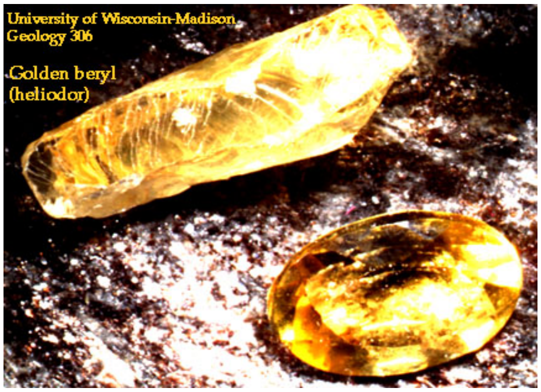


- color: Green
- another example of an emerald, and another another! and another emerald sample.
- emeralds can differ greatly in price and size as a consequence of thier depth and color
- due to presence of Chromium (Cr); pale green due to iron (Fe) impurities that absorb red (transmit green) and fluoresce red
- Comments

Aquamarine

- Aquamarine is usually flawless. Next to emerald, it is the most highly prized of the beryls.
- color: pale to medium blue (Latin for sea water); Another example of aquamarine.
- Color is due to presence of iron (Fe) in two oxidation states (ferric and ferrous) and the charge transfer between these ions.
- Heat treatment involves conversion of ferric to ferrous iron.

Heliodor (Golden Beryl) ('present of the sun')



- color due to presence of Fe-O charge transfer (and rarely, due to uranium)
- rarity and value: rarer than aquamarine, but less valued
- largest gem: 2054 ct (Smithsonian)

Morganite (named after a mineral collector)

- morganite is typically a soft pink / violet, rare peach and salmon
- color due to the presence of manganese (Mn)

Red Beryl

- color: red
- due to the presence of manganese (Mn)

Goshenite (named after Goshen, Massachusetts)

- color: colorless
- use: used in eyeglasses

Maxixe

- color: deep blue, fades
- involves irradiation effects and nitrate and carbonate groups in channels in the structure.

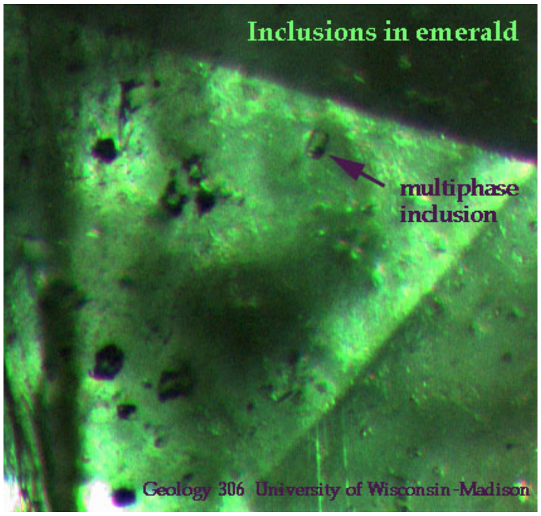
Flaws

Emerald

- crystals of emerald are very brittle
- most emeralds contain flaws:
  - inclusions (multiphase inclusions); may reveal geographic location
    - another example
  - cracks
- many emeralds are oiled, see below
- cutting emerald: the emerald cut
  - was developed specifically because emeralds are

very prone to cracking when knocked.

- cut with table perpendicular to the length of crystal -> yellowish green
- cut with table parallel to the length of the crystal -> bluish green



Other beryl gems

- generally far more perfect than emerald
- few cracks or inclusions

Geologic and Geographic origin:

Geologic: requires *source* of the element Beryllium !

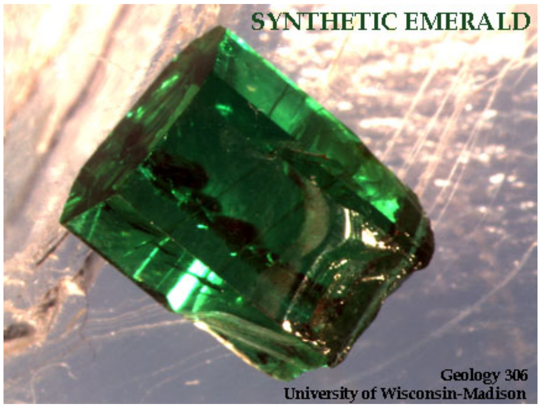
- veins
- hydrothermal and pegmatites
- also found with feldspar and quartz

Geographic:

- Most famous: Colombian - from veins in shales and limestones
- Ancient sources: Egypt (Cleopatra's emerald mines; 2000 B.C.); Austria
    - Other: Africa, Pakistan, Brazil, USSR

Synthetics

- Emerald synthesized since 1848 (no facetable gems until 1934)
    - generally not economic to synthesize aquamarine etc.
- 3 common methods: (details not required for EPS2 students)
    - Catham (since 1940) and Gilson flux method
    - Linde hydrothermal method
    - Lechteitner hydrothermal overgrowth method.



Make sure you understand the meaning of

"hydrothermal"!

Treatments

- heat treatment
- (irradiation)
- most aquamarines in jewelry are heat treated because the natural blue color is pale
- oiling : introduction of oils into fractures that intersect the surfaces of faceted emeralds. This treatment makes the flaws less obvious and enhances the general appearance of the stone.

The treatment or enhancement most commonly encountered is colorless cedar oil. Colorless Canadian balsam, Opticon and other natural and synthetic oils or resins are also in common use. Emeralds treated with these substances are certified as"enhanced or treated".

Using green oil is considered dying. There are certain inferior quality Indian, African, Brazilian, and possibly some Colombian emeralds which do get dyed. It is a fairly common practice with low end beads made in India (information provided by Jeffery Bergman, JLB@thaiphotovoltaics.com).

For the FTC guidelines on treatment disclosure, click here

Trivia

Gallery of beryl images!

Previous Lecture: Corundum
Next Lecture: Topaz

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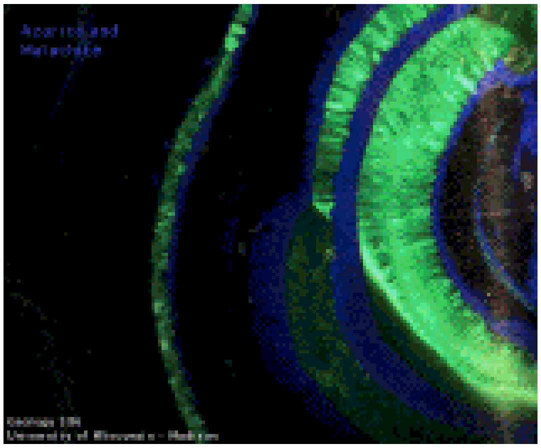
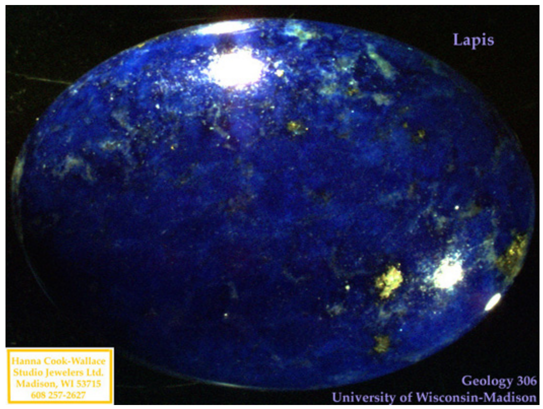
Argentite

Argentite, a silver sulfide mineral, is an important constituent of silver ore deposits. It contains 87% silver, and forms blackish-gray coatings or masses with a metallic luster and a shining black STREAK. Characteristic is the ease with which it is cut. Argentite is stable only above 179 deg C; thus, although few crystals found appear outwardly to be isometric, they are actually composed of acanthite, a chemically identical paramorph belonging to the monoclinic system. Argentite's hardness is 2 - 2.5 and specific gravity is 7.2-7.4.

Precious Stones: Lapis Lazuli, Turquoise & Malachite



Quick Links
Lapis lazuli
Turquoise
Malachite and Azurite



Lapis Lazuli

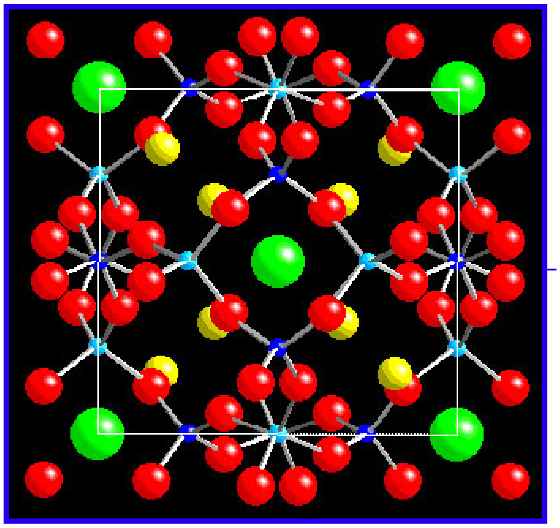
Lapis Lazuli is normally a mixture of three minerals:

- Lazurite (very complex blue mineral)
- calcite (calcium carbonate, which is white)
- pyrite (an iron sulfide that is white-gold in color)

Lazurite is the essential ingredient of lapis lazuli and is the mineral that gives it the blue color. The best quality material contains less calcite and pyrite. Lazurite is a sodium, calcium, aluminosilicate mineral that contains sulfur: the color is due to a charge transfer between sulfur atoms.

- it is a felspathoid (somewhat feldspar-like)
- cubic (thus, isotropic)
- hardness: 5.5

- S.G. 2.7 - 2.9
- vitreous / greasy luster



See a movie on a lapis (sodalite) structure!

Formation of lapis lazuli

Lapis lazuli, is a contact metamorphic rock with variable composition and varying physical properties. It usually forms by contact metamorphism of limestones.

Uses of lapis, durability, and simulants

Use of lapis lazuli: beads, cabochons, carvings

"Durability": sensitive to heat, acid, alkali

- sometimes dyed or coated with wax
- Swiss Lapis is dyed quartz

Comments

The name lapis is Persian for blue.

Prior to 1828, it was used as pigment for ultramarine paint.

For more that 6000 years, it has also been used as an ancient precious stone/gem in Afghanistan, and traded throughout Africa and Europe.

Other comments

Copper-bearing minerals formed at low temperatures: turquoise, malacite, and azurite

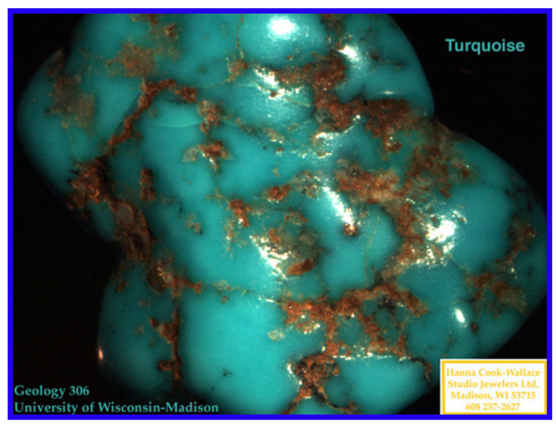
Formation of turquoise, malachite, and azurite

Turquoise commonly occurs in veinlets penetrating weathered, aluminum - rich, sedimentary or volcanic rocks (where it has been deposited near the surface from circulating phosphatic waters) in arid climates, and in small, fine-grained, rounded masses and crusts.

Turquoise:

- turquoise is a "cryptocrystalline" material: it's made of tiny crystals (you will rarely see individual crystals)
- it's a hydrous (water) copper (Cu) - bearing phosphate mineral
- hardness= 5 - 6
- color: medium green - blue (greener material contains more Fe)
- greasy (waxy) luster
- other information

- Turquoise is formed in association with Cu deposits; copper is transported in waters which interact with phosphorous and aluminum-bearing rocks.
- Turquoise is often veined and frequently contains inclusions of surrounding rocks.
- sometimes occurs as kidney-shaped or grape-like aggregates.



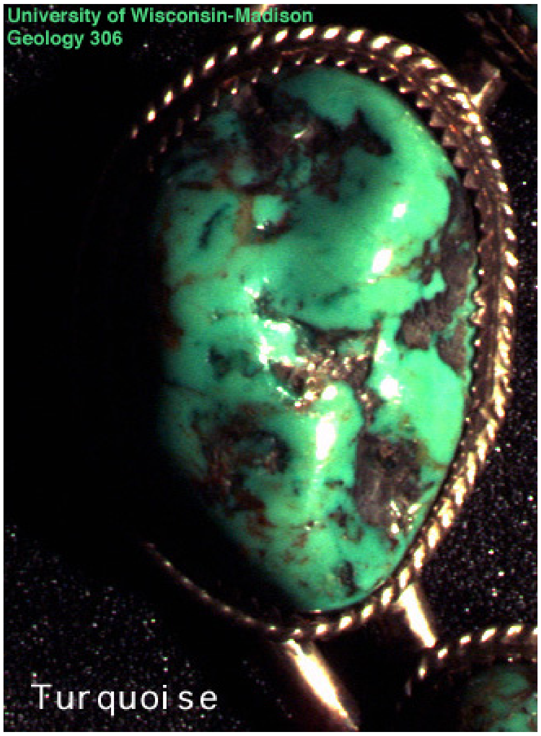
View some images of malachite, azurite, and turquoise

Geographical:

well known deposits occur in Persia, Sinai Peninsula, China, Chile, Egypt, Turkey, Mesoamerica (Arizona)

Comments

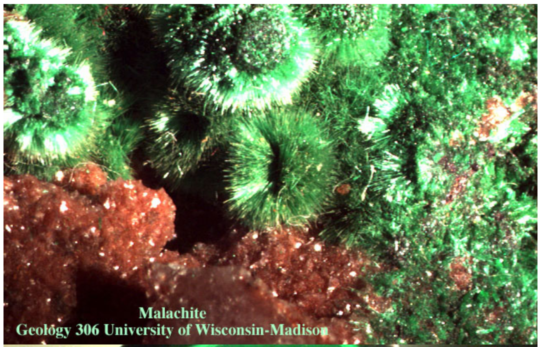
Other name: Turkish stone
The use of turquoise use dates back to 3000 B.C.- 4000 B.C.+ (Sinai)
Stability: sensitive to temperature: above 250 degrees C, a loss of water leads to a dull green color
Enhancements: impregnated with plastic, parafin, oil
Synthetics: ceramic material containing small blue spheres
Simulants: glass, plastic, dyed material (e.g., calcite)--imitations can be found from 4000 B.C.!

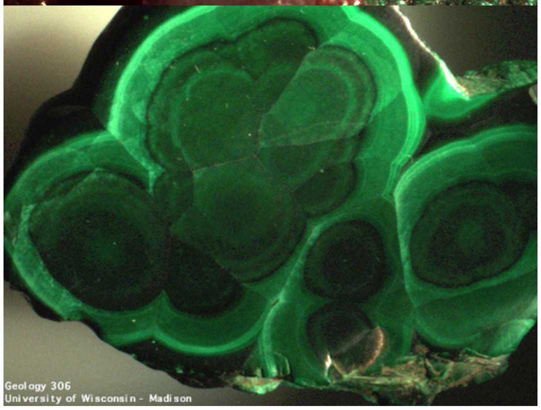


Malachite and Azurite

Malachite:

- copper (Cu) - carbonate mineral
- soft, green material
- hardness= 3.5 - 4.0
- S.G.: 3.75 - 3.95
- crystal system: monoclinic
- bubbles with acid
- it commonly grows as aggregates of crystals that form concentric rings.





Geological

- Cu-bearing solutions interact with carbonate rocks (cavelike deposits)

(Ancient) Uses:

- jewelry, ornaments, carving, etc.
- make up (eye shadow)
- green pigment

- cure for vomiting
- protection from witches!

Azurite:

- Cu-bearing carbonate
- a soft, blue material
- hardness: 3.5 - 4.0
- S.G.: 3.7 - 3.9
- vitreous luster
- refractive index: 1.73 - 1.758 max. 1.838
- crystal system: masses of tiny monoclinic crystals
- occurrence: Arizona, Chile, Rhodesia

Azurite commonly occurs with malachite (azur-malachite is an intergrowth of the two minerals). Because of its similarity with malachite (formed in similar way), azurite has similar physical properties and uses.

Previous Lecture: Pyroxenes (and Amphiboles), Tourmaline and Garnets
Next Lecture: Precious Stones: Agate and Opal

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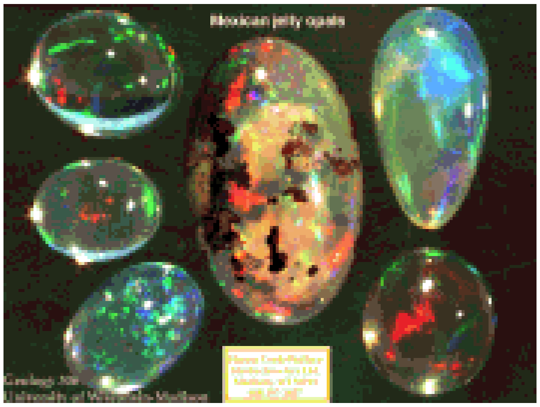
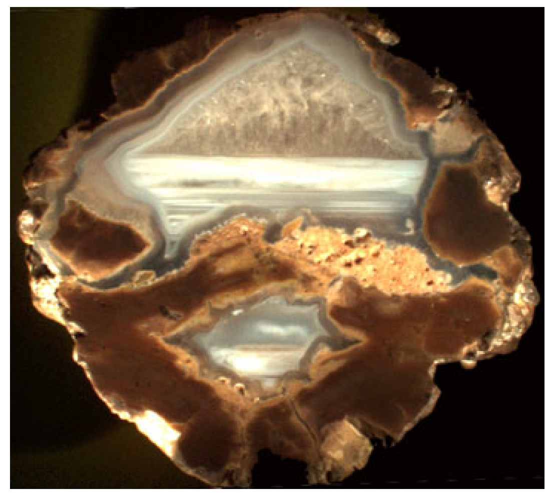
Agates and Opals



Agate



- finely crystalline, microcrystalline or cryptocrystalline quartz
- termed chalcedony: often fibrous, botryoidal masses, fibres perpendicular to hummocks
- S.G. ~ 2.6 (lower than quartz, slightly porus)
- silica rich solutions fill up cavities in rocks to form geodes
- porosity allows coloration by dyes:
  - black/brown: sulfuric acid + sugar
  - red: iron oxide
  - blue: potassium ferrocyanide
- Agate is most common variety of chalcedony
- crystals at core may be amethyst note the color bands

Opal

View some opal images!

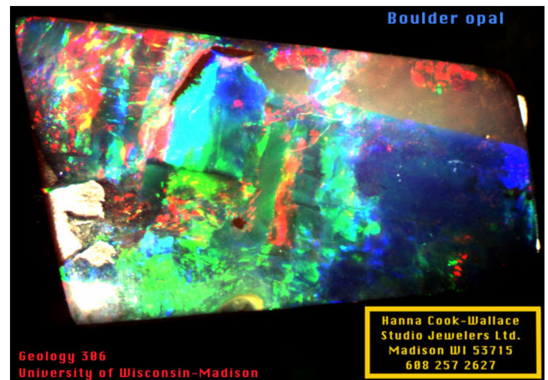
- it's made from essentially amorphous or non-crystalline material
- despite the lack of crystal structure, opal does display internal order!
  - constructed from balls of amorphous silica (like non-crystalline quartz)
  - size, and thus spacing, of spheres is ~ wavelength of light
  - consequently, light of the appropriate wavelength is diffracted
  - you see pure spectral color (pure color, single wavelength)

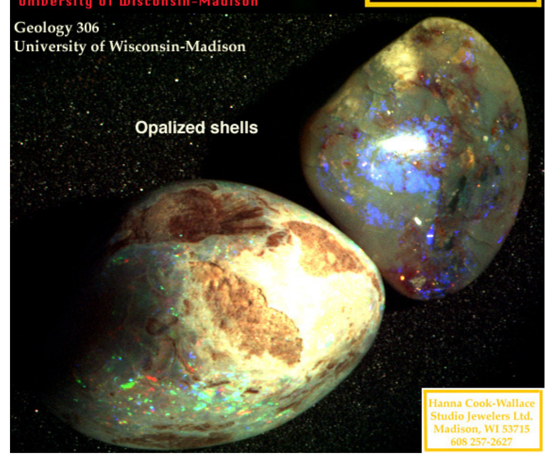
- composition = SiO2*nH2O (up to 30 % water)
- hardnesss = 5.5 -6.0
- color = variable, with play of color
- "opalescence" = color change with orientation

Opal Varieties

There are three general opal groups:

Precious Opal





Precious opal, which displays 'opalescence' (spectral color, irridescence that changes with the angle at which the gem is viewed).

Two subgroups:

White opal is an opaque stone in which the colors appear as flashes or speckles.

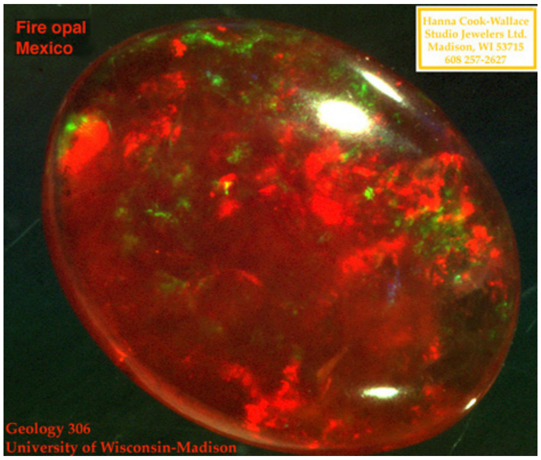
Black opal contains fire with a dark body color. These are less common and tend to be costly.

Examples:

- precious opal note the rainbow-like iridescence.
- colors and patterns
- opalized wood
- shell
- stem

Fire Opal

Fire opal is transparent or translucent with an orange or red body color. Fire opals are named for their color (but are not opalescent). The term is often misinterpreted to indicate that fire opal is opalescent because in precious opal, (with a play of color) the play itself is called fire.



Examples of fire opal and related varietites

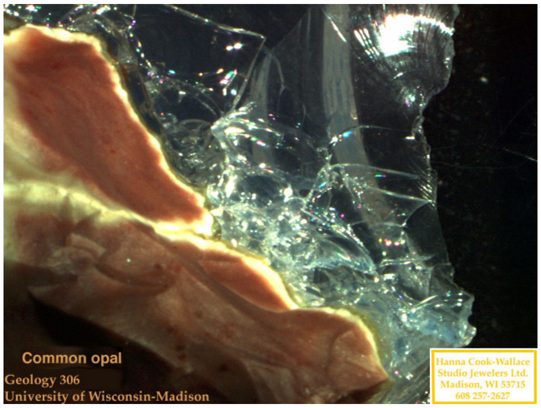
(Mexican) water opal is transparent and contains flashes of fire.

- jelly opal
- also found in a rhyolite matrix
- "water-bearing opal"

  Water can still be seen inside the opal!
- fire opal
- note the orange color, no opalescence

Common Opal

Common opal is rather opaque. Many names are used to describe varieties, e.g., honey opal, milk opal, moss opal, etc.



Examples:

- common opal: opaque, no play of color
- "petrified" opal

Where is opal formed and where is it found?

Geological:

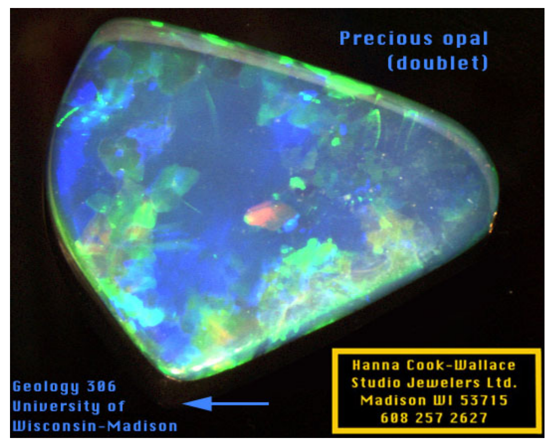
precipitated near the Earth's surface from circulating ground water or hydrothermal solutions; esp. where seasonal rainfall and extended dry periods, often as linings of cavities or crack fillings

Geographical

90 % of World's supply of opal from South Australia

Assembled Opal Products

Doublets and Triplets:



Doublets and triplets consist of a thin slice of opal cemented to a dark substrate. In the case of opal triplets, a colorless glass or crystalline cap is cemented to the opal slice.

Doublets and Triplets are common, as these are substantially less expensive than precious opal.

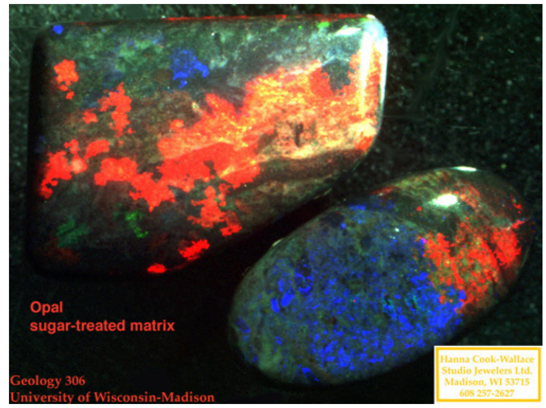
Examples:

- doublets
- triplets

Enhancements

- impregnation with plastic, surface oiling
- carbon or sugar treatment:
  - heating the opal in paper (manure) leaves a deposit of carbon below the surface of the stone
  - soaking the opal in sugar-rich solutions in sulfuric acid bath gives it a peppery 'pinfire' effect (play of color)

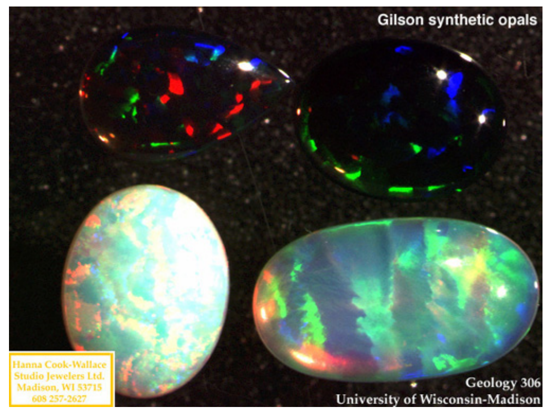
    (this is a superficial treatment, which leads to low S. G. and porus stones)



Preservation and handing of opals

Synthetic Opals

There are several manufacturers of synthetic opals, including Gilson Opal, Inamori Opal, etc.



Simulants

- glass: "slocum stone"
- foil-backed/reflected light: foil-like particles and cellophane-like foils of transmitted light
- may contain obvious bubbles

Previous Lecture: Precious Stones: Lapis, Turquoise, Malachite and Azurite
Next Lecture: Pearls

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Bauxite

Bauxite is a main ore of aluminum It is actually a rock mixture consisting mostly of several hydrous aluminum oxide minerals, including boehmite, diaspore, gibbsite, and impurities such as quartz, clay minerals, and iron hydroxides. The nature of the rock makes individual minerals difficult to distinguish.

Boehmite occurs in microscopic plates (orthorhombic system) as well as in pea shaped aggregates called pisolites. Diaspore, identical in chemical composition with boehmite but structured differently, occurs in emery deposits and in bauxite and laterite. It forms thin whitish, grayish, or colorless platy or elongated crystals, as well as scales and cleavable, foliated masses. Its luster is brilliant or vitreous pearly. Gibbsite forms white or gray six - sided tabular crystals (monoclinic system) with one perfect cleavage. Often the chief mineral of bauxite or laterite deposits occurs in low-temperature hydrothermal veins.

Bismuth

Bismuth is often used in pharmaceutical and cosmetic products. The chemical element bismuth is a soft, brittle, highly lustrous metal belonging to the same group in the periodic table as arsenic, Group VA. Its symbol is Bi, its atomic number is 83, and its atomic weight is 208.9806. The discoverer of the element is unknown, as is the origin of its name. No record exists of its use in ancient times, but Europeans had become aware of its existence by the Middle Ages.

The average abundance of bismuth in the Earth's crust is about 0.00002%. It is most commonly found as an oxide, sulfide, or carbonate in silver, lead, zinc, and tin mineral deposits. The metal is a by-product of the smelting of these ores. Bismuth metal has a melting point of 271 deg C (520 deg F) and a boiling point of 1,560 deg C (2,840 deg F). On freezing, molten bismuth expands 3.3% by volume, a property shared by only one other element, gallium. Bismuth forms compounds in the +3 and +5 oxidation states; the +3 state is the more stable of the two. The metal dissolves in nitric acid to form bismuth nitrate, which on controlled hydrolysis produces bismuth subnitrate. Other mixed oxide salts of bismuth are similarly named.

The very low toxicity of ordinary bismuth salts permits their use in the cosmetic and pharmaceutical industries. An important new application is the use of the complex salt bismuth phosphomolybdate as an industrial catalyst in the synthesis of acrylonitrile, an intermediate product in the manufacture of acrylic fibers and various plastic products.

Borax

Boron is a metalloid chemical element with properties intermediate between those of carbon and aluminum. Its chemical symbol is B, atomic number 5, and atomic weight 10.811. Boron is relatively rare, constituting only 3 ppm of the Earth's crust. It is most commonly found in the borate minerals borax, and kernite.

The element was first isolated by Sir Humphry Davy in 1807 and by Joseph Gay-lussac and Louis Thenard in 1808.Research suggests that boron may be nutritionally important. Apparently it helps to maintain appropriate body levels of minerals and hormones needed for bone health. The low electrical conductivity of boron increases greatly as its temperature is raised. At certain temperatures, therefore, boron behaves as a semiconductor, and it is often added to germanium and silicon to increase their electrical conductivity. The use of cubic boron nitride as a high - temperature semiconductor is also being explored. Small additions of boron to steel appreciably increase the hardness of the alloy. Boron is also used in the production of pure, strong metals to remove the oxygen and nitrogen dissolved in the metal or chemically bound to it, and it is used to absorb fast neutrons in nuclear reactors.

The most important boron compound is borax, which has been used in pottery glazes since the Middle Ages. Borax deposits were first found in Tibet, and borax was brought to Europe by the Arabs. It is still important in the ceramic industry. Borax combines with chromium, copper, manganese, cobalt, and nickel to form beautifully colored compounds. Borax beads were once used as a reagent in the detection of these elements. Borax is also important in the production of borosilicate glass, which has a high refractive index and is suitable for the manufacture of lenses. Other applications of borax include the impregnation of textiles and wood to make them fire resistant; softening water for laundry; and as a flux in brazing (dissolution of oxides). A weak base, borax is also used in buffer solutions and photographic developers. Since boron is important in the calcium cycle of plants, borax or boric acid is often added to boron poor soils as a fertilizer. Boric acid is obtained by the action of strong acids on borax and is used as a mild disinfectant. Although its toxicity is low, it is not completely harmless. Its use as a food preservative is prohibited in many countries.

Bornite

Bornite is an important copper ore (it is both a copper and iron sulfide mineral). It forms brittle, granular, or compact masses that on fresh fractures are metallic and brassy. Upon exposure to moisture, bornite tarnishes to a purplish iridescence, for which reason it is commonly called peacock ore. Hardness is 3, streak pale grayish black. Bornite occurs with chalcopyrite and chalcocite, both more important as ores, in copper deposits that typically form as zones of contact metamorphism (see metamorphic rock) and as sulfide ore veins.

Diamonds and Diamond Simulants

Remarkable facts:

- **All diamonds are at least 990,000,000 years old**.

  Many are 3,200,000,000 years old (3.2 billion years)!!!
  How do we know this?

  Age: from Carbon dating? **NO!** C-dating only works for very young carbon. You need to use other radioactive decay schemes (e.g., uranium-lead) to date inclusions in diamonds. Inclusions used for dating are around 100 microns in diameter (0.1 mm).

- **Diamonds are formed deep within the Earth: between 100 km and 200 km below the surface.**

  Diamonds form under remarkable conditions!
  - The temperatures are about 900 - 1300 C in the part of the Earth's mantle where diamonds form.
  - The pressure is between 45 - 60 kilobars. (kB)
    - 50 kB = 150 km = 90 miles below the surface
    - 60 kB = 200 km = 120 miles below the surface

- **Diamonds are carried to the surface by volcanic eruptions.**

  The volcanic magma conduit is known as a kimberlite pipe or diamond pipe. We find diamonds as inclusions in the (rather ordinary looking) volcanic rock known as kimberlite.

  NOTE: The kimberlite magmas that carry diamonds to the surface are often much younger than the diamonds they transport (the kimberlite magma simply acts as a conveyer belt!).

- **Diamond is made of carbon (C), yet the stable form (polymorph) of carbon at the Earth's surface is graphite**.

- **To ensure they are not converted to graphite, diamonds must be transported extremely rapidly to the Earth's surface.**

  It is probable that kimberlite lavas carrying diamonds erupt at between 10 and 30

Quick Links

Rarity
Basic Data
Famous Diamonds
Color
Clarity
Cut
Carat Weight
Treatment
Simulants
Synthetics

Famous diamonds

This is just for fun -- not required information!

- Dresden
- Hope
- Cullinan (Before)
  - After
- Sancy
- Tiffany
- Kohinoor
  - a-section
- Shah
- Nassau
- Florentine
- The Great Mogul
- Orloff
- Stern
- Regent

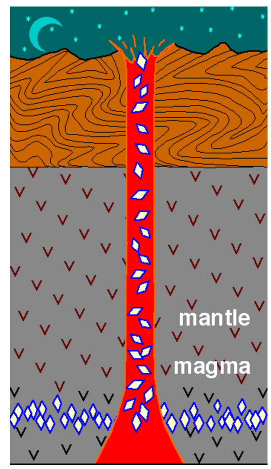
km/hour (Eggler, 1989). Within the last few kilometers, the eruption velocity probably increases to several hundred km/hr.

- **Diamond is the hardest material.**

  Diamond is the hardest gem on the MOHS harness scaleand graphite (also made from carbon atoms) is the softest! Given that both diamond and graphite are made of carbon, this may seem surprising.

  The explanation is found in the fact that in diamond the carbon atoms are linked together into a three-dimensional network whereas in graphite, the carbon atoms are linked into sheets with very little to hold the sheets together (thus the sheets slide past each other easily, making a very soft material).

- **Diamonds are found in many localities, both overseas and in the US.**



This movie (68 k) emphasises that diamonds do **not form in the kimberlite magma**, but are carried up to the surface by the magma.

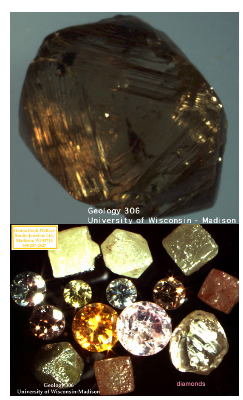
How rare are diamonds?

How many grams do you need to mine to get 5 grams of diamonds?

(5g/1000 kg) @ 1000 g/kg = 5 g /1,000,000 g!

But only 20 % are gem quality (80 % of these are sold in a "managed selling environment") and the remainder are used for industrial purposes (this material is known as "bort" or "carbonado" (carbonado is finer)).

Basic Data



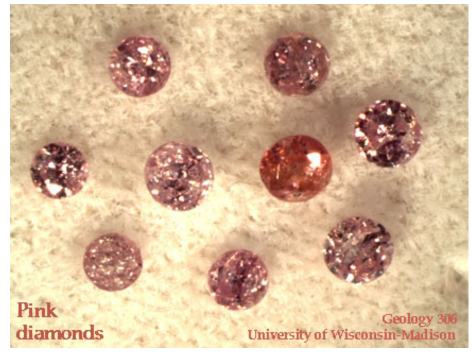
- Hardness = 10
- Crystal System = cubic
- This is what crystals look like before they are faceted: note their natural octahedral shape! Uncut diamonds are also found in cubic forms.
- Diamond has four good cleavages, thus diamonds tend to cleave on impact.
- Refractive Index = 2.42
- Dispersion=0.044
- Specific Gravity = 3.52

Value

The 4 "C" words are used to summarize the value determining factors:
The required basic information describing what is meant by these terms is provided below.

- **Color** is determined by 'grading' visual comparison with 'knowns' or by instrumental means.
  - Consider the amount of yellow color (yellowish color decreases the value of a "colorless" stone). In order of increasing yellow content:

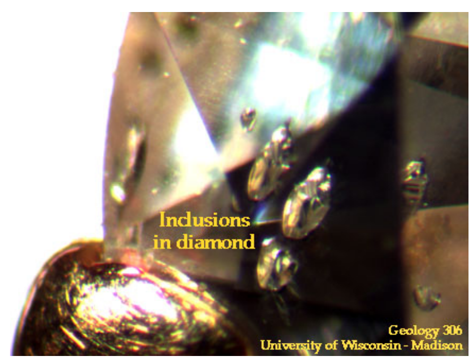
    blueish-white -> white -> silver -> yellow
  - 'Fancy', or strongly colored stones have their own appeal and special value.



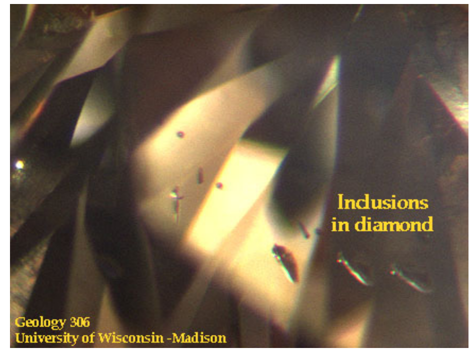
  - Colored diamonds may be yellow, green or brown, green or shades of pink.
  - Larger pink diamonds are quite rare and currently very expensive.
  - Natural blue diamonds contain the element boron (B), and this changes the conductivity of the diamonds. Natural yellow diamonds contain the element nitrogen (N).

- **Clarity** is decreased by the presence of blemishes or flaws, scratches, nicks, 'naturals' (the original surface of an uncut stone).
  - There are many systems of nomenclature.
  - Some terms include:
    - perfect
    - flawless
    - imperfect
    - very slightly included
    - very very slightly included

IF	VVS1	VVS2	VS1	VS2	SI1	SI2 I1 I2	I3
internally flawless	very, very slightly **included**		very slightly **included**		slightly included		imperfect



  - other descriptions:
    - "Perfect," "internally flawless," and "flawless" are not synonymous. "Flawless" is reserved for diamonds having no visible inclusions under 10x magnificantion and having no external blemishes of any kind.
    - Clarity grades refer to what is visible at 10x magnification. With sufficient magnification, inclusions will be revealed in any diamond. "Perfection" is relative.

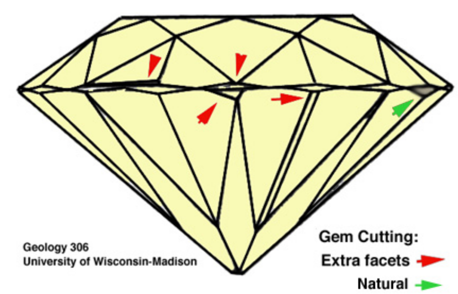


- "pique" (used below and in older literature) is an old trade term and has been supplanted by the GIA-developed international standard, from IF to I3.
- "first pique" inclusions readily recognizable at 10x mag., not significantly diminishing brilliance
- "second pique" larger inclusions, can be seen with naked eye
- "third pique" many large inclusions, diminishing brilliance

- Examples of clarity-reducing inclusions:
  - inclusions
  - cracks
  - a crack along the pavillion

- **Cut:** Facets are placed so as to maximize the brilliance and fire of a stone.
  - Remember that in the first lecture we talked about how the proportions of a faceted gemstone are determined based on the refractive index?
  - Review the basic concepts:
    - Refraction is dependent upon the wavelength.
    - Refractive Index (RI) is proportional to wavelength; red RI < violet RI (dispersion is due to the different amounts different wavelength are bent).
    - Fire,which is seen as rainbows and glints of color, is due to dispersion (a consequence of the placement of faces on the crown to take advantage of the prism effect).

Review the light path in a correctly cut gem!



  - The brilliant cut (modern round brilliant cut or Tolkowsky cut) is a typical cut chosen for diamonds. Tolkowsky determined the optimal proportions are such that the table width is 53% of the diameter of the cut stone. Appraisers will penalize diamonds with tables above 64%. Significant deviations, up to table widths of more than 70% are not uncommon.
  - There are many alternative diamond cuts.
  - A poorly cut stone is characterized by poorly chosen proportions (poor optimization of brilliance and fire or, worse still, leakage of light from the pavillion). Misplaced facets, extra facets, and problems at facet junctions are also characteristics that reduce the quality of "cut".
  - Ranking: VERY GOOD ... GOOD .... MEDIUM ... POOR

- **Carat Weight**
  - Recall: 1 carat = 0.2 g, thus 5 carats=1g
  - For example, compare the size of a one point diamond to that of a 0.67 carat diamond.

Just FYI: This site explains the GIA grading report used for diamonds, including information on desirable characteristics.

Other issues: Treatment, simulants, synthetics

Treatments:

- **filling of cracks**

  Surface cracksand cleavages reaching the surface are often filled with a glass-like material.

  Identification: when examined with an optical microscope, filled stones will show:

  - greasy appearance
  - flash effects
  - bubbles

  Problem: Filling does not always resist polishing and cleaning

- **drilling of inclusions**

  Drilling inclusionsinvolves using a laser to drillin into the inclusion. Solutions can be poured into the resulting "hair-width" diameter hole to bleach colored inclusions. This is comparaed to getting a filling in your tooth.

- **irradiation**

  Irradiation is used to change the color of the diamond. A common color produced by irradiation is green.

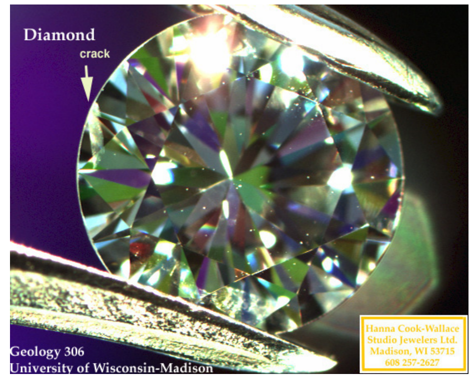
  Early attempts: beginning of 20th Century: diamonds exposed to radium - the problem was that the diamonds remained radioactive! However, modern irradiation treatments do not produce radioctive stones.

  Irradiation involves the use of devices such as:

  - linear accelerators
  - gamma ray facilities
  - nuclear reactors

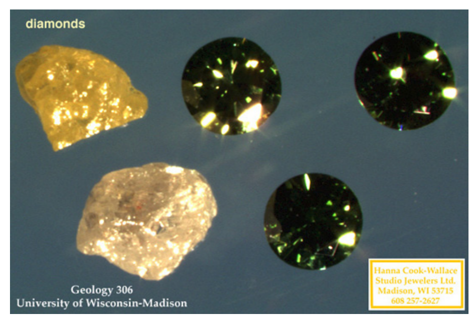
  Detection of irradiation treatment:

  Electron irradiation only changes the surface of the stone. Thus, it produces a concentration of color where the gemstone is thin. For example, electron irradiation produces a color concentration at the culet or keel line of the faceted gem.



Above, a diamond with a surface crack.

Below, examples of irradiated diamonds.



Simulants - simulate the appearance of diamond

The distinction between a synthetic diamond (man-made diamond consisting of carbon atoms arranged in the typical diamond structure) and a diamond simulant (not a carbon compound with the diamond structure) is **very** important!

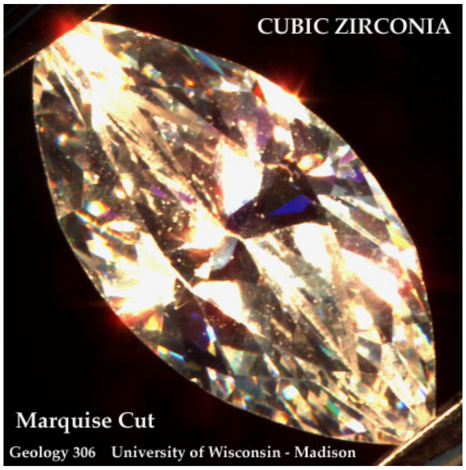
In order of increasing R.I., the most common simulants are:

- YAG = yttrium aluminum garnet
- GGG = gadolinium gallium garnet
- CZ = cubic zirconia
- Strontium titanate
- diamond.

This mnenonic can be used to memorize the common diamond simulants in the above order:

You **g**o **c**razy **s**taring at **diamonds**.

Again: Simulants (look alikes) differ from synthetics (synthesized by humans!)!



Another diamond simulant, **synthetic moissanite** (Silicon carbide or carborundum) was introduced to the jewelry market in 1998; manufactured by C3 Inc. and Cree Research. It has become the gold standard for diamond simulants in the last few years.

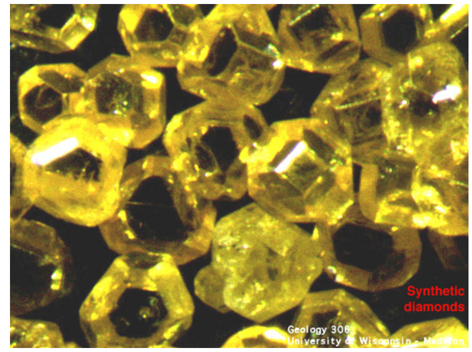
Source: *Jewelers of America*

Crystal Structure	hexagonal
HARDNESS	9.5
R.I.	2.65-2.69
Specific gravity	3.17-3.20

Simulants are distinguished from diamonds using measurement or observation of various properties, such as:

- R.I.
- "Read through effect"
- Dispersion
- Hardness
- Specific Gravity
- Reflection pattern
- Shadow patterns

Note: not all diamond simulants have been around for the same length of time!

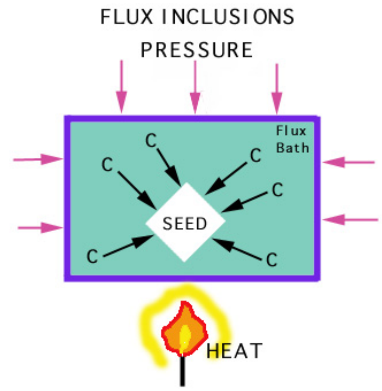


Synthesis (Details on gem synthesis)

Synthetic diamonds are often yellowish in color (rarely used for gem purposes, more commonly used as diamond grit for industrial purposes. Modern synthesis of thin film diamond has other industrial applications).

A 5 mm diamond (0.5 carat) takes over a week to grow. Synthesis requires:

- high pressure
- high temperature
- a special apparatus



Synthetic diamonds can sometimes be distinguished from natural diamonds by the presence of flux inclusions (Ni, Al or Fe).

 Lots of diamond images!

Previous Lecture: How are gems identified?
Next Lecture: Color in Minerals

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Breccia

Rocks of all types are used for decorative purposes or for inside paving. Breccia is a type of rock composed of large angular fragments that have become cemented together. Unlike the cobbles in conglomerates, which have been rounded by transport, the angular fragments of breccias have been formed in place rather than by erosion and sedimentation. Common in stratigraphic formations, they form in many ways: collapse of cave deposits, igneous activity, diastrophism, and meteorite crater impacts. Nearly all rocks are subject to some natural breakage, but they are considered breccias only when a considerable amount of fine grained cementing material (matrix) is produced during fragmentation.

Calciphyre

Calciphyre is a contact metamorphic rock which contains calcite wollastonite, garnet, plagioclast, scapolite monticellite, diopside, fassaite pyroxene; it also sometimes contains titanite, ilmenite, xanthophyllite (calcium mica), and humite graphite.

Chalcedony subtypes

Cornelian (red to brown red); Sard (red - brown);Chrysoprase (green, apple green); Heliotrope / Bloodstone (dark green with red spots); Moss Agate (colorless w/green inclusions); Dendritic Agate / Scenic / Mosquito (white gray with tree like inclusions); Banded Agate (all colors with bands of colors);...Subtypes of Agate; Eye; Layer; Dendritic; Enhydritic; Fortification; Orbicular; Moss; Scenic; Pseudo; Tubular; Sard; Brecciated; Jasper; onyx.

Chalcopyrite

Chalcopyrite is an ore of copper with by products of gold and silver. In fact, 80 % of worlds copper comes from this ore. It usually forms brittle, metallic, compact masses with a brassy yellow, often tarnished or iridescent color, but is also found as striated tetragonal crystals. It's streak is greenish black and commonly occurs in igneous rocks as the original constituent from which many other copper minerals have been derived by alteration. It also occurs in pegmatites, contact metamorphic zones in limestone, and sulfide ore veins. It sometimes contains gold and silver as impurities.

Crysoberyl

Crysoberyl is a beryllium aluminum oxide, which produces the gemstones alexandrite and cat's - eye. It's tabular crystals (orthorhombic system) are transparent to translucent, yellowish green to green or brown, and have a vitreous luster. Common chrysoberyl occurs as crystals or loose, rounded grains in granitic pegmatites, and in metamorphic rocks such as schist and gneiss.

Cinnabar

The only common ore of mercury is the mineral cinnabar, a mercuric sulfide, HgS. It occurs as bright-red crusts, granular masses, or earthy coatings. Cinnabar yields a scarlet streak and displays perfect cleavage in one direction. The luster is adamantine to metallic. It occurs in areas of recent volcanic activity, where it was probably precipitated from alkaline solutions in veins, hot-spring deposits, and porous volcanic rocks. It has been mined for more than 2,500 years at Almaden, Spain, which has the world's most important deposit. Used as an ornamental stone, and in vermillion paint, faceted crystal is rare @ $500 pc.

Copper

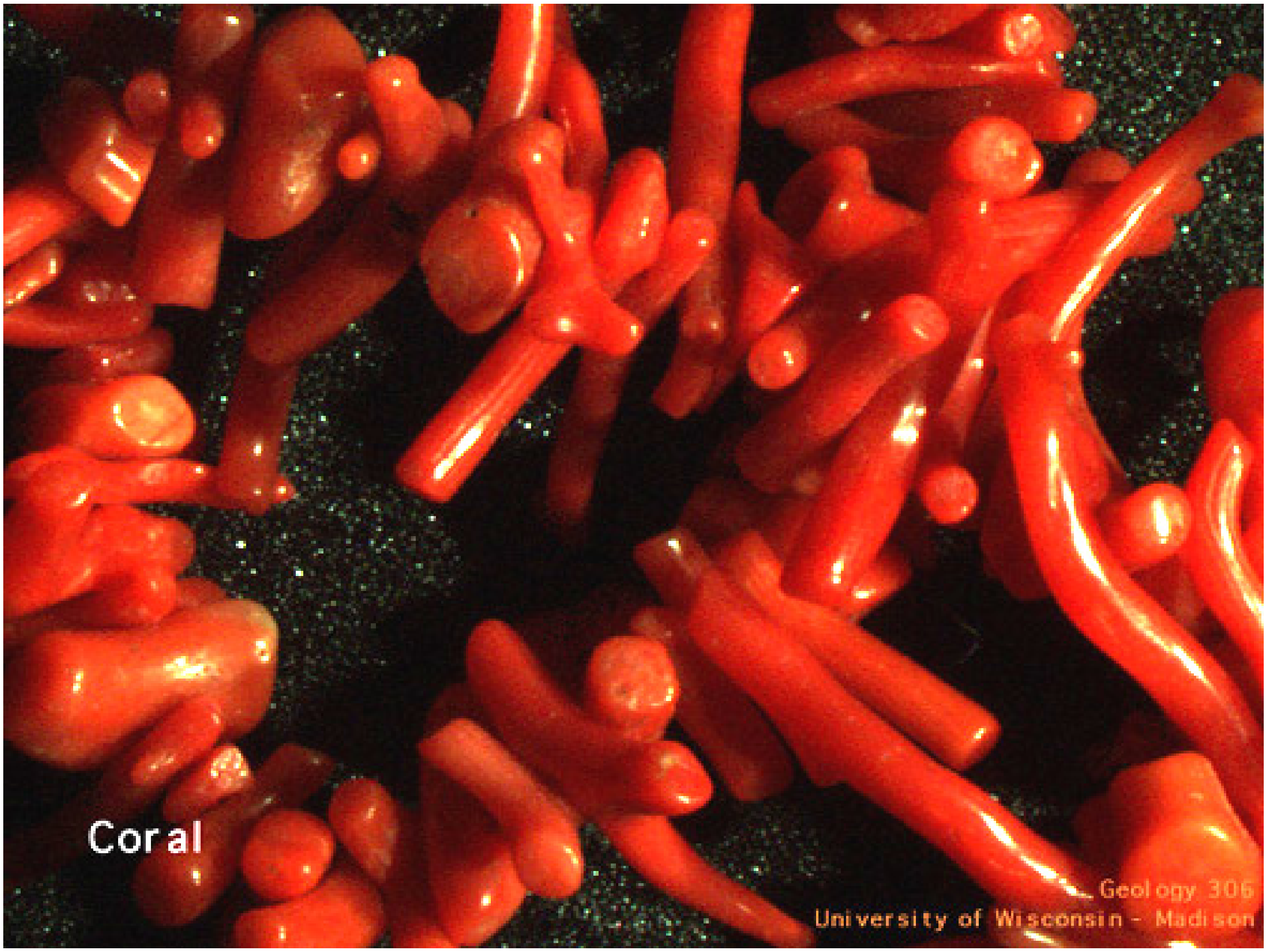
The chemical element copper is a reddish metal at the head of group IB in the periodic table. Its symbol is Cu; atomic number, 29; and atomic weight, 63.546. Copper follows the first transitional series of elements. It was the first metal used by humans and is second only to iron in its utility through the ages.

The name is derived from the Latin cuprum, "copper," from the earlier Latin Cyprium, "Cyprian metal." The discovery of the metal dates from prehistoric times, and it is estimated that copper was first used about 5000 BC or even earlier. In Roman times much of the copper was obtained from the island of Cyprus, as the name implies. Copper today is mined in many parts of the world, the largest producers at present being Chile, Peru, Poland, the United States, Zaire, and Zambia.

More than 160 minerals containing copper are known. Copper constitutes 70 parts per million of the Earth's crust and is present to the extent of 0.020-0.001 parts per million in seawater. In its native state such as that found in the Lake Superior region of North America it is often so pure that it requires only melting with a flux to produce "lake copper," which for many years was the world standard for pure copper. About 80% of all copper mined today, however, is derived from low grade ores containing 2% or less of the element. Half of the world's copper deposits are in the form of chalcopyrite ore. All important copper-bearing ores fall into two main classes: oxidized ores and sulfide ores.

Sulfide ores are more important commercially. Ores are removed either by open-pit or by underground mining. Ores containing as little as 0.4% copper can be mined profitably in open-pit mining, but underground mining is profitable only if an ore contains 0.7%-6% copper. The oxidized ores, such as cuprite and tenorite, can be reduced directly to metallic copper by heating with carbon in a furnace, but the sulfide ores, such as chalcopyrite and chalcocite, require a more complex treatment in which low-grade ores have to be enriched before smelting begins. This involves the ore-flotation process, in which the ore is crushed and powdered before it is agitated with water containing a foaming agent and an agent to make the copper bearing particles water-repellent. These particles accumulate in the froth on the surface of the flotation tank, and this froth is skimmed off and heated to about 800 deg C to remove some of the water as well as antimony, arsenic, and sulfur, which are also present. The residue is then mixed with silica and melted in a furnace at 1,400 deg 1,500 deg. C. This produces two liquid layers: a lower layer of copper matte (cuprous sulfide mixed with iron sulfide and oxides), and an upper layer of silicate slag, which is drawn off. Silica or siliceous copper ore is added to the liquid matte in a converter, and air under pressure is blown through the liquid. Upon removal of the iron slag, the copper(I) sulfide that remains is reduced to copper by heating in a controlled amount of air. The remaining molten copper, which is 98%- 99% pure, is either cast into blocks of blister copper or into anodes. The final stage of purification is mainly by electrolytic refining, which yields copper of 99.95% - 99.97% purity. The impure copper is made the anode of an electrolytic cell that contains pure strips of copper as the cathode and an electrolyte of aqueous copper (II) sulfate. During electrolysis, copper is transferred from the anode to the cathode. An anode sludge containing silver and gold is produced during this process, and this increases its economic feasibility.

Eleven isotopes of copper are known, two of which are not radioactive and occur with a natural abundance of 69.09% and 30.91%, respectively. Copper melts at 1,083.4 deg plus or minus 0.2 deg C (in a vacuum), boils at 2,567 deg C, and has a density of 8.96 at 20 deg C. The element has a hardness of 3, takes on a bright metallic luster, has a cubic crystal structure, and is malleable, ductile, and a good conductor of heat and electricity, second only to silver in electrical conductivity. Copper exhibits oxidation states of +2 (the most common, forming Cu (II) compounds), and + 1 (Cu(I), stable only in aqueous solution if part of a stable complex ion); a few compounds of copper (III) are also known. Although the electronic configuration of copper is formally similar to that of the alkali metals (Group IA) in general and potassium in particular, the behavior of copper is considerably different from that of the alkali metals. The shielding of the outer electron from the attraction of the nucleus is stronger than in copper. Thus the outer electron in copper is more tightly bound, resulting in a comparatively high first ionization potential and a relatively small ionic radius for copper. The outstanding feature of copper and the other metals of Group IB (gold and silver) is their resistance to chemical attack. Copper is slowly attacked by moist air, and its surface gradually becomes covered with the characteristic green patina that consists of basic sulfate. At about 300 deg C copper is attacked by air or oxygen, and a black coating of copper(II) oxide forms at the surface; at a temperature of 1,000 deg C copper(I) oxide is formed instead. The metal is attacked by sulfur vapor, with the formation of copper (I) sulfide; and by the halogens, which form copper (II) halides, except iodine, which forms copper (I) iodide. When copper is not attacked by water or steam, and dilute nonoxidizing acids, such as dilute hydrochloric and dilute sulfuric acids, have no effect in the absence of an oxidizing agent. The metal is attacked by boiling concentrated hydrochloric acid with the evolution of hydrogen, by hot concentrated sulfuric acid, and by dilute or concentrated nitric acid.


Coral
Geology 306
University of Wisconsin - Madison

Cordierite

The gemstone variety is called iolite or dichroite. Cordierite, or iolite, is a magnesium and iron aluminosilicate mineral of widespread occurrence. It forms short, blue prismatic crystals, embedded grains, and compact masses, and has poor cleavage in one direction in addition to a vitreous luster. Although found in some igneous rocks, cordierite most typically occurs in metamorphic rocks, such as gneiss and schist. The gemstone variety, dichroite, shows strong pleochroism -- it is colorless when viewed from one direction and violet when viewed from the other.

Corundum

Two varieties of corundum exhibit asterism: star ruby and star sapphire. The Burma ruby is bright red w/ strong dichroism with silky 6 and 12 ray stars. Thai ruby is red garnet with less dichroism and no silk. It is uniaxial negative. Sapphires show strong dichroism. Green sapphire has slightly higher SG /RI. Corundum occurs in massive amounts and used as abrasive. It is a widespread and common aluminum oxide mineral, from which the gemstones ruby and sapphire, and the abrasive material emery, are made. Common corundum, which includes all dull, opaque varieties, is usually light blue to gray, brown, or black. luster adamantine to vitreous. It forms pyramidal or barrellike crystals (hexagonal system) and granular masses. It occurs in feldspathoid bearing igneous rocks as an accessory mineral, in recrystallized limestone, in placer sands, and in aluminum-rich metamorphic rocks.

Diabase

Diabes is green to brown, and contains plagioclase, labradorite, olivine, hornblende, magnetite, limenite, apatite, calcite, pyrrhotite, chalcopyrite, serpentine, clorite, and calcite. It is a fine grained, dark colored igneous rock composed of lath shaped plagioclase (feldspar) crystals surrounded by smaller grains of pyroxene and olivine. It is equivalent to the coarser grained gabbros or diorities in chemical composition. It commonly occurs as tabular bodies (dikes and sills) intruded into surrounding rocks. Diabasic texture is best seen on a weathered surface where the feldspars stand out against the more altered mafic minerals (minerals rich in magnesium and iron). The Palisades of the Hudson River, near New York City, are an example. Diabase dikes are common in areas of crustal tension, such as the eastern coast of North America and mid ocean spreading centers.

Diamond Occurance

Diamonds occur in two general types of deposits world wide:

- volcanic pipes, also known as kimberlite pipes
- alluvial, or placer, deposits, which were formed by the erosion of diamond pipes over millions of years.

The following is not required information for students of EPS 2

The earliest productive mines were in the Golconda region of India, particularly along the Kristna River. After 1725 this mining district was gradually eclipsed in importance by the diamond deposits of Brazil. Diamonds were first mined there along the Jequitinhonha River, in the Diamantina area of the state of Minas Gerais.

In 1867 a 21-carat stone was discovered on the banks of the Orange River near Hopetown, South Africa. A great diamond rush started, and new deposits were discovered that were more productive than any the world had ever known. Another major diamond resource was developed in the 1950s in the Yakutia region of the Soviet Union. By the 1980s the Yakutia and South African regions and the country of Zaire dominated the world's diamond market. The mineral has also been found in smaller amounts in numerous other places. In the United States the leading producers include Arizona, Nevada, and Montana, although the largest gemstones have been found in an eroded volcanic pipe in Pike County, Ark.

For many years, microscopic diamonds have occasionally been noted in meteorites; they were attributed to high-speed collisions in space or with the Earth. In 1987, however, following the discovery of many more such diamonds, the theory was developed that they are the product of ancient supernova explosions of giant stars.

In recent years, diamonds have been found in unusual metamorphic rocks that were subjected to very high temperatures and pressures.

Diamond Comments

Diamond, one of the world's most important mineral resources, is made of pure, natural carbon with the atoms organized in a close-packed cubic arrangement that gives the stones their hardness. The external forms of natural diamond crystals (isometric system) shows the same symmetry. The common crystal form is the octahedron, which looks like two four- sided pyramids placed base to base. Because diamond is so much harder than any other natural or artificial substance known, it is ideal for both gem and industrial purposes. Special optical properties guarantee its preeminence among gems. First, its high refractive index (2.418) to 2.417, or light-bending ability, enables it to throw back almost all the light that enters a well cut gem. This gives rise to the gem's brilliant, or adamantine, luster. Second, it exhibits strong dispersion (0.058), or the ability to separate the various colors of the spectrum. This causes the gem to throw back the bright flashes of separated colors ("fire") for which it is particularly noted.

Fewer than 20 percent of the diamonds mined each year are suitable for use as gems. Most are sold at monthly "sights" through the Diamond Trading Company in London. At a "sight" the buyer is presented with a parcel of uncut stones to examine; the buyer must either purchase or reject the entire package without choosing among the various stones. The stones are finished in various kinds of cuts, or "make." The best proportioned ones throw back the most light. No universal standards have been adopted for " make, " but the American Standard Brilliant Cut is the closest to ideal proportions. Finished stones are graded according to quality and then marketed. Various classification systems --based on color, clarity (freedom from flaws and inclusions), cut, and carat weight--are used to determine quality and, thereby, the market value of gem diamonds.

The largest single rough diamond ever found, the Cullinan diamond, found in 1905 in South Africa, weighed 3,106 carats. Several other large stones have been found, including the Excelsior (1893), weighing 995.2 carats and also from South Africa, and the Star of Sierra Leone (1972), weighing 969.8 carats and from Sierra Leone. Several fine gems were cut from the Cullinan, including the world's largest, the Star of Africa (530.2 carats), now in the royal scepter of the British crown jewels. The Hope diamond, an infamous deep - blue diamond of 44.5 carats, most likely came originally from India. It is now in the gem collection of the Smithsonian Institution in Washington, D.C. It demonstrates the beauty of "fancy," or highly colored diamonds, which are also found in shades of yellow, pink, champagne, and other colors. Industry uses most uncut diamonds.

Diamond-studded rotary bits are used to drill oil wells and bore tunnels in solid rock. Much low - grade diamond is crushed to dust, sorted by grain size through special sieves, and used as abrasive powder. Depending on the kind of abrasion or grinding needed, the powder is either sintered into metal disks, formed in carbide grinding wheels, pressed into metal, or mixed in an oil paste. The powder is also used to cut and polish gems. Diamond -tipped glass cutters, glass etching pencils, and other similar tools find widespread use. Very thin wire is formed by pulling thick wire through a graduated series of diamonds with tiny holes drilled through them. Diamonds for industrial purposes have been synthesized since the

1950 s using high temperature, high-pressure techniques, and since the 1960 s using shock-wave techniques. (Gem- quality diamonds can also be synthesized , but the process is costly.) Technological uses for diamonds were expanded the late 1980s by the development of methods for depositing diamond coatings on surfaces. Such uses include the coating of integrated circuits as a whole instead of having to cool the components of the circuits individually. The coatings may also be used in prosthetic devices and biosensors. Can be irradiated to change or improve color.

Diorite

Diorite is a plutonic igneous rock composed of coarse grains of plagioclase feldspar and less than 40 percent hornblende (see amphibole) and biotite (see mica), or, more rarely, pyroxene or olivine. Small amounts of potassium feldspar and quartz may also occur, along with traces of magnetite, apatite, sphene, and zircon. Diorite is the plutonic equivalent of the volcanic rock andesite and is intermediate between gabbro and granite. Diorite occurs around margins of granitic batholiths, in separate plutons, and in dikes. It forms by the melting of rocks in the lower crust, by the assimilation of crustal rocks in basaltic magma, or as by metamorphic processes.

Dolomite

Dolomite is, after calcite, the second most important and abundant of the carbonate minerals. Chemically and structurally, it may be regarded as calcite with half the calcium ions replaced by magnesium. Iron or manganese may substitute for magnesium in dolomite, forming isostructural series with ankerite and kutnohorite. The crystal structure, hexagonal-rhombohedral, is similar to that of calcite, with alternate layers of calcium ions totally replaced by magnesium. This ordered arrangement of cations slightly impairs the overall symmetry of the structure but is essential to the stability of the mineral. specific gravity 2.85, luster vitreous to pearly, color ranges from colorless to white with green, brown, or pink tints, and cleavage is perfect in three directions.

Like calcite, dolomite occurs in virtually all geologic settings in igneous rocks as carbonatite, in metamorphic rocks as marble, and in hydrothermal deposits. Also like calcite, the most abundant occurrences are in sedimentary rocks; rocks composed primarily of dolomite are sometimes referred to as dolostone. Such rocks form vast deposits; in Italy, the Alpine range known as the Dolomites is almost entirely composed of dolomite. However, unlike calcite, dolomite's sedimentary origin is enigmatic. Although it is the most stable carbonate mineral where magnesium is abundant in the marine environment, it is unknown as a primary mineral. The vast, ancient deposits apparently formed from primary calcite or aragonite by diagnosis, yet this process is not observed in modern marine environments.

Dolomite is quarried for building and ornamental stone, road stone, and the production of refractory brick. It is the principal ore of magnesium metal and the source of the magnesium used by the chemical industry. It is also used as flux and in preparing mag. salts. Brazil up to 35 cts. or more @ 100.00 per ct.

Dunite

Dunite granular, green igneous rock composed of coarse grains of olivine, is the source of the world's supply of chromium. It weathers to a dun brown color, as at Mount Dun, in New Zealand, its namesake. Some dunites are rich in chromite, magnetite, ilmenite, or pyrrhotite; they may also contain a small amount of pyroxene. Dunite occurs in layered, gabbroic igneous complexes (see gabbro). It probably forms from the accumulation of dense, early crystallizing grains of olivine that sink to the bottom of low silica magma. Intrusions of dunite form sills or dikes. Some dunite has been altered to form serpentine.

Eclogite

Eclogite is a dense, green plutonic rock composed of coarse grains of green, sodium-rich pyroxene (omphacite) and pale pink, magnesium rich garnet (almandite and pyrope); kyanite and rutile are also common. Chemically, an eclogite is equivalent to basalt. It occurs as small bodies or blocks that appear to have been formed in the lowermost crust and upper mantle, where igneous and metamorphic processes merge. Most eclogites shows signs of retrogressive metamorphism, with the pyroxene and garnet crystals separated by rims of hornblende and plagioclase that have developed from the reaction between these crystals. Common minerals are: garnet, quartz, omphacite pyroxene, and sometimes kyanite, phengite, paragonite, zoisite, dolomite, and corundum.

Emerald

Not required for EPS2 students

History

- Emerald was dedicated by the ancients to the goddess Aphrodite. It is the symbol of immortality and faith.
- It is one of the most highly prized of all gems, as well as rare and valuable. Emerald, the most valuable of gems, is a transparent variety of the beryllium aluminosilicate mineral beryl that owes its bright green color to small amounts of chromic oxide. Large, flawless stones are very rare. Lacking the fire and brilliance of diamond, emerald is usually step cut, with elongated narrow facets and an oblong table, to enhance its color.
- Emeralds have been obtained from the schists of Cleopatra's mines, rediscovered in 1818, in the Sikait-Zubara region of Egypt. Vast quantities were taken from South America during the Spanish conquest, but the original mines have since been lost.
- The finest stones come from Colombia, where they are mined from the calcite veining bituminous limestone at Muzo, Cosauez, and Somondoco, Bogota; these deposits were discovered in the late 1500s. Emeralds were discovered in 1830 in mica schists near Sverdlovsk, in Russia's Ural Mountains.
- They have been produced artificially by using a process developed by Carroll F. Chatham in the 1930s. The emerald (Greek: smaragdos) of the ancients probably referred to a number of distinct species of green stones.
- Superstitions abound concerning the emerald, which is the birthstone for May: it supposedly soothes the eyes, preserves chastity ?, cures dysentery, prevents epilepsy, drives away evil spirits, and facilitates childbirth.

TITLE>Flint

Flint

Flint is the dark variety of chert that contains organic matter. It was a favored material of prehistoric humans, who used it (and chert in general) to make tools and weapons, because it would chip into sharp edges. Later, it was discovered that flint gave off a spark when struck against some hard metals and could be used to start fires. Many geologists and archaeologists suggest that the term flint be discarded or used only to identify artifacts of prehistoric humans.

It is a hard, extremely dense, dull to semiglossy sedimentary rock (microcrystalline to cryptocrystalline quartz). Chert consists predominantly of silica, with occasional impurities such as calcite, iron oxides, clay minerals, and the organic remains of marine organisms made of silica, amounting to about 10 percent. Because it is so finely crystalline, a characteristic of chert is its conchoidal fracture; thus, it breaks like glass into smooth, curved flakes. It may be white or one of various shades of gray, green, pink, red, yellow, brown, or black. Chert (Flint), occurs principally as nodules or concretions in limestone, dolomites, and chalk beds. Sometimes, however, it forms a bedded or layered deposit or a thin wedgelike discontinuous layer; such beds are commonly associated with volcanic deposition. Some are made up largely of spines and shells of silica secreted by microscopic organisms such as diatoms, radiolarians, and sponges,or of their partly dissolved and reprecipitated remains. Other cherts are of inorganic origin. Some precipitated around hot springs rich in silica, others formed when silica bearing solutions replaced wood, limestone, shale, or other materials, and some are associated with volcanic activity.

Gabbro

Gabbro is a dark colored plutonic rock composed mainly of coarse grains of calcium rich plagioclase feldspar and pyroxene. In addition, the rock may contain olivine, hornblende, biotite, garnet, rutile, apatite, zircon, magnetite, ilmenite, and chromite. Chemically and mineralogically, gabbro is equivalent to basalt. Gabbros may occur as border rocks around granitic and other plutons, or as small individual plutons or dikes. Their most common occurrence is in the lower parts of large, layered complexes. Most gabbros appear to intrude the rocks surrounding them and so are thought to be of igneous origin, although some may also be produced by metamorphic processes. It is lower in silica and darker in color than diorite, and chemically the equivalent of diabase.

TITLE>Galena

Galena

Galena, a lead sulfide, PbS, is the most important ore mineral of lead. Its metallic, lead gray cubic crystals (isometric system) and cubic, perfectly cleavable masses are distinctive and characteristic. Streak lead gray. Galena is a widespread mineral deposited by hydrothermal solutions as large, irregular masses in dolomitized limestones and in zones of contact metamorphism and as veins in volcanic rocks. It often contains enough silver to be mined as an ore.

Glass

Type	SG	RI	
colorless	2.3	1.47	borosilicate
pale blue	2.35	1.5	"
yellow	2.43	1.498	calcium
blue	2.44	1.515	fused beryl
emerald green	2.49	1.516	fused beryl
colorless	2.87	1.54	light flint
yellow	3.627	1.633	lead(flint)
ruby red	3.69	1.63	lead
jade	3.73	1.63	lead
colorless	3.74	1.635	
orange	4.12	1.68	lead
red	4.16	1.683	lead
emerald	4.25	1.70	lead
yellow	4.98	1.77	lead
refractometer glass	6.33	1.962	extra dense lead(flint)

Gneiss

Gneiss is a coarse to medium grained banded metamorphic rock formed from igneous or sedimentary rocks during regional metamorphism. Rich in feldspars and quartz, gneisses also contain mica minerals and aluminous or ferromagnesian silicates. In some gneisses thin bands of quartz feldspar minerals are separated by bands of micas; in others the mica is evenly distributed throughout. Common orthogneisses (gneisses formed from igneous rocks; those formed from sedimentary rocks are called paragneisses) are similar in composition to granite or granodiorite, and some may have originally been lava flows. Augen gneiss is a variety containing large eye shaped grains (augen) of feldspar. Injection gneisses are formed by injection of veinlets of granitic material into a schist or some other foliated rock. Banded gneisses called migmatites are composed of alternating light colored layers of granite or quartz feldspar and dark layers rich in biotite. Some migmatites were formed by injection, others by segregation of quartz and feldspars.

The origin of a gneiss can usually be determined by its chemical composition and mineral content. A distinction between gneiss and schist is difficult to draw, for many gneisses look far richer in mica than they are, when mica rich parting plane is seen.

Gold

The chemical element gold, atomic number 79, symbol Au (from the Latin aurum), is a soft, lustrous yellow, malleable metal. It is one of the transition metals and its atomic weight is 196.967; it belongs to group 1B in the periodic table along with copper and silver.

Although the Earth's crust averages a mere 0.004 grams of gold per ton, commercial concentrations of gold are found in areas distributed widely over the globe. Gold occurs in association with ores of copper and lead, in quartz veins, in the gravel of stream beds, and with pyrites (iron sulfide). Seawater contains astonishing quantities of gold, but the process of recovery is not economical. The ancients found quantities of gold in Ophir, Sheba, Uphaz, Parvaim, Arabia, India, and Spain. By the time of Christ, written reports were made of deposits in Thrace, Italy, and Anatolia. Gold is also found in Wales, in Hungary, in the Ural Mountains of Russia, and, in large quantities, in Australia. The greatest early surge in gold recovery followed the first voyage of Columbus. From 1492 to 1600, Central and South America, Mexico, and the islands of the Caribbean Sea contributed significant quantities of gold to world commerce. Colombia, Peru, Ecuador, Panama, and Hispaniola contributed 61% of the world's newfound gold during the 17th century. In the 18th century they supplied 80%. Following the discovery (1848) of gold in California, North America became the world's major supplier of the metal. From 1850 to 1875 more gold was discovered than in the previous 350 years. By 1890 the gold fields of Alaska and the Yukon edged out those in the western United States, and soon the African Transvaal exceeded even these. Today the world's unmined reserves are estimated at 1 billion troy oz (31 billion grams), about half in the Witwatersrand area of the Republic of South Africa.

The distribution of gold seems to validate the theory that gold was carried toward the Earth's surface from great depths by geologic activity, perhaps with other metals as a solid solution within molten rock. After this solid solution cooled, its gold content was spread through such a great volume of rock that large fragments were unusual; this theory explains why much of the world's gold is in small, often microscopic particles. The theory also explains why small amounts of gold are widespread in all igneous rocks; they are rarely chemically combined and seldom in quantities rich enough to be called an ore. Because of its poor chemical reactivity, gold was one of the first two or three metals (along with copper and silver) used by humans in these metals' elemental states. Because it is relatively unreactive, it was found uncombined and required no previously developed knowledge of refining. Gold was probably used in decorative arts before 9000 BC. Even civilizations that developed little or no use of other metals prized gold for its beauty.Elemental gold has a melting point of 1,063 deg C and a boiling point of 2,966 deg C.

In addition to its softness, it is both the most malleable and most ductile of all elements. This means that it can be hammered into extremely thin sheets (approaching a small number of atoms) and can be drawn into extremely fine wire. Gold in the form of very thin sheets, called gold leaf, has many decorative uses. Elemental gold is an excellent conductor of electricity and heat, surpassed only by the other members of group 1B, copper and silver. Gold usually forms compounds (and complexes) by giving up either one of three of its valence electrons. It is commonly alloyed with other metals, as in jewelry, in proportions that yield desired hardiness and colors, (see metal section). An alloy of gold, silver, and copper, in which the amounts of silver predominates, is called "green gold." An alloy of the same three elements in which copper predominates is called "red gold." An alloy of gold and nickel is called "white gold." The purity of alloyed gold is expressed by the karat system, where the percent of gold by weight is given as a fraction of 24. Therefore, pure gold is 24 karat, whereas 18 karat gold is 18/24, or 75%, gold by weight. Gold dissolves in very few solvents, among them aqua regia and the various solutions of cyanide that are used in ore extraction. When gold does dissolve, it is generally by forming complexes. Gold also forms amalgams with mercury and as such is used in dentistry.

Gold is obtained by two principal mining methods; placer and vein mining, and also as a by product of the mining of other metals. Placer mining is used when the metal is found in unconsolidated deposits of sand and gravel from which gold can be easily separated due to its high density. The sand and gravel are suspended in moving water; the much heavier metal sinks to the bottom and is separated by hand. The simplest method, called panning, is to swirl the mixture in a pan rapidly enough to carry the water and most of the gravel and sand over the edge while the gold remains on the bottom. Panning is the classic method used by the forty niners and is immortalized in story, art, and song. Much more efficient is a sluice box, a U shaped trough with a gentle slope and transverse bars firmly attached to the trough bottom. The bars, which extend from side to side, catch the heaviest particles and prevent their being washed downslope. Sand and gravel are placed in the high end, the gate to a water supply is opened, and the lighter material is washed through the sluice box and out the lower end. The materials caught behind the bars are gleaned to recover the gold. A similar arrangement catches the metal on wool, and may have been the origin of the legend of Jason's search for the golden fleece. Another variation of the placer method is called hydraulic mining. A very strong stream of water is directed at natural sand and gravel banks, causing them to be washed away. The suspended materials are treated much as if they were in a giant sluice box. Today's most important placer technique is dredging. In this method a shovel of several cubic meters capacity lifts the unconsolidated sand and gravel from its resting place and starts the placer process. Vein, or lode mining, is the most important of all gold recovery methods.

Although each ounce of gold recovered requires the processing of about 100,000 ounces of ore, there is so much gold deposited in rock veins that this method accounts for more than half of the world's total gold production today. The gold in the veins may be of microscopic particle size, in nuggets or sheets, or in gold compounds. Regardless of how it is found, the ore requires extensive extraction and refining. One third of all gold is produced as a by product of copper, lead, and zinc production. Copper, for example, must be electrolytically refined to raise its purity from 99% to more than 99.99% as required for many industrial purposes. In the refining process an anode of impure copper is electrolyzed in a bath in which the cathode is a very thin sheet of highly refined copper. As the process continues, copper ions leave the impure anode and are deposited as atoms on the cathode. Because impurities are not transported through the bath, as the anode is consumed, the impurities fall to the bottom as a sludge. This anode sludge contains gold in quantities sufficient to make recovery profitable. One third of all gold is obtained from such by products. Silver and platinum are also recovered from the copper anode sludge in quantities large enough to more than pay for the total refining process. In obtaining gold from vein ore, the ore is first crushed in rod or ball mills. This process reduces the ore to a powdery substance from which the gold can be extracted by amalgamation with mercury or by placer procedures. About 70% is recovered at this point. The remainder is dissolved in dilute solutions of sodium cyanide or calcium cyanide. The addition of metallic zinc to these solutions causes metallic gold to precipitate. This precipitate is refined by smelting. The purification is completed by electrolysis and the sludge produced will contain commercial quantities of silver, platinum, osmium, and other rare earth metals.

One of the principal uses of gold today is as a currency reserve. Gold was for centuries used directly as currency along with silver. During the 19th century it assumed a role as the sole basis of the currencies of most nations; paper money was directly convertible into gold. World War I disrupted this system. The original gold standard was gradually abandoned (the United States stopped minting gold coinage in 1934), and the dollar eventually emerged as the principal unit of international monetary transactions . Since the 1970s gold has been bought and sold on the market, with widely fluctuating prices, and gold reserves maintain only a very indirect relationship with the values of currencies. There is a large and rapidly growing demand for gold in industrial processes. Its relatively high electrical conductivity and extremely high resistance to corrosion make the metal critically important in microelectrical circuits. Minute quantities dissolved in glass or plastic sheets prevent the passage of infrared radiation and make an efficient heat shield. Because of its chemical stability, gold is in demand for bearing used in corrosive atmospheres. It is also plated on surfaces exposed to corrosive fluids or vapors. Its lack of toxicity and its compatibility with living systems make it indispensable in dentistry and medicine, and its beauty has made it outstanding in the arts and crafts since ancient times.

Granite

Granite is a light-colored plutonic rock found throughout the continental crust, most commonly in mountainous areas. It consists of coarse grains of quartz (10-50%), potassium feldspar, and sodium feldspar. These minerals make up more than 80% of the rock. Other common minerals include mica (muscovite and biotite) and hornblende (see amphibole). The chemical composition of granite is typically 70-77% silica, 11-13% alumina, 3-5% potassium oxide, 3-5% soda, 1% lime, 2-3% total iron, and less than 1% magnesia and titania. Volcanic rock of equivalent chemical composition and mineralogy is called rhyolite. Granites are the most abundant plutonic rocks of mountain belts and continental shield areas. They occur in great batholiths that may occupy thousands of square kilometers and are usually closely associated with quartz monzonite, granodiorite, diorite, and gabbro.

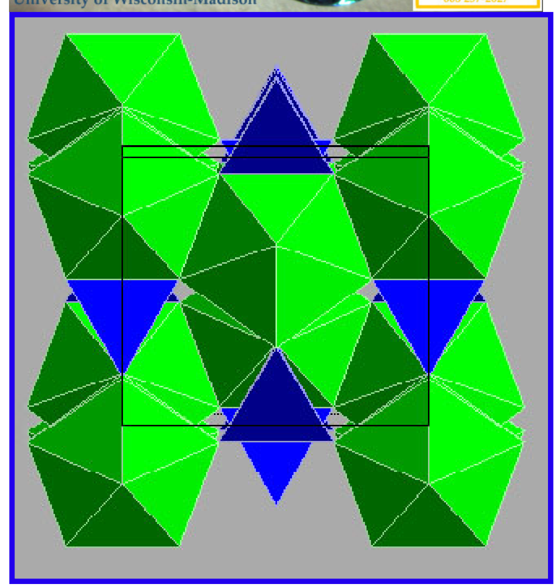
Debate has long centered on whether granite is igneous or metamorphic in origin. Originally granite was thought to form mainly from magmatic differentiation of basaltic magma, but geologists now believe there is simply too much of it for it to have formed this way, except locally. Most granite seems to have formed either by melting, partial melting, or metamorphism of deeply buried shale and sandstone. Granite dikes are clearly igneous, and granite emplaced in the upper few kilometers of the Earth's crust also often shows evidence of forceful intrusion into surrounding rocks, whereas some granites that formed deeper within the crust seem not to have been forcefully emplaced. Evidence of intrusion or great mobility is considered to indicate an igneous origin that stems from melting of sediments; but where no good evidence of either a magma chamber or of fluidity is observed, a metamorphic origin must be considered.

Granite is used as a building and ornamental stone. Many ore deposits (copper, lead, zinc, gold, and silver, for example) were produced by hydrothermal solutions created during late stages of cooling of granite bodies. These may be emplaced around the peripheries or related to fissures and fractures within bodies of granite. approx. 27% quartz + mica, amphibole, pyroxene, albite feldspar, a building stone.

Quick Links

What is zircon?
Where is it found?
Important characteristics
Treatments
Radioactivity in gems

Zircon



See a movie of the zircon structure!

Zircon

Zircon is a zirconium silicate mineral. It is the principle source of the element zirconium (Zr)

COMPOSITION	$ZrSiO4$
HARDNESS	7-7.5
CRYSTAL SYSTEM	Tetragonal
COLOR	yellow-brown/red/colorless ("Hyacinth")
FRACTURE	Conchoidal
RI	High
Dispersion	Strong
SPECIFIC GRAVITY	(High) 4.6-4.7 (Low due to radiation damage)4.0

Where is it formed and where is it found?

The mineral forms square prismatic crystals and grains in igneous and metamorphic rocks (large crystals are rarer)

- usually small and inclusion-rich
- Zircon is highly resistant to weathering (maybe the most resistant of any mineral) This, and its high specific gravity, favor its concentration in placer deposits and alluvial gem gravels.
- Gemstones have historically been recovered from many localities

Important characteristics:

- Easy to chip
- Doubly refractive with very obvious doubling of facets. A second example showing doubling of facets. High dispersion.
- Contains Uranium (U) and thorium (Th)
- undergoes radioactive decay and leads to damaged crysals ("Metamict") (appear cloudy)
- decay of U and Th occur at specific and well known rates. Measurement of isotopic abundances allows age dating of zircons ! (Thus zircons are very important minerals in the geological scheme of things.)

Treatments:

- Metamict crystals + heat (1450 C) can restore crystallinity
- Brown zircon + 800 - 1000 C in reducing environment -> colorless or blue zircon
- Brown zircon + 800 - 1000 C in air-> colorless or golden yellow zircon
- **Most colorless or blue crystals have been irradiated or heat treated!**
    - colorless : brilliant cut (colored stones

often in emerald cut) to resemble diamond: you can distinguished by double refraction (which doubles the image of the facets), and by signs of wear

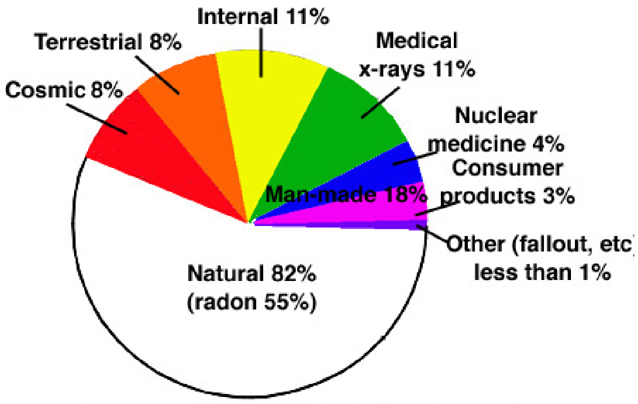
- Note: UV (sunlight) can modify the color!
- Heat treatment makes zircons more brittle, facets tend to abrade more

Radioactivity in Minerals

Detection: Geiger counter
Measurement: many scales:

- nCi = nanoCurie (billionth of a Curie)
  Curie is the radioactivity of 1 g of radium
- mrem (thousanth of a rem)
  rem = roentgen equivalent man (like a sunburn measure)
- rad = measure of absorbed dose: quantity of radiation able to deposit 100 ergs of energy)

Average dose the average American receives in one year



The average dose of radiation an average American receives in one year (360mrem/yr.).
After Sinclair, 1987.

- 360 mrem / year or 1 mrem/day
- Safety limit: 5,000 mrem to entire body per year

Gems: calculations are complex, but roughly:

Sc 46 or Ta 182 in blue topaz: ~ 25 nCi/g

Thus: for two identically sized stones:

- blue topaz (~ 25 nCi/g)
- natural zircon (1.0 nCi/g of U238)

over 10 years dose is exactly the same

Does this matter?

- the average human contains 200 nCi of K40 and eats and drinks ~ 140 nCi of K40 / year
- the 2 nCi/ g from gems is insignificant.

View some images of Zircon

Previous Lecture: Topaz

Next Lecture: Crysoberyl, Rutile and Spinel

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Jadietie

Jadeite is often confused with nephrite. It is biaxial + and natural colors fluoresce in LW. Treated material usually is inert.

Jadeite is a translucent ornamental material, and has been carved since ancient times. Jade carving has flourished in China since 2000 BC, notably during the Chou dynasty and the Ch'ien-lung era of the Ch'ing dynasties. The Chinese have ascribed many human virtues to this gem. The Han scholar Hsu Shen, for example, asserted that its bright yet warm luster typified charity; its translucency, revealing inner color and markings, represented rectitude; its pure and penetrating note when struck displayed wisdom; its ability to break but not bend exemplified courage; and its sharp edges, not intended for violence, symbolized equity. Jade ornaments and tools also have been carved by the Mesoamerican Maya and Aztec, the Maori of New Zealand,the Alaskan Eskimo, and by inhabitants of India since the 17th century.

Jade consists of two separate silicate mineral species: nephrite, and the less common but more valued jadeite. Both are monoclinic. Nephrite has a splintery fracture, vitreous or silky luster, and dark-colored inclusions. A calcium and ferromagnesian silicate, nephrite is the massive form of actinolite and tremolite (see amphibole). It forms translucent-to-opaque, mottled-green, compact aggregates composed of interwoven long, thin fibers. Nephrite occurs in rocks subjected to low-grade metamorphism. Jadeite has a granular fracture, a glassy or pearly luster, and a pitted or polished surface. A pyroxene mineral, jadeite is a sodium aluminosilicate. It occurs as transparent-to-opaque compact lenses, veins, or nodules that vary in color due to impurities: the white through emerald- or apple-green, red, blue, and brown varieties contain calcium; the dark-green to blackish varieties (chloromelanite) contain iron. Jadeite occurs in rocks once subjected to deep-seated metamorphism and subsequently uplifted and eroded.

Kaolinite

Several clays in commercial use consist largely of kaolinite, a hydrated aluminum silicate. Large deposits of this mineral occur in China; Czechoslovakia; Cornwall, England; and several states of the United States. Various grades of kaolin clays may be distinguished. White kaolin clays are fine in particle size, soft, nonabrasive, and chemically inert over a wide pH range. Their largest consumer is the paper industry, which uses them as a coating to make paper smoother, whiter, and more printable, and as a filler to enhance opacity and ink receptivity. Ball clays are usually much darker because they contain more organic carbonaceous material. These fine grained refractory bond clays have excellent plasticity and strength, and they fire to a light cream to white color. For these reasons, ball clays are used in ceramics.

Limonite

Limonite is an ore of iron, and it causes coloration in soil. The widespread and common hydrated iron oxide mineral limonite is a minor ore of iron and a source of ocher and umber pigments. Having no crystalline form and containing highly variable amounts of water, limonite forms yellowish earthy coatings or brown to blackish, stalactitic, grapelike, or fibrous masses and concretions. Hardness is 4-5.5, luster is silky or earthy, streak is yellowish brown, and specific gravity is 2.7-4.3. Much of the material formerly thought to be limonite now is known to be goethite, which is crystalline and has a definite chemical composition. Limonite, always formed from the oxidation (weathering) of other iron minerals, is common in the gossan capping of sulfide deposits, in marshes as bog iron ore, and in oolites.

Mercury

The chemical element mercury is a shiny metallic liquid. Its chemical symbol, Hg, is derived from the Greek word hydrargyrum, meaning "liquid silver," or "quick silver." Although now obsolete, the word quicksilver has long been used as a synonym for mercury. The element shares group IIB of the periodic table with zinc and cadmium. The atomic number of mercury is 80; its atomic weight is 200.59. Mercury is very heavy, weighing 13.6 times as much as an equal volume of water. Stone, iron, and even lead can float on its surface. Mercury occurs in only trace amounts in igneous rocks; sedimentary rocks are slightly richer.

The element constitutes only 0.5 ppm of the earth's crust, making it scarcer than uranium but more plentiful than gold or silver. Mercury is found principally in the form of the ore cinnabar (mercury sulfide) and can also be found in the uncombined state. The preparation of mercury from its ores is fairly simple. The ore is ground up and heated to about 580 deg C in the presence of oxygen. Mercury vapor escapes from the ores and sulfur dioxide is removed. The metal is condensed and purified by washing with nitric acid, followed by distillation.

Mercury was among the first metals known, and its compounds have been used throughout history. Archaeologists found mercury in an Egyptian tomb dating from 1500 BC. The Egyptians and the Chinese may have been using cinnabar as a red pigment for centuries before the birth of Christ. In many civilizations mercury was used to placate or chase away evil spirits. The alchemists thought that mercury, which they associated with the planet Mercury, had mystical properties and used it in their attempts to transmute base metals into gold. The Greeks knew of mercury and used it as a medicine. Mercury and mercury compounds were used from about the 15th century to the mid 20th century to cure syphilis. Because mercury is extremely toxic and its curative effect is unproven, other syphilis medicines are now used. The usefulness of mercury is limited by its poisonous nature and scarcity.

Mercury is used in electrical switches; these consist of a small tube with two contacts at one end. If the tube is held in such a way that the mercury collects at this end, then contact is made and the circuit is completed. If the tube is tilted, contact is broken. Mercury switches are used in thermostats and some doze alarm type alarm clocks. Mercury is highly suitable for use in thermometers because it does not moisten glass and its thermal expansion is uniform. Although many liquids could be used in pressure measuring devices, mercury is used because its high density requires less space. Mercury will dissolve numerous metals to form amalgams and is thus used to extract gold dust from rocks by dissolving the gold and then boiling off the mercury. The amalgam used in dental fillings contains tin and silver (and sometimes gold) dissolved in mercury. Mercury vapor lamps are widely used because they are powerful and economical sources of ultraviolet and visible light.

Mercury is also used in a number of industrial applications, such as fluid bearing and fluid clutches that require a heavy liquid. Mercury is a fairly unreactive metal and is highly resistant to corrosion. When heated to near its boiling point (346.72 deg C/675 deg F), mercury oxidizes in air, and mercuric oxide is formed. At 500 deg C, mercuric oxide decomposes into mercury and oxygen, a phenomenon that led to the discovery of oxygen by Joseph Priestley and Karl Scheele. Mercuric oxide is a constituent of mercury batteries, which have been invaluable as compact, efficient power sources in exploration of outer space. The most useful mercury salts are the two mercury chlorides and mercury sulfide. Mercurous chloride, or calomel, is a white, relatively insoluble salt. It is used in calomel electrodes, which are commonly used in electrochemistry, and in medicine as a cathartic and diuretic. When calomel is used as a teething powder for young children, it can poison them. Mercuric chloride, or corrosive sublimate, is highly poisonous because it is so soluble. It was used for deliberate poisonings as early as the 14th century. It is now used as a disinfectant, in preparing other mercury compounds, and in antifungal skin ointments.

Mercuric sulfide occurs in a red form and an amorphous black form. The red form (vermilion) is used as a coloring material. Cinnabar is sometimes used to color tattoos red, but it causes significant skin irritations and obstructions of the lymphatic system. Mercuric fulminate is an explosive that is sensitive to impact and is used in percussion caps for munitions. Mercurochrome is an organic mercury compound that is used on wounds as an antibacterial agent. There are two types of mercury poisoning, acute and chronic. Acute mercury poisoning results from the ingestion of soluble mercury salts, which violently corrode skin and mucous membranes. Although cases have occurred in which persons have ingested elemental mercury without suffering permanent damage, mercury vapor aspirated into the lungs can cause severe pneumonia and death. Chronic mercury poisoning occurs through the regular absorption of small amounts of mercury. This condition is often a disease of workers in mercury mines, laboratories, and industries that use mercury. The most toxic mercury compounds are those that are fat soluble, because this property assists in their distribution throughout the body. Methyl mercury compounds, such as dimethyl mercury, are among the most dangerous. Mercury salts released into the environment may frequently be converted by anaerobic bacteria into such compounds, which can then be carried through the food chain to humans as in the disaster at Minamata Bay, Japan Other micro organisms can convert methyl mercury compounds into the insoluble, and therefore harmless, mercury sulfide.

Mica

Mica is a generic name for a group of complex hydrous potassium-aluminum silicate minerals that differ somewhat in chemical composition; examples are biotite, lepidolite, muscovite, phlogopite, and vermiculite. Mica has a low coefficient of expansion, high dielectric strength, good electrical resistivity, a uniform dielectric constant, and capacitance stability; at one time it was the best electrical and thermal insulator known. The iron content determines the color. Muscovite is generally gray, green, or brown; biotite, brown or black; lepidolite, pink or green; phlogopite, light brown to yellow; and vermiculite, brown. Muscovite has the greatest commercial value and is the mica that is ground and pulverized into pigment grades. Muscovite crystals develop in booklike form with a well-developed basal cleavage that allows splitting the large books into extremely thin sheets or grinding the flakes into thin leaves to produce dry ground mica. These leaves have a diameter-to-thickness ratio of more than 25 to 1--a ratio higher than that of any other flaky mineral.

Large crystals or books of mica--ranging from less than 2 cm (0.8 in) up to 2 m (6.6 ft) in length--are generally found in granitic pegmatites, which are light-colored, coarsely crystalline, igneous rocks. Variation of size within an individual deposit is not uncommon. Deposits of mineral materials containing some form of mica exist throughout the world. The largest resources of muscovite are in Brazil, Western Africa, and the Madras and Bihar areas of India. The Malagasy Republic is the major world source of phlogopite mica. Mica was first mined in the United States in New Hampshire. After about 1870 production of mica began on a large scale in North Carolina, which now produces more dry and wet ground mica than does any other state, and the United States is the dominant world source of muscovite scrap and flake micas. Small dry ground mica flakes are used as a thin coating on rubber surfaces to overcome tackiness and sticking. In exterior house paints dry ground mica adds body, reduces running and sagging, and improves weatherability. The addition of mica to all types of sealers for porous surfaces (such as wallboard, masonry, and concrete blocks) greatly reduces penetration and improves holdout. The inclusion of mica in road and highway paints improves wearability, gives good adhesion, and reduces flaking and cracking. Micas are also used in caulking compounds,lubricants, greases,welding rodcoatings, and dry-powder fire extinguishers. Wet ground mica is produced by grinding mica flakes in water until they are reduced to fine scales. Wet ground mica costs more than twice as much as dry ground mica and is used predominantly in paint and rubber, as well as in plastics and lubricants. Wet ground mica is also used to coat wallpaper, because it imparts an attractive silky or pearly luster.

Obsidian

Obsidian, a volcanic glass, usually of rhyolitic composition, forms by rapid cooling of a viscous lava. Most obsidians are more than 70 percent silica and are low in volatile contents. Microscopic crystals of quartz or feldspar are sometimes included in the glass. Obsidian occurs as thick, short flows or domes over volcanic vents. It is usually black in color but occasionally red or brown (if iron-oxide dust is present), clear, or green. Obsidian displays a well developed conchoidal fracture, which makes it an excellent material for arrowheads, knives, and other sharp tools and weapons. Archaeologists use obsidian tools to trace trade routes, because such tools are relatively rare and each occurrence has a slightly different chemical composition. Thus the source of primitive obsidian tools may be located even if the tools have been traded across thousands of kilometers.

Obsidian has also been used as a semiprecious gem because of its shiny luster. Perlite, a hydrous form of obsidian, is used as a lightweight aggregate. When heated it expands into an artificial pumice like material. Its potential expansion after transport is a major shipping advantage. The rounded nodules of obsidian left after hydration and alteration of surrounding material into perlite are known as Apache tears. Looking like black teardrops, they are collector's items in the American Southwest. Now used in rock wool.

Platinum

Platinum is a silvery metallic chemical element, a member of the six transition elements in Group VIII of the periodic table known collectively as the platinum metals (ruthenium, rhodium, palladium, osmium, iridium, and platinum). Platinum has the symbol Pt, its atomic number is 78, and its atomic weight is 195.09. The name is derived from the Spanish platina, meaning "silver."

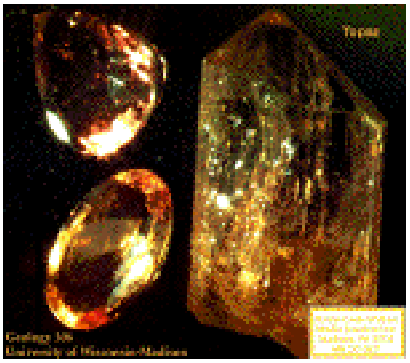
Platinum was discovered in South America independently by Antonio de Ulloa in 1735 and by N. Wood in 1741, but it had been in use by pre-Columbian Indians. The platinum metals are extremely rare elements; platinum itself is the most common, with an abundance in the Earth's crust of about a millionth of 1 percent, whereas the others of the group have abundances of about one ten millionth of 1 percent. Platinum occurs in nature as the pure metal and also in alloys with other metals of the group, principally in the alluvial deposits of the Ural Mountains, of Columbia, and of some parts of the western United States. In addition the element occurs in the mineral sperrylite and in the nickel bearing deposits of Ontario in Canada.

The large scale production of nickel makes it feasible to recover the small amounts of platinum (only 1 part of platinum to 2 million parts of ore). The recovery of the individual platinum metals from the natural alloys is a complex process that depends upon the distinct properties of the individual elements, even though all members of the group are generally similar in their chemical behavior and are quite unreactive. For example, when the natural alloy of platinum, palladium, osmium, and rhodium is digested with aqua regia, the palladium and platinum dissolve and are extracted as a solution of chloropalladic acid and chloroplatinic acid. Platinum is then precipitated from this solution as ammonium chloroplatinate.

Platinum is an attractive silvery white metal with a melting point of 1,774 deg C, a boiling point of 3,827 deg C and a density of 21.45 g/cu cm at room temperature. It has a coefficient of thermal expansion close to that of soda lime silica glass and is consequently used to make sealed electrodes in soft glass systems. The predominant oxidation states of platinum are +2 and +4. Platinum is chemically inert and will not oxidize in air at any temperature. It is resistant to acids and is not attacked by any single mineral acid but dissolves readily in aqua regia. The metal is rapidly attacked by fused alkali oxides and by peroxides and will react with fluorine and, at red heat, with chlorine. On heating, platinum combines directly with elemental phosphorus, silicon, lead, arsenic, antimony, sulfur, and selenium, a fact that influences the use of platinum laboratory equipment. In keeping with the other members of the platinum group, the metal shows a fairly strong tendency to form complex ions. The most common Pt(I) complexes have square planar structures and are diamagnetic.

Because of its inertness and attractive appearance, one of the major uses of platinum is in the manufacture of jewelry. Gold platinum alloys, referred to as white gold, are widely used in dentistry and in the making of jewelry. Platinum and its alloys are used in the manufacture of crucibles and evaporating dishes for chemical analyses. Other applications include the formation of thermocouple wires, electrical contacts, corrosion resistant apparatus, and the manufacture of platinum resistance thermometers used in the temperature control of furnaces. The alloy, consisting of 76.7% platinum and 23.3% cobalt by weight, forms an extremely powerful magnet. More recent applications of the metal involve the coating of missile cones and jet engine fuel nozzles. Along with palladium, the metal absorbs large volumes of hydrogen, retaining it at ordinary temperatures but desorbing it at red heat. The fact that the absorbed hydrogen is extremely reactive suggests that it is present either as atomic hydrogen or as a very reactive platinum hydrogen compound or complex. In finely divided form platinum is an excellent catalyst; about half of the annual production of the metal serves this purpose, most of it in the petrochemical industry. It is also used as a catalyst in the contact process for the manufacture of sulfuric acid from sulfur dioxide and oxygen. There is much current interest in the application of the metal as a catalyst in fuel cells and in catalytic converters as antipollution devices for automobiles. In the latter instance a suitable form of platinum will catalyze the oxidation of carbon monoxide to carbon dioxide and will convert nitric oxide to nitrogen and water. Fine platinum wire glows when placed in methyl alcohol vapor, where it acts as a catalyst, converting the alcohol to formaldehyde. This effect is used commercially to produce cigarette lighters and hand warmers. The price of platinum has varied widely relative to the price of gold. Although it is slightly more valuable today, it was once used as a gold adulterant.

Topaz



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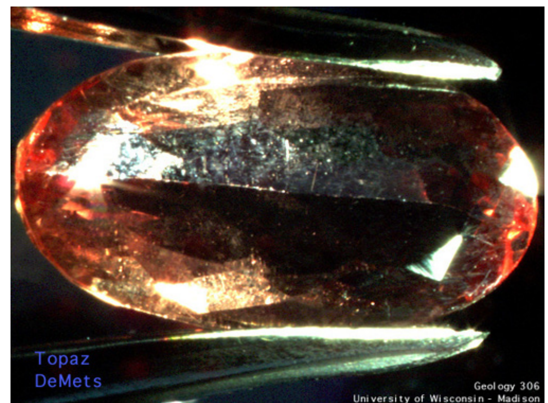
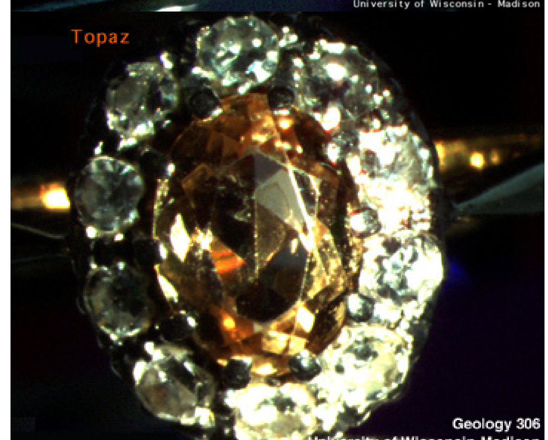




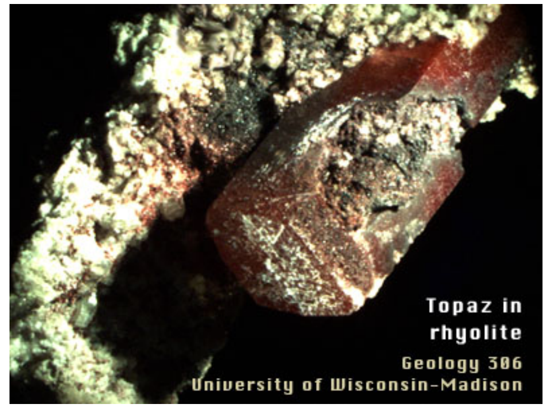
Topaz

COMPOSITION	Al2SiO4(F,OH)2
HARDNESS	8
CRYSTAL SYSTEM	ORTHORHOMBIC
COLOR	Various (see below)
PLEOCHROISM	Light yellow or pink
CLEAVAGE	Basal
HABIT	Prismatic
SPECIFIC GRAVITY	3.53

How are topaz crystals cut?

- crystals: up to 100 lbs in weight !
- world's largest facetable gem (22,982 ct)
- appearance: vitreous (glassy luster)
- color:
  - reddish-yellow ("imperial")
  - orange-brown ("sherry")
  - clear
  - blue
  - pinkish
  - natural and treated blue (see below)

Geologic conditions of formation:



Topaz crystallizes from fluorine-bearing vapor in last stages of solidification of igneous rocks. Thus, cavities in lavas and granitic rocks:

- in pegmatites
- in alluvial deposits

Secondary concentrations of topaz occur in stream beds and other alluvial deposits.

Geographic location:

- Brazil: Ouro Preto and Minas Gerais
- Siberia and the Ural Mnts.
- Pakistan (esp. pink topaz)
- Sri Lanka (esp. irradiated topaz)

Treatments:

Irradiation and Heat Treatment

Topaz is the most common irradiated gem on the market. Particles, or electromagnetic rays (ionizing radiation), have enough energy to produce color centers. High energy particles include:

- electrons
- alpha particles
- beta particles
- gamma particles: Co-60 Gamma Cell
- neutrons

Details:

- alpha particles = high speed helium (He) atoms with no electrons
- beta particles = high speed electrons
- gamma rays = high energy photons of

electromagnetic radiation (similar to x-rays, but shorter wavelenght and thus, more energetic)

- neutrons = neutral subatomic particles

- Irradiation is most often carried out in Linear accelerators (high energy electrons) and Nuclear reactors (high energy neutrons)
- residual radioactivity potentially a problem. Stone may have to be stored to allow radioactivity to decay (half life may be hours to days)
- Nuclear reactors create an intense blue (that does not need secondary heat treatment)
- gamma rays => brownish greenish color + HEAT (see below) -> steel grey/blue ("cobalt")

marketing names: "sky", "london", "swiss" , "super", "cobalt", "max", etc.

Some examples:

- very light blue
- light blue
- medium blue
- medium-dark blue
- deep blue

Irradiation is used to change the color of many gems!

Examples of color manipulation:

Heat only:

orange brown Cr-bearing topaz + HEAT (450 C) and cool -> pink-purple (termed 'pinking')

Why ?

- color = sum of: Cr -> pink and a color center -> yellow-brown
- recall, a color center is often an electron trapped in an atomic site, a form of structural damage often caused by

radiation
- Heat allows crystal to heal itself and release electron from trap, removing brownish tinge (leaving pink)

Heat after irradiation:

topaz irradiation -> greenish brown color (= blue + yellow + reddish tinge)

each of the components of the color is due to a color center. Least stable are the yellow and reddish; controlled heating removes these, leaving blue color centers.

Who cares?

Treatment is controversial because:

- Ready availability of artificial material could swamp out naturally colored material, reducing its value.
- Irradiation can not be detected.
- The color may not be stable; it may change over time.
- safety concerns (rarely a problem)

How much radiation is associated with gemstones?

How does this source compare with the major sources of radiation exposure to a human being? Continued next lecture!

Specially for students:

Further explanation of the key concepts

View a collection of topaz images

Previous Lecture: Beryl

Next Lecture: Zircon

Other Tools

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Pyrite

The iron sulfide mineral pyrite has been called fool's gold because of its pale, brass yellow color and glistening metallic luster. It is the most widespread and abundant sulfide mineral in rocks of all ages. The cubic, dodecahedral, and octahedral crystals and the fine grain masses may be distinguished from gold by their higher Mohs hardness of 6 to 6.5 and their lower specific gravity of 4.9 to 5.02; pyrite has a greenish black streak, conducts electricity, and generates a weak electric current when heated. Its darker colored isometric crystals distinguish pyrite from the chemically identical marcasite, which has orthorhombic crystals. Pyrite forms large bodies in moderate to high temperature hydrothermal deposits and in contact metamorphic ore deposits, is an accessory in many igneous rocks, and is common in sedimentary beds and metamorphosed sediments. It is mined as a source of sulfur and iron as well as of the impurities gold and copper. Pyrite is readily oxidized to create sulfuric acid, both commercially and naturally; in the latter case it helps form the enriched zone of ore deposits, especially of copper; oxidation also creates limonite, which forms the gossan, or iron capping, or sulfide deposits.

Quartz Subtypes

Rock crystal (colorless); Smoky Quartz (brown to brown, gray); Amethyst (violet, reddish to purple); Citrine (yellow to gold brown); Prasiolite (green); Rose Quartz (pink); Adventurine(green,gold brown, iridescent) Prase (green); Blue Quartz / Siderite (blue); Cat's Eye (white, gray, green, yellow); Hawk's Eye (white, gray,green yellow); Tiger Eye (gold-yellow, goldbrown); Chalcedony (all colors, may be dyed) Agate, Jasper, quartzite (metamorphism of sandstone)

Although coarsely crystalline quartz occurs in colorless or white (milky) masses, colored varieties are numerous and popular. AMETHYST (violet); smoky quartz; cairngorm, or morion (black); citrine (yellow); and rose quartz are common and arise by the incorporation of a tiny fraction of elements that substitute for silicon atoms, such as iron, aluminum, manganese, and titanium. The entry of such elements requires the concomitant entry of small atoms such as hydrogen, lithium, or sodium to preserve charge balance. Inclusions of other minerals, in some instances oriented, can occur throughout quartz crystals. The included minerals can be RUTILE (sagenite or rutilated quartz); fibrous amphiboles (CAT'S-EYE is grayish green; TIGER'S-EYE is yellow brown; hawk's-eye is blue); and platy minerals, such as mica, iron oxides, or chlorite (aventurine). Very fine grained and cryptocrystalline varieties of quartz are numerous. Collectively called chalcedonic quartz, these varieties form slowly from evaporating or cooling solutions as crusts and fillings of veins and open spaces. When color banding is conspicuous, the variety is called AGATE. Agate with numerous flat bands of white, black, or dark brown is called ONYX. Translucent red or brown chalcedonic quartz colored by iron oxides; green varieties colored by chlorite, amphiboles, or nickel minerals; and mottled moss agates are used as semiprecious stones. BLOODSTONE is a green variety of chalcedonic quartz with red spots. Chalcedonic quartz is often colored by chemical processes. Finely crystallized quartz called CHERT AND FLINT occurs within calcareous or silty sedimentary rock as gray or black layers or nodules. JASPER is very fine-grained quartz with abundant incorporated iron oxides, it may be red, brown, yellow, dark gray, or black.

Salt

Common salt, sodium chloride, occurs naturally in pure, solid form as the mineral halite and in widely distributed deposits of rock, or mineral, salts. It makes up almost 80 percent of the total dissolved solids in ocean water and even greater amounts in inland saltwater lakes and seas. Biologically, blood is a saline solution. The sodium component of salt operates in regulating osmotic pressures in the body and helps prevent excessive water loss. The sodium and chloride components also play a major role in the transmission of impulses in nerves.

Salt is used in greater quantities and for more applications than any other mineral. It is the primary source of sodium and chlorine, and other chemicals are produced directly from salt, including sodium hydroxide (NaOH) and hydrochloric acid (HCl). As a chemical, salt is used in the production of textile dyes, soap, glass, and pottery and to preserve leather hides. When mixed with crushed ice it acts as a refrigerant, and, spread on icy streets, it melts the ice. Table salt has been valuable for centuries in seasoning food and preserving it either by pickling or by salting down meats. Today .01 percent potassium iodine is often added to table salt (iodized) in order to supplement iodine intake in diets and thereby to prevent the disorder goiter. Excess salt intake can cause fluid retention (edema) and contribute to the circulatory disorder hypertension. Salt is produced commercially by rock-salt mining; by solar evaporation; or by solution mining, the tapping of brine wells. In rock-salt mining a vertical shaft is sunk down in a salt dome or an underground salt stratum. Parallel galleries are blasted out, leaving pillar supports for the rock salt overhead. Once hoisted to the surface the rock salt is crushed into several commercial sizes, ranging from 19-mm (3/4-in) chunks to fine powder.

Samarium

Samarium is a chemical element, a very hard, silvery white metal of the lanthanide series in Group IIIB on the periodic table. Its symbol is Sm; its atomic number, 62; and its atomic weight, 150.4 (average weight of its seven natural isotopes). Three natural samarium isotopes are radioactive. Samarium was discovered in 1879 by Lecoq de Boisbaudran, who isolated it from samarskite. The metal ignites in air at 150 deg C (302 deg F). Because one of its isotopes has a high cross section of neutron absorption, samarium is used in the control rods of nuclear reactors. An alloy of samarium with cobalt is used to make a magnetic material with the highest resistance to demagnetization of any known material.

Schist

Schist is a type of metamorphic rock in which lamellar minerals, such as muscovite, biotite, and chlorite, or prismatic minerals, such as hornblende and tremolite, are oriented parallel to a secondary platy or laminated structure termed the schistosity. The mineral grains in many examples are large enough to be recognized in hand specimens. Schist breaks easily into thin layers parallel to the schistosity. Schists are commonly rich in quartz and contain some feldspars and carbonates. The specific mineral composition of a schist is indicated by placing the name or names of significant subordinate minerals in front of the word schist; commonly occurring types include biotite schist, muscovite-chlorite schist, garnet-mica schist, staurolite kyanite schist, and hornblende schist. A general composition or texture of the schist can be indicated by prefixing; examples include calc-silicate schist and spotted schist. The mineral assemblages and textures of the schist change with the temperature and pressure of recrystallization. With increasing metamorphism, the grain size usually increases and, depending on appropriate chemical availability, minerals such as chloritoid, garnet, staurolite, cordierite, andalusite, and kyanite crystallize as large crystals (called porphyroblasts) in a foliated micaceous matrix. Many porphyroblasts contain inclusions, indicating that they crystallized by replacement of some other mineral or rock.

Silver

Silver, atomic number 47, is a coinage metal with properties closely resembling copper and gold, with which it is grouped (1B) in the periodic table. Its symbol (Ag) is derived from the Latin argentum, meaning "white and shining," Because silver is easily reduced to pure metal from its ores by relatively low heat, and because it is occasionally found free in nature, it probably became the third metal (after gold and copper) that ancient civilizations learned to use. It was well known earlier than 4000 BC.

Silver is the 68th most abundant element in the Earth's crust and 65th in cosmic abundance. It is found in small quantities in many locations on Earth. Large amounts of the metal have been mined in both North and South America, which together produce over half the world total. Its mostly important ores are sulfides, of which argentite (silver sulfide, Ag2S) is the most common. Silver often occurs as a minor constituent in the ores of copper, lead, and zinc. Refinement of these metals yields large quantities of silver (and some gold). Silver is found in minute quantities in seawater.

The atomic weight of silver is 107.868, and natural silver consists of two stable isotopes: silver-107 (51.82%) and silver-109 (48.18%). The melting point of the metal is 960.8 deg. C and it boils at 2,210 deg. C. Next to gold, silver is the most malleable and ductile metal known. It is harder than gold but softer than copper. This softness limits its use, even for coinage, unless it is alloyed with about 10% copper. When alloyed with 7.5% copper, it is known as sterling silver. As a pure element it can absorb oxygen in the amount of 20 times its own volume at its melting point. It is the best conductor of heat and electricity of any of the metals.

Although silver dissolves readily in nitric acid, it resists such acids as hydrochloric, sulfuric, acetic, citric, lactic, phosphoric, oxalic, and benzoic. It will also dissolve in solutions of sodium or potassium cyanide, but not in sodium or potassium hydroxide solutions or fused salts. It does not normally oxidize in air, but it does react with sulfides and with the hydrogen sulfide found in the atmosphere of many industrial cities, forming a black film of silver sulfide. Major producers of silver in order of their production are Mexico, Peru, the USSR, Canada, Australia, and the United States.

Uranium

The actinide elements are the 14 chemical elements that follow actinium in Group IIIB of the periodic table. Because of some chemical similarities, actinium is usually included in the series. All of the actinides are radioactive, because their nuclei are so large that they are unstable and release great amounts of energy when they undergo spontaneous fission. Most of the actinides are not found in nature but are artificially produced in the laboratory.

Two of the actinides found in nature have isotopes with such a long half - life that they have not completely decayed since the Earth was formed. One isotope of thorium, Th-232, has a half - life of 14 billion years and has an abundance of 12 parts per million in the Earth's crust. It is a principal constituent of some minerals, notably thorite and monazite (a mixed rare-earth and thorium phosphate). Three isotopes of uranium are found in nature. Their isotopic abundances and half-lives are U-234, 0.006%, 230,000 years; U-235, 0.72%, 696 million years; and U-238, 99.27%, 4.51 billion years. Some laboratory produced isotopes of uranium also have long halflives. The overall abundance of uranium in the Earth's crust is about 4 parts per million, and it is concentrated in many minerals, principally pitchblende, autunite, torbernite , and carnotite.

Deposits of uranium minerals large enough to be profitably mined are found principally in parts of Africa and in Canada, the Soviet Union, and the southwestern United States. Actinium and protactinium, as well as some isotopes of thorium and uranium, are found in nature as decay products of Th-232, U-235, or U - 238. All of the heavier actinide elements, the transuranium elements, as well as some isotopes of the lighter actinides, have been synthesized since 1940. Small amounts of neptunium-239 and plutonium-239 have been found in uranium ores; they are produced by the absorption of neutrons generated by the spontaneous fission of U238. Discovery of Actinide Series. Many chemists at first considered actinium to be chemically similar to lanthanum, thorium to hafnium, protactinium to tantalum, and uranium to tungsten. Neils Bohr suggested in 1923, however, that actinium might begin a series of elements similar to the series of rare earth elements and filling the 5f subshell, parallel to the lanthanide series, which fills the 4f subshell.

In 1944 Glenn Seaborg and co-workers hypothesized that the elements following uranium would indeed parallel the lanthanides. These predictions were correct, and many of the actinides are in fact chemically similar to the lanthanides-- for example, the chemistry of curium is much like that of gadolinium. All of the actinide elements are shiny, hard metals that tarnish in air and are so electropositive that they are difficult to reduce from their compounds. Oxides have been prepared for all the elements through einsteinium the elements thorium through berkelium have stable dioxides. Thorium, uranium, and plutonium dioxides are used in nuclear reactors. Because U-235 and Pu-239 undergo nuclear fission when they absorb neutrons, they are used in nuclear reactors and in nuclear weapons. The actinide elements are among the most prevalent of radioactive waste products from nuclear reactors. Many compounds of the actinide elements have been studied,often using only a few micrograms because of the elements' scarcity and intense radioactivity.

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