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Multicolored tourmaline crystal specimen with rosettes of cleavlandite. Transparent top sections are gem quality. Recently recovered from the Himalaya Tourmaline Mine, Mesa Grande, San Diego County, California.

GIA Photo

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Historical Himalaya Tourmaline Mine Resumes Production

By

JEANNE G. M. MARTIN, G.G.

Introduction

The recent activity at the Himalaya Tourmaline Mine, Mesa Grande, California, is reminiscent of the early part of the century, when approximately $1,500,000 worth of tourmaline and smaller amounts of other gem minerals were produced between the years of 1902 and 1912 by the gem mines in Southern California, with a total production valued at more than $2,000,000. As many as 70 prospects and mines were being worked at one time during this period. Although the Himalaya Mine was inactive and considered depleted for 44 years, it is now evident that vast stores of tourmaline, both gem quality and specimen material, were being held in the reserves of the dikes on Gem Hill, quiescently awaiting discovery by some undaunted searcher of this gem mineral.

The tourmaline production of the Mesa Grande district, where intensive mining was confined to a period between 1900 and 1910, was by far the most productive of the tourmaline-bearing areas of California; it has been estimated at "nearly one-quarter of a million pounds valued at $800,000, with a smaller output of quartz, beryl and other gem minerals valued at $14,000."[1] The Himalaya Tourmaline Mine, with an output that probably totaled 150,000 to 200,000 pounds of gem tourmaline and several hundred pounds of gem beryl, has been the most productive of the gem mines in this area.

Much of this production was exported to China, where it was used extensively for carving; the share of the Himalaya Mining Company's lapidary in New York was approximately six tons. About 300 to 400 pounds was composed of fine nodules and pencil-shaped crystals of the very highest quality. It was fortunate for the mine owners that the development of these deposits came at a time of high tourmaline prices, which were brought about primarily by its popularity in China; pink (*shan*) tourmaline was greatly, almost superstitiously, prized by the

Entrance to the Himalaya Tourmaline Mine, Mesa Grande, San Diego County, California, as it appeared in 1915.

Courtesy U.S. Geological Survey

Chinese. However, the fall of the last Chinese dynasty (the Republican Revolution in 1912) caused the market to decline and the resulting drop in prices necessitated the closing of the mines, thus ending the profitable gem mining in this area. Most of the readily detected and easily worked gem deposits had been well exploited by 1914, and the additional work and expense involved in further exploratory work in the gem-bearing pegmatites was prohibitive in the view of a dropping market.

It has been reported that the miners working in the Himalaya Mine dropped their tools and walked out of the mine when they received reports of what the future held for them, leaving recently recovered crystals of tourmaline on the floor of the drift.

Since the tourmaline had been mined essentially for two outlets (i.e., China, which wanted only massive pink material for carving, and the Himalaya Mining Company of New York, which desired only gem-quality material for their New York lapidary), a vast quantity of the product was relegated to the dumps on the hillside.

The dumps at the Himalaya Mine were a mecca for the rockhound fraternity of California and the Southwest for many years. Eventually, the mine was sold and free access to this collector's paradise was curtailed in 1952. By this time, good material in the dumps was getting increasingly hard to find, and only the diligent searcher was fortunate in recovering any worthwhile tourmaline. There is, of course, no record of the amount of gem material removed in those years between the closing of the mine and the present mining activity, although many of the mineral cabinets of fortunate collectors attest to the richness of the dumps during the early rockhound era. Therefore, although this removal of gem material has been almost wholly confined to the mine dumps, another,

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1. *The Gem Deposits of Southern California*, by Richard H. Jahns, Engineering and Science Monthly, Volume XI, No. 2, 1948.

but smaller, undisclosed fraction has been added to the overall production of these rich mines.

It has been reported that the Himalaya Mine was opened on several occasions since it was shut down in 1914, but with generally poor rewards.

The small amount of tourmaline marketed during World War II came from the Pala district.

Himalaya Mine

The historical mining property is situated on Gem Hill in the eastern half of Section 17 (T. 11S., R. 2E., S.B.M.) at an altitude of 3800 feet. It is about 4½ miles northwest of the Mesa Grande store and on the watershed between the San Luis Rey River and Mesa Grande Creek. The zone of pegmatite dikes that runs through the diorite hills in the northeastern part of the county from Mesa Grande northwestward through Pala traverses the mining property on Gem Hill.

When the mining activity ceased in 1914, the buildings consisted of a dwelling house, a barn, tool houses, a blacksmith shop, and a windmill that furnished piped water to all of the buildings. Herbert Hill, one of the miners who had been employed by the Himalaya Mining Company since 1904, was retained as caretaker for the mining property and continued to live on the premises in this capacity until his death in 1954. The buildings had deteriorated due to weathering and lack of proper upkeep. The windmill was no more, and the only available water supply for the caretaker was a spring that disappeared during the very dry season. The primitive road was rutted and often became impassable. In general, the property was in a very dilapidated condition.

Mine Changes Hands

The 120-acre property, with existing buildings, was purchased by Ralph R. Potter, La Mesa, California, in 1952. The transaction was executed through an agent of the former owner, Helen Quin Kong, San Francisco, California (an heir to the property). Although the property was listed at $20,000, the actual purchase price was never divulged. In 1951, however, there was a rumor to the effect that the property could have been purchased for the small sum of $12,000.

Shortly after acquisition of the property, Mr. Potter began making improvements, grading and filling the narrow rutted road and putting the remaining buildings in a livable condition. Exploratory work at the mine was also begun about this time. Mr. Potter's mining experience was limited to coal mining and some gold mining in the State of Colorado, so this was his first attempt at gem mining. Several drifts were driven toward the gem-bearing ledge in the pegmatite dike, but without any worthwhile rewards.

In 1956, a jet plane crashed on one of the wooded hills nearby, setting fire to the surrounding acreage. The pilot barely escaped with his life, by outrunning the terrible blaze being fanned in his direction by a strong wind. However, the surrounding tree- and brush-covered acreage was not so fortunate. The fire burned for several days and resulted in the destruction of many valuable acres of standing timber. Most of the buildings on the Himalaya Mining property were gutted; only the building now being used as a bunkhouse escaped serious damage. Many of the beautiful 300-year-old oaks and pines that covered the gently sloping hillsides were victims of the catastrophic fire, which came within yards of the store at Mesa Grande. Undaunted, even after the ravages of fire had been added to his unsuccessful mining experiences, Mr. Potter resumed his exploratory work. After approximately 750 feet of drifts had been driven, and with only a small amount of tourmaline being recovered, Potter, in July, 1957, decided to drive a tunnel from a more advantageous direction, aiming at the dike at an angle that he hoped would strike the old tunnel near the point where work was progressing at the

The owner of the Himalaya Tourmaline Mine, Ralph R. Potter, La Mesa, California.
GIA Photo

A view of surrounding terrain as seen from the entrance to the Himalaya Mine, Mesa Grande, California.
Courtesy Elbert McMacken

Present-day entrance to the Himalaya Tourmaline Mine, Mesa Grande, California
GIA Photo

time the mine ceased operations in 1914. This latest and most successful tunnel extended about 550 feet into the dike area. This is one of the deepest penetrations made in any of the mines in the area.

The 550 feet of the newly constructed tunnel had to be timbered and, in addition, the timbers in the section of the old tunnel had to be replaced. Although a few of the timbers in the old tunnel were still in fair condition, some sections showed signs of deterioration; therefore, the entire length of the tunnel was reinforced with square sets, the timber of which was supplied from the remaining timber standing on the wooded slopes of Gem Hill. Since many dormant springs were reactivated by the heavy rains experienced by Southern California early in 1958, the tunnels are extremely damp and slippery as the result of seepage from the claylike soils of the terrain. Small mine cars on narrow rails carry the debris from the tunnels and stopes. Much of the old-time equipment has been restored and is now in use in the present mining operations.

Recent Production

The ledge, which is about 36 inches in the widest part but usually averages 18 to 24 inches in width, dips at from 26 degrees to 33 degrees southwest. Many small pockets of tourmaline have been opened during this last penetration into the ledge. Several have been productive of large crystals of multicolored or bicolored tourmaline, many with both terminations intact. Approximately 2½% to 3% of the material recovered is of gem quality. To date, no pockets of comparable size to those found in the heydey of the mine have been uncovered. (One pocket found during the early part of the century was said to have produced six tons of tourmaline!) The recovered tourmalines are of various colors, consisting principally of green, rubellite (red) and yellow (a beautiful golden color is apparent when a yellow crystal is viewed parallel to the C axis). At least 50% of the specimens are blue-green, pink or red. So far, 25% of the production has consisted of complete doubly terminated crystals. The largest one produced to date is 7½ inches long and 1½ inches in diameter, with a small ¾-inch pink-and-white crystal protruding from the side; the smaller crystal has the necessary inclusions for producing a cat's-eye tourmaline. The main crystal, which has both positive and negative terminations, is green, pink and yellow and has one pink tip.

Associated minerals found are quartz, morganite (beryl), albite, cleavlandite, lepidolite, muscovite, apatite, allanite (radioactive), microcline and stibiotantalite.[2]

A Tourmaline Pocket

The careful opening of gem pockets is the key to successful pegmatite mining. Since it is mentioned only casually in the discussions on the mining operations of this material, it may be of interest to readers who have never witnessed it to have a first-hand account of this aspect of gem mining.

In May of this year, the author was accorded the rare privilege of watching the opening of a tourmaline pocket at the Himalaya Mine. The author and Robert Crowningshield, Director of the New York Laboratory, met Mr. and Mrs. Potter at their home in La Mesa, California. After a 65-mile drive, we encountered the three-mile primitive road that winds into the hills at a point a few miles beyond the Mesa Grande store. This narrow, winding road, although reconditioned in 1952, shortly after the acquisition of the property by the Potters, had become deeply rutted and extremely hazardous for late-model cars. We were warned upon reaching the mine entrance of the slickness of the tunnel floor, which was the result of seepage from the surrounding spring-filled, claylike soil. Mr. and Mrs. Potter led the way into the drift. The light was provided by two carbide lamps. As we approached the point where the most recent tunnel reached the original one, the owner informed us that at least one of the rumors concerning the cesation of mining activity when the market dropped was true: the tools and lanterns of the early-day miners were found when the old part of the tunnel was broken into; also, specimens that had been mined more than 44 years ago were lying in profusion on the tunnel floor, just as the report claimed.

Farther along, we sighted an opening that

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[2] Dr. George F. Kunz, in his Bulletin #37, 1905, states that a mineral in the form of dark transparent crystals, with a specific gravity of about 10.00 and a hardness of 5½, had been found in the Himalaya Mine but had not been identified. He stated that only a few specimens had been encountered. It was later (1909) identified as stibiotantalite ($SbTaO_4$).

A pocket of tourmaline as it appears in the ledge. Crystals are barely visible. Ruler gives comparative size of pocket.
Courtesy Elbert McMacken

led up a steep, dark incline to the left. This, we were informed, was the stope that would enable us to reach a pocket located at the top of the incline. The stope at this point followed along the ledge, and at places it was necessary to crawl in order to negotiate the low and narrow opening. Finally, we reached a part of the stope that flared out into an oval; it was still too low to stand upright, but it was nevertheless somewhat larger than the section from which we had just emerged. Along one side of the oval opening, and about two feet farther along, the character of the ledge changed abruptly to a very coarsely crystalline texture — large crystals of feldspar mixed with plates of mica heralded the zone where the pocket of tourmaline had been discovered. The crystallization of the rock encompassing the cavity has barely discernible in the low light, so the coarsely crystalline area stood out in relief. The cavity was about 14 inches from the floor of the oval enclosure that terminated the tunnel. The lights were turned on the cavity as soon as the remainder of the group had reached the oval and found footholds in the slanting floor.

Anyone who had anticipated seeing a gleaming display of crystals would have been disillusioned, since all of the crystals were covered with a sticky, brownish-pink decomposed feldspar — the clay mineral montmorillonite. The roof of the elongated pocket was lined with crystals of quartz and solid growths of cleavlandite (a form of albite), with small "books" of muscovite (mica) on blocks of feldspar. Unattached crystals of tourmaline embedded in the clay lay in profusion on the floor and sides of the pocket; others were attached to the walls. The contours of a few crystals were visible, but only at the extreme front edge of the pocket; most of them were well concealed by the clay. The afternoon was spent in removing crystals from the pocket. Each crystal had to be freed carefully from the montmorillonite,

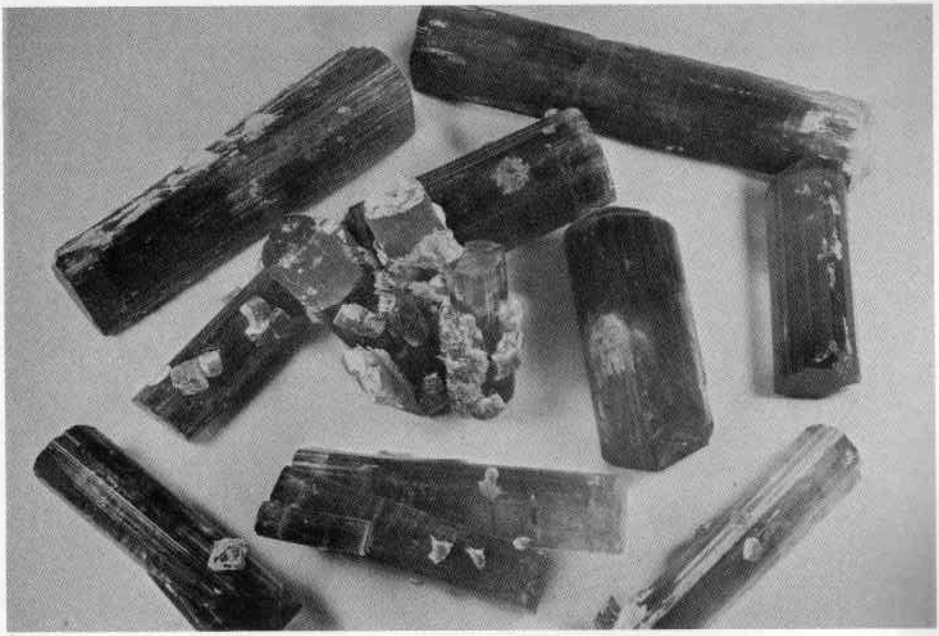
Close-up view of the pocket pictured on page 168. Top center shows a quartz crystal protruding from the ceiling of the pocket. Tourmaline crystals are covered with sticky claylike pocket material.
Courtesy Elbert McMacken

which was reminiscent of modeling clay. The clay was kneaded to locate any small crystals, then the remainder was placed in a sack kept for that purpose. This material was later taken outside, where, with access to water and sufficient light, it was screened for any elusive tourmaline and associated minerals.

Many of the crystals appeared to be held securely in place, but, to our consternation, upon trying to remove some of the coating in order to obtain a more desirable photograph of the tourmaline pocket, they became dislodged easily. Since there was a possibility that the crystals might roll down the stope and be lost, this attempt to clean them off in place was discontinued. Although the crystals appeared to be intact, they frequently came out in separate pieces. The fracturing is thought to have been caused by disturbances in the earth, rather than by the concussion of blasting operations. In many instances, crystals had been broken and later healed by natural processes. Some bore the imprints where other crystals had grown in contact with them. One crystal encountered had been bent and fractured and then healed by later solutions. The accompanying photographs of the pocket do not show the individual crystals clearly because they are covered with clay. The majority of the crystals removed were bicolored and doubly terminated. Some were largely of gem quality, but most of the others had at least small areas of gem quality. The photographs represent only the largest crystals that were removed from this pocket, since the remaining material had not been washed and screened at the time the photographs were taken.

We were informed that the pocket from which we removed the crystals was just one of a series that had been discovered in recent mining activities. A few of the pockets were large, but the vast majority were small.

Since the hand drilling for the dynamite charges had been done with great care, and



A group of bicolored terminated tourmaline crystals removed from the pocket. Largest of these is about seven inches. Cleavlandite forms rosettes on the crystals. ***GIA Photo***

since the crystals were cushioned by the clay, few had been fractured by blasting.

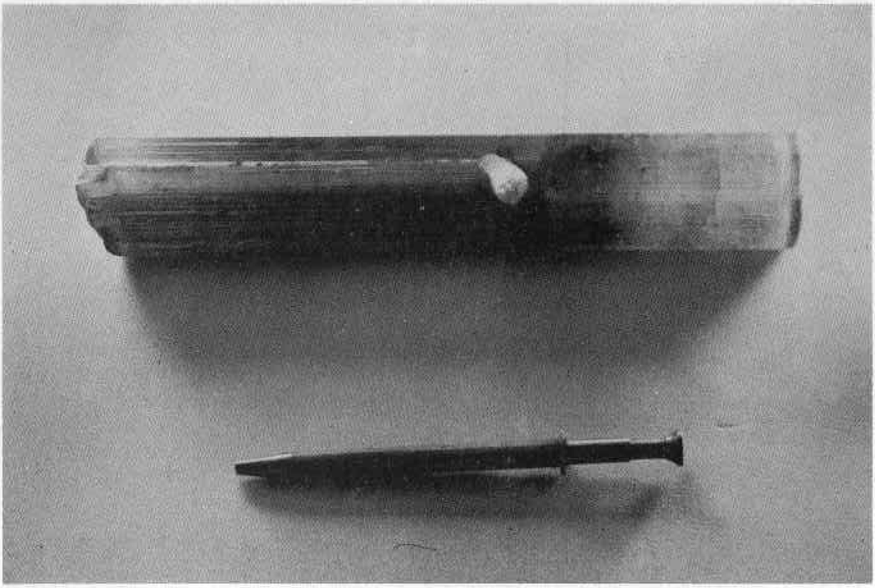
Marketing of the Himalaya Tourmaline

At the present time, only specimen material and smaller gem-quality crystals are being marketed. This material is being handled by various gem and mineral dealers in the Southwest. High-quality material retails for approximately $2 per carat. Specimen crystals (collector's items) are sold from a few dollars to hundreds of dollars, depending on the perfection, the number of associated minerals, and their sizes, clarity and color. Because so many are bicolored and doubly terminated, there has been great demand for them among collectors. The finest tourmaline from this mine is considered to be the most desirable in the world; the green specimens make particularly beautiful faceted stones. The strong dichroism that characterizes most green Brazilian tourmaline and the tendency toward opacity in the direction of the C axis is absent in the green Himalaya material, thus resulting in a more attractive color.

At the present time, it is not known if this latest mining activity will in any way compete with that of the earlier era, when it was not unusual to find pockets having a capacity of several tons, according to some of the stories of early-day mining.

Early History

The fact that some of the highly colored crystals were found in graves of the Indians in the Mesa Grande vicinity suggests that tourmaline was known and valued by the Indians for a very long period. It has been said that the Indians succeeded in crude mining, enabling them to reach the hidden cavities; however, they may have recovered tourmaline from pockets in outcrops or as float. But it was not until 1898 that this famous locality was made known to the world.



This 7½-inch tourmaline crystal, doubly terminated and multicolored, is just one of the many outstanding specimens recovered since the reopening of the Himalaya Tourmaline Mine, Mesa Grande, California. It is further described in the text. ***GIA Photo***

There have been many stories about the Indians and their knowledge of the tourmaline deposits. One of the most popular accounts of the first discovery in San Diego County tells how Indian children found an oddly shaped crystal about three inches long and a little thicker than a common lead pencil near the Mesa Grande postoffice. According to the story, the crystal was cleaned and then rubbed with a piece of hide, revealing it to be a beautiful blue color, very shiny and partially clear. The natives, although having no conception of its true nature, were attracted by its beauty. Subsequently, other brightly colored stones of the same appearance were found by the Indians and cowboys in the same vicinity. No one realized at that time that they were valuable.

However, the first recorded discovery of colored gem tourmaline in the State of California goes back to June, 1872, when Henry Hamilton recognized this mineral on the southeast slope of Thomas Mountain in Riverside County. He traced the float to an eroded pegmatite dike, which was later developed by the Thomas Mountain Mine. Subsequently, other occurrences of tourmaline were mined in this area. In the course of a few years, three localities in the vicinity were located and prospected. Although some mining was accomplished at this time, few fine gems were recovered. Evidently, these discoveries were not made public for several years, for no mention was made in mineralogical survey reports at that time. However, Dr. George F. Kunz issued a statement in one of his reports to the effect that he had in his possession a fine specimen of tourmaline that had been obtained prior to 1873 from the above-mentioned deposit.[3]

The next significant discovery, 20 years later (1892), was made by Mr. C. R. Orcutt, near Pala. (In the Pala area about 18

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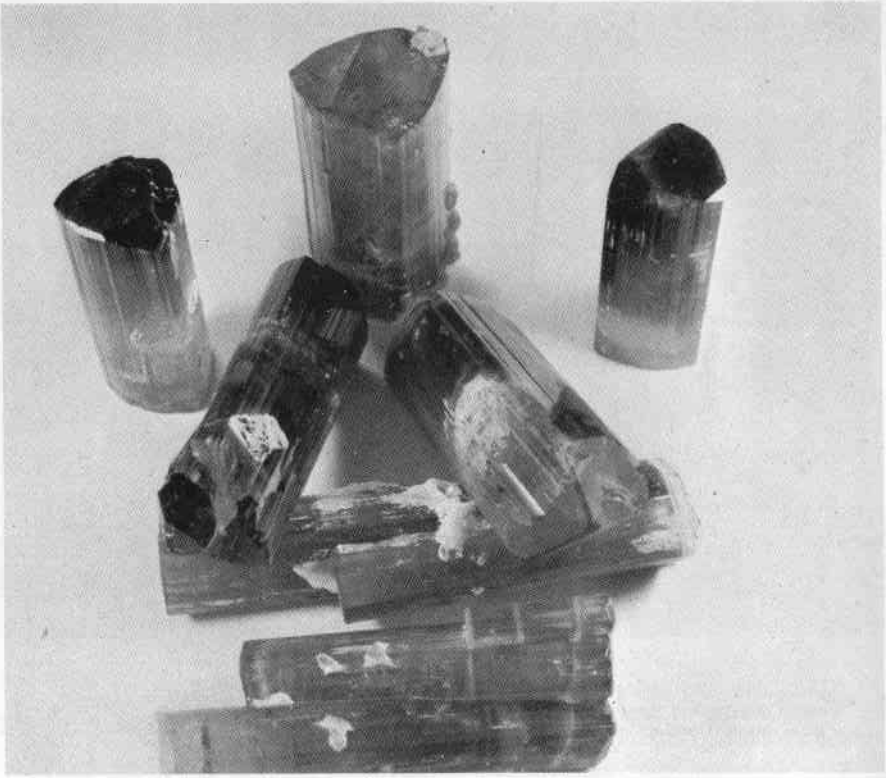
[3] *Gems, Jewelers' Materials, and Ornamental Stones of California*, issued by the California State Mining Bureau in 1905 as Bulletin 37.



Another group of the tourmaline crystals showing terminations. *GIA Photo*

tons of tourmaline was mined during 1892.) Other discoveries in the Pala vicinity followed but were overshadowed when the rich tourmaline deposits at Mesa Grande were discovered.

The greatest discovery of all was made in 1898, when the source of the tourmaline crystals that had been displayed by the Indians was located. It was found on a high wooded slope, called Gem Hill, south of the San Luis Rey River and about 11 miles south of Palomar Mountain. This is the ridge on which the world-famous Himalaya Mine is located — the greatest producer of gem tourmaline in North America.

The value of the locality was made known by Mr. C. R. Orcutt, who opened it and for a time worked it; afterwards, it was operated by Dr. A. E. Heighway. This led to later development by the Himalaya Company, New York.

For several years, these above-mentioned mines were the only tourmaline mines in this region. But in 1902, a number of new deposits were found and worked.[4]

Pegmatites of Southern California

The most productive and most extensively developed of the gem-bearing pegmatites in California are exposed in a 25-mile belt that lies within San Diego County and embraces three pegmatite districts; one at Pala, at the northwestern end of the belt, another at Rin-

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[4] *Recent Gem Mining at Pala, San Diego County, California*, by Captain John Sinkankas, U.S.N., which appeared in the Fall, 1957, issue of GEMS & GEMOLOGY, gives recent information concerning this area.

con, near the center of the belt, and a third at Mesa Grande, at the southeastern end.

All of the gem-bearing pegmatites of Southern California are located in the province of the so-called Peninsular Ranges, a series of ridges and mountains that extend southward from the edge of the Los Angeles Basin. This region is underlain mainly by plutonic igneous rocks of the Southern California batholith and pre-batholith metamorphic rocks. This great mass separates the Salton-Imperial depression on the east from the coastal areas on the west, and also forms the "backbone" of much of Baja California. It is characterized by medium- to coarse-grained igneous rocks that have a wide range in composition.

The gem materials and associated minerals occur in pegmatite, a granitic rock characterized by extreme coarseness of grain. The pegmatite is usually encountered in dikes. In Southern California these range in thickness from less than an inch to 100 feet or more. In most of the zones the pegmatite is surrounded by other, less coarse-grained, igneous rocks of more basic composition. The majority of the dikes trend north to north-northeast and dip westerly at gentle to moderate angles. Although many of them are shorter, some reach 1000 to 4000 feet in length. Many of the pegmatite masses are very regular in thickness and attitude and most of them contain little or no gem material. The percentage of tourmaline in a dike evidently bears no relationship to the average thickness of the dike. For instance, the dike at the Himalaya Mine at Mesa Grande averages only about four feet in thickness, whereas many larger dikes have yielded no gem material.

The upper part of the typical complex dike is composed of graphic granite, whereas its lower part contains a finer-grained quartz-feldspar (aplitic) rock. Much of this finer-grained rock shows a distinct banding known as "line rock," which is caused by thin layers rich in minute grains of garnet or black tourmaline and albite feldspars.

In the central parts, or cores, of some dikes, commonly along or near contacts between line rock and overlying graphic granite, is the so-called pocket zone. Ordinarily, this is an irregular series of tabular or pod-like masses that are rich in quartz. Associated with the quartz are albite, microcline and orthoclase feldspars, muscovite and lepidolite micas, tourmaline of various colors, beryl, and a number of rare minerals. This is popularly known as "pocket pegmatite," because the crystals are found in spaces filled with soft matter rather than hard rock. Pink to brownish-pink clay is regarded by miners and prospectors as a very favorable indication of gem material in the Mesa Grande area.

Most of the gem tourmaline occurs in prisms that are pencil-like in size and shape, but individual crystals as much as four feet long and six inches in diameter have been mined.

Future of the Himalaya Mine

The vast potential of the Himalaya Mine has been emphasized by the recurrence of mining activity, its recent substantial production and the large areas of the dike as yet unexplored. Although "bonanza-type" operations may not be in store for the future of this historical mine, it will nevertheless be interesting to follow the trend of revived mining operations and to see what inducement, if any, it may provide for the reactivation of other of these famous early-century mines of San Diego County.

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Clarity

By

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The purpose of this paper is to present a suggestion that may possibly develop into a better method of describing quality in diamonds, or at least a better way of *thinking* about quality.

The present-day thinking by many members of the trade and the public in general is in terms of imperfection—certainly a negative view, to say the least.

In recent years, through a greater knowledge of value, many jewelers have discontinued the use of the word semiprecious when describing other than the so-called precious stones. Many people accept the suggestion implied by the prefix *semi* to mean that a stone has less value than one that is called precious. A satisfactory solution to this was the adoption of the word *gemstone.* The term is all inclusive; it suggests a superior quality of stone that possesses the factors that are necessary in order for the stone to be valuable.

In describing diamonds, some of us use the word *flawless* to identify the finest grade. This has been done because, through abuse, the meaning of the word *perfect* has become more and more vague. The use of numbers and letters to describe color and clarity is common with many firms. In this there is no accepted standard, since one firm may use the letter A to mean the same grade that another firm describes as AA. These symbols are sometimes confusing to the trade, even more so to the layman. It is often intended that they should be.

Knowing that repeated attempts have been made to standardize grading, without much success, it is not my intention here to criticize these systems. They are at least a step away from the older terms of Wesselton and River, which no longer have a definite meaning.

When speaking of diamonds, *clarity* is one of the most important words in our vocabulary; even more important is its use in our thinking. For example, the average American has a fairly clear picture in his mind of an ordinary yardstick. Some of us can visualize one hundred of these units in terms of a track for a foot race. Most of us are familiar with the inch and the foot; we can visualize the yard being divided into these units. As we get farther away from the common yardstick and its most common subdivisions, fewer and fewer of us have a clear picture of linear measure. The same is true for weights and other forms of measurements. It is even more true in measuring wealth.

What is wealth? An economist has one definition, but to most of us it is synonymous with luxuries that most people cannot afford or do not have. Someone has said that this country of ours is without peer in the world and that our economic strength is unique in the entire history of mankind. No other nation has ever accumulated such wealth; no people have ever enjoyed such standards of living. Just what did he mean by "economic strength," "wealth" and "standards of living?" Of course, he was making comparisons. He was comparing our country, our people and our way of life with what he had seen in other parts of the world. He was also comparing our circumstances with those of past generations and past civilizations.

The object of this introduction to my subject is to point out the fact that there are several factors that affect the viewpoint we take in evaluating a diamond. Certainly, the wealth of our country is one of these factors. Who can say which Americans may or may not own a diamond? Surely, many more Americans own diamonds today that at any other time in history.

Is this because of our wealth? Yes, partly. Mode? Certainly that, too, is important. Mode may even be the more important factor.

There was a time when the owning of jewels was limited to a very select few, but today in this country many millions of women and men own and wear diamonds and other jewels. Certainly, there is no better way to express a feeling of well being.

It is true that jewelry does not satisfy the three most basic necessities of life, but there is a quality in jewelry that canot be found in food, shelter or clothing. The very fact that jewels are not necessities ideally qualifies them as gifts. And gifts of this nature express a feeling of sentiment on the part of the giver much better than gifts of necessities.

When two young people walk into a jewelry store and pick out an engagement ring, they are following a well-established custom, motivated by one of the greatest forces on earth: love. To get a clear view of this picture we must stand off a few feet, or a few generations. How does the conduct of this young couple compare with that of one or two or even a hundred generations ago? We know that their grandparents seldom had such beautiful diamonds from which to choose. Very likely they did not even buy a diamond at all, just a plain gold band. However, there was just as much sentiment in the purchase of this ring. The pattern of behavior has changed very little.

The symbol of an engagement in America today is a diamond ring. This custom did not come about by accident; it was planned and engineered. We in the jewelry trade have all contributed to the furthering of this custom. In other parts of the world and in other generations, a diamond-set ring never attained the popularity that it enjoys today.

What, then, is our wealth? Merely something that can be shaped into convenient-size gold discs or anything else that is tangible? Not in the case of our young couple. They can see the beautiful picture of their future. Castles in the air? Possibly. But the chances of their achieving success are greater than at any other time in the history of the world. They may not be able to explain in cold logical terms the wealth they possess, but there are physical evidences of wealth that back up this kind of thinking: a way of life, conveniences and the privilege of enjoying beauty. The latter may include a diamond.

This is applied ambition. The young man may have a job in a service station. He will earn the money to make the payments on the diamond. He may not know the relationship between the carbon in a car muffler and the diamond he is buying, or he may know just that. He may become a great scientist. In our time, in our country, these are the possibilities. Probably this is one of the forms of wealth to which our economist referred.

Nor does the jeweler need to feel defeated because there is a car payment that has to be taken into consideration along with the purchase of the diamond. Our young friends are planning big things for their future, and the car and the diamond are both included in their plans. Why, then, should these young people be confused by having this beautiful symbol of their happiness described in terms that are out of tune with this most special occasion?

Possibly the jeweler is thinking about his competitor's advertisement. So he begins by talking about size, perfection and price. Instead of calling attention to the enduring beauty of this rare gem that he is showing them, he all too often starts by talking in terms of flaws and imperfections. This is not only a case of poor salesmanship but it is a case of nation-wide *negative thinking.* Too many of us are guilty of using the language of the other fellow.

Someone has said that "We are most vulnerable when we fight with an enemy's weapons only."

Our prospective customers may have just come from a competitor's store, or they may have merely heard about the different prices of diamonds. One thing is certain; they are planning to symbolize the most important event in their lives. We can do no less than "tune ourselves in" to the spirit of this occasion.

Last summer, while taking a trip in southern Utah, my wife and I were eating breakfast in a cafe in Green River. The uranium boom was at its peak. The waitress, who could have been the wife of one of the prospective millionaires, placed a small paper table cover in front of each of us. In each corner of the cover was a typical western picture. The border consisted of cattle brands. These brands caught my attention. Each was designed as a distinctive identification. What relationship could there be between a cattle brand and a diamond? Each has its own identifying characteristics. The cattle man proudly displays his brand on his stationery, his home, his car—anywhere it can be used to identify him. With diamonds it is probably a little different. However, each diamond has some identifying characteristic. In the trade we recognize this and use it on our side of the counter, but we apologize for it over the counter. Our predecessors in this business set up certain methods of describing standards that are today antiquated and impractical. Still many of us continue to use these "measuring sticks," realizing, as we use them, that they are inaccurate and uncomplimentary.

It seems to me that the expression *clarity* grading rather than *imperfection* grading is more desirable. But what is most important is the *timing* when we mention this to the customer. We should not wait until he asks "Is this a perfect stone?" Right then we are obligated to talk *his* language. We are showing him a good diamond, a beautiful stone. Although it has a tiny identification mark near the edge (possibly we need not elaborate beyond that), at least we have given the inclusion something other than an uncomplimentary name. Certainly this does not classify the stone as a cull from the apple barrel. It is true these inclusions do affect the value, but where is our measuring stick? We are not grading perishable fruit, discarding all that do not measure up to a standard called "perfect."

Can we in the jewelry trade change our thinking about quality in diamonds—not necessarily our opinion of grades, but the words we use to express quality? Many firms have adopted the "four C's" as a guide, or ruler, but clarity is still graded in terms of perfection and imperfection. Let us place more emphasis on clarity and omit the reference to imperfections and flaws. Let us assume the attitude that all diamonds, other than industrial stones, are graded for clarity, not perfection, flawlessness, imperfection or other negative terms. Let us remove from our vocabulary, as far as diamonds are concerned, the words perfect, flawless, imperfect and flawed.

The idea has been advanced many times, but the whole-hearted acceptance is like diverting a stream from its course. The tendency is to return to the "old way."

When the word flawless was substituted for the word perfect, it was a step in the right direction. The opposite, however, was still a negative term: flawed. And we had no other way to describe all the diamonds that did not qualify in the flawless grade. So we are right back where we started.

I do not propose here to set a pattern of ethics, although much can be said in favor of improving that. My object is to think in terms of grading diamonds without having to resort to the use of terms that have a negative suggestion, no matter how minutely they may apply to a stone in question.

What I am doing is eliminating from my sales vocabulary and my thinking negative terms such as the word "imperfect" when referring to the quality of diamonds.

Since writing my first lesson in gemology I have gradually developed more confidence in my ability to discuss gems over the counter, before an audience, and with other people in the trade. I have learned to avoid being too technical when the customer's best interest is to be considered. That was not easy, but it was a valuable lesson. As a retailer, whose time is spent behind the counter more than at a desk, my knowledge of gemology has had an increasing influence on my selling. The caution I try to exercise in this connection is best brought into focus when I recall two experiences in which sales were not made. One was that of a refrigerator sales manager years ago. He had just completed a talk to his crew of salesman on stressing the *benefits* to be derived from mechanical refrigeration, not the mechanical functions of the machine. At the conclusion of the sales meeting a customer walked into the store and said he was an engineer and wanted to know what made the machine work. The sales manager seated the customer before a compressor and spent the next hour explaining the mechanism in detail. As the customer arose to leave he thanked the man and said, "I'll let you know when I decide to buy." He was back in fifteen minutes and said, "I agreed to let you know. I bought a "——" refrigerator. It has no fans, belts, or drain pipes." Another point here was the fact that the successful salesman had actually capitalized on a deficiency: he did not apologize for the ungainly appearance of his product, but *bragged* about it and *sold* more refrigerators.

The other experience was my own. A young couple came into our store and asked to see "a diamond." Without first finding out that what they had in mind was a ring of a definite style with a diamond in it, I attempted to determine what grade of stone they might consider. I was so sure that a display of three pairs of stones, in different grades that I had recently purchased, all in the same style of mountings, would get my answer that I failed to see that I did not have their interest. As they started to leave, one said, "These ain't the style we want," and there was nothing I could do to find out what they did want.

With these two pictures clear in my memory, I can see the importance of selling a person what he WANTS, NOT what he SAYS he wants. In diamonds this means, first of all, beauty; and it cannot be stressed by starting out with a negative or an apologetic approach. The engineer said he wanted to know what made the refrigerator work, but he bought one that had all the mechanism "sealed in, free of mechanical difficulty."

The young couple had a certain style of mounting in mind, probably one the young lady had seen on another girl's hand. Any colorless stone in the right mounting would have been more interesting to them right then than the finest gem in any other mounting.

Recognizing the value of a favorable first reaction, a large national sales organization has a policy of three grades for all their products: good, better, best. Many of us in the jewelry business begin with "best" or "perfect," but we then go to "not quite so good" then "worse still."

In some instances, the "best" grade is sold by this kind of comparison. In other cases, the customer will justify himself with the thought that "the cheaper grade is all I can afford" or "this is a bigger *show* for the money."

I believe that it is not necessary to apologize for any diamond. If it is good enough for me to buy, then there should be no reason why it is not at least a GOOD diamond, even a *pique.* Of course, they are not the best, but they are *real* and they are good.

One of the most common questions a jeweler is asked by a prospective diamond customer is "Is this a perfect stone?" How many of us have taken the time to figure out the thinking (or the lack of it) behind this question? How many good, positive, assuring and honest answers do we have that will be appropriate regardless of the quality of the stone. The simplest answer would be "yes" or "no." But if the answer is "yes," is the answer honest? If it is "no," is it satisfactory? We know that the affirmative answer can only be true (according to FTC rules) in a very few instances. On the other hand, even a poor salesman would try to answer the question with other than a flat "no," leaving the customer reaching for another step.

There are, of course, many good answers that will open the customer's mind for an honest explanation of clarity without having to handicap oneself by saying "no, it isn't perfect *but* it just has a very, very, slight imperfection."

The following answers will not fit all situations, but they have been used successfully: "Perfection is a rare quality." "This diamond is better than most." "It is truly one of the few fine gems." "Isn't it clear?" "Isn't it beautiful?" Here we have pointed out that it is a clear stone and a beautiful one. This is what most people want. Another answer is "A diamond can be perfect and still not be good. Government standards for a good diamond are clearly outlined to all jewelers who will use them, and this (stone being considered) is a *good* diamond." Both of these answers may require further explanation. But there is nothing negative suggested by either one as far as the stone under consideration is concerned. Further explanation should be as brief as possible and still answer the customer satisfactorily. If a comparison is called for, possibly a statement like this will be in order: "This is our finest quality, but this (showing a second stone) is *still* better than most."

This may be the time to ask if the customer would like to see how we grade diamonds. Using whatever equipment is available to best accomplish this, and again as brief as possible, show two or three grades, but not more than four.

A patient was recuperating in a hospital. The dietitian came in, sized up the situation, visited awhile and then asked, "Would you like peas or beans for lunch?" Possibly either one would have been equally good, but the important thing was that the patient had been given a *choice.* We can do the same thing in selling diamonds. An example: "This stone has a better color, but this one has better clarity, although they both cost about the same."

Having mentioned this subject of clarity to several diamond men, including the president of a large company, I get the sensation of trying to move an extremely large boulder or of starting a crusade. However, I believe that, in keeping with sound ethics, steps can be taken to revise our thinking from terms that imply imperfection to terms that can be useful without apology or embarrassment to anyone—terms that may even be helpful in describing a gem. For this reason, I submit the expression *identification characteristics.* These are two rather long words, admittedly, but they suggest something other than "full of flaws" or "imperfect."

Let us consider a stone that has no internal inclusions that could properly be described as flawless. However, it has a small "natural" on the girdle. This is not sufficent to "downgrade" the stone, but the customer who has it called to his attention as an identification characteristic, and who is given a reason for its existence, can be made to feel that it is something special, not undesirable.

I maintain that the jeweler should capitalize on this feature. Certainly, we do just that when we show a star sapphire or a cat's-eye. These stones have internal inclusions that cause the unusual phenomena. It is also true that, to a collector of unusual stones, a diamond with a perfectly formed included crystal may be *more* desirable because of the inclusion. He would undoubtedly point with pride to the inclusion and would only be willing to part with it at a premium over a stone without such an inclusion.

Here I would like to repeat that it is not my intention to suggest that inferior stones be "whitewashed" or sold as "perfect," but I believe we can alter the thinking about these inclusions so that in our minds, at least, we will not think of a stone that is only slightly less valuable than a flawless stone as being imperfect. The point I want to make is that tiny inclusions that have so little effect on light interference can properly be pointed out as identification characteristics. I know that many a salesman would rather not a mention such inclusions for fear of losing the customer's confidence and the sale. Price-wise, they do, of course, alter the cost of the stone. But this can be justified by the fact that such stones are more plentiful, just as the smaller sizes are more plentiful than the larger ones. Here, too, we have an excellent opportunity to make comparisons if the customer wants size. We might show him two stones at the same price, but of different grades, and suggest that *he* make a choice. When *he* does this he may "close" the sale for us right then. It is also true that one or two microscopic inclusions can serve as identification characteristics in a diamond and still not affect its beauty.

We can mention that a cattleman does not feel any lack of pride when he sees his brand on a steer; it is his means of identification. And if a stone contains no visible inclusions, that in itself is an identification characteristic.

To the jeweler who has difficulty getting away from the expression "imperfect" (as I have done), may I suggest trying to substitute the word "inclusion" or "feather" or "crystal." Another jeweler may smile at this, but if one is sincere the customer will not object, because he is less experienced in this line than we are. And when we *show* him the inclusion, it may be much less objectionable than he thought. Possibly he will have no objection at all when he *sees* what it is.

Obviously, we are following the line of least resistance when we recognize a needed change but refuse to accept it. We have done it successfully when we quit calling colored stones semiprecious. We can do it here when we quit using an expression to describe quality that actually implies *lack* of quality.

I do not expect a landslide of approval to this suggestion. Frankly, I am not entirely satisfied with the words "identification characteristics" myself. Maybe someone will come up with a better idea. If this just starts someone else thinking along the same line, I believe something good will come from it. Certainly, if the idea is sound, the acceptance will spread.

Here I am taking the liberty to suggest a revised GIA's grading list. I appreciate the value of the list for instruction purposes, but after we have learned how to grade stones fairly well, possibly something like the following suggestion would be better over the

(Continued on page 190)

The Nature of Crystals—Geometric Relationships

By

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This is a continuation of the article by Professor Richard Jahns on the structure of matter and the nature of crystals that began in the Spring 1958 issue of GEMS & GEMOLOGY.

Crystal Lattices and Crystal Structures

Every crystal is an assemblage of atoms (or ions) in which units of structure are repeated regularly in space to form a specific three-dimensional arrangement. The pattern of this arrangement can be compared with the two-dimensional pattern on a figured wallpaper, in which elements of design are repeated at regular intervals when traced in any direction. The smallest identical units of pattern that are stacked together to form the structure of a crystal may contain only a few atoms or ions or they may contain a great many, just as the design on a wallpaper may consist of small and simple figures or very large and intricate ones.

The three-dimensional network of points that define the repetition of the pattern units is known as a *point-space lattice,* and the lines connecting these points form a *line-space lattice.* It is obvious that many different line lattices can be established from a given point lattice. Any crystal lattice is a purely geometric feature that is useful in describing and visualizing the internal pattern of the crystal and relating it to external faces, crystal form and other physical characteristics, as described farther on. The crystal structure itself, as distinguished from a lattice, is the actual assemblage of atoms or ions, and is determined by their sizes, positioning and the nature of the forces that bind them together.

Ions can be regarded as rigid spheres and atoms as somewhat deformed spheres in considering their distribution within crystals that show different types of chemical bonding. Indeed, a deductive approach to the study of crystals, based entirely upon variations in the packing of spheres in three dimensions, led to some astonishingly accurate predictions concerning the internal structure of minerals long before satisfactory means for making absolute determinations of structure were available. The structure of crystals commonly is represented by means of *packing diagrams,* in which the constituent atoms and ions are placed in their proper relative positions and are shown to proper scale with respect both to one another and to the structure as a whole *(Figures 5 and 7 in this issue and Figures 3 and 6 in Spring 1958).*

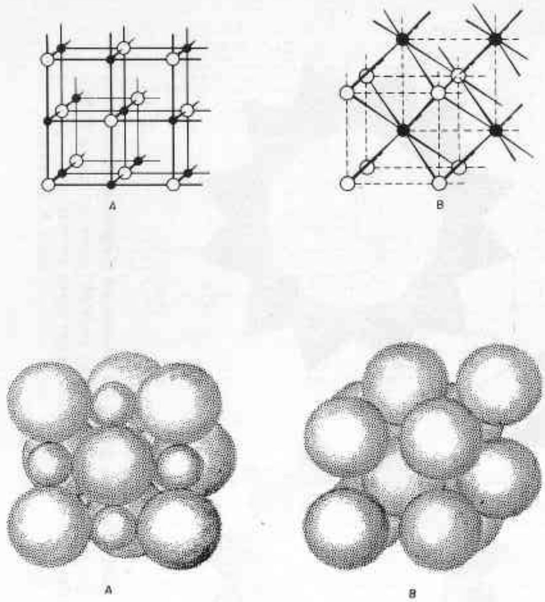
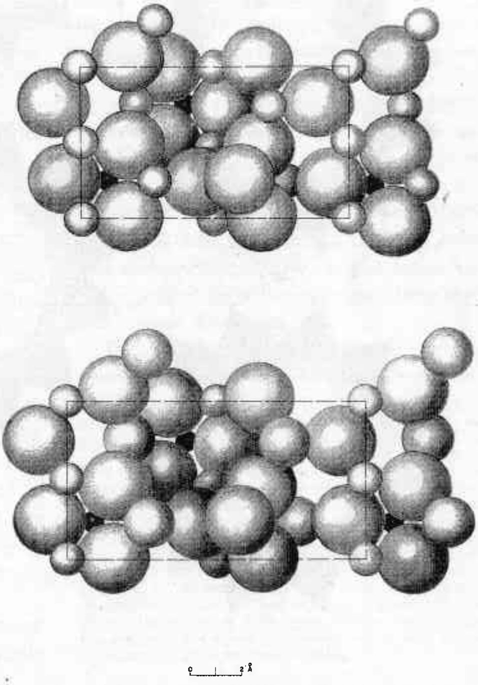


Figure 5

The structure of sodium chloride (A), as contrasted with that of cesium chloride (B). In the lattice diagrams (top) the sites of Cl^- ions are shown by open circles, and those of the cations by solid circles.

Figure 7

The structure of olivine. The upper diagram illustrates common olivine, $(Mg,Fe)_2 SiO_4$, in which the large spheres represent oxygen ions, the small dark spheres silicon ions, and those of intermediate size represent iron and magnesium ions. The lower diagram illustrates montecellite, Ca(Mg,Fe) Si)$_4$. Note how the structure is expanded slightly, owing to the presence of alternate rows of somewhat larger calcium ions in positions occupied by iron or magnesium ions in the common olivine structure. The diagrams are incomplete in that only enough of the ions are shown to indicate the basic elements of the structure.



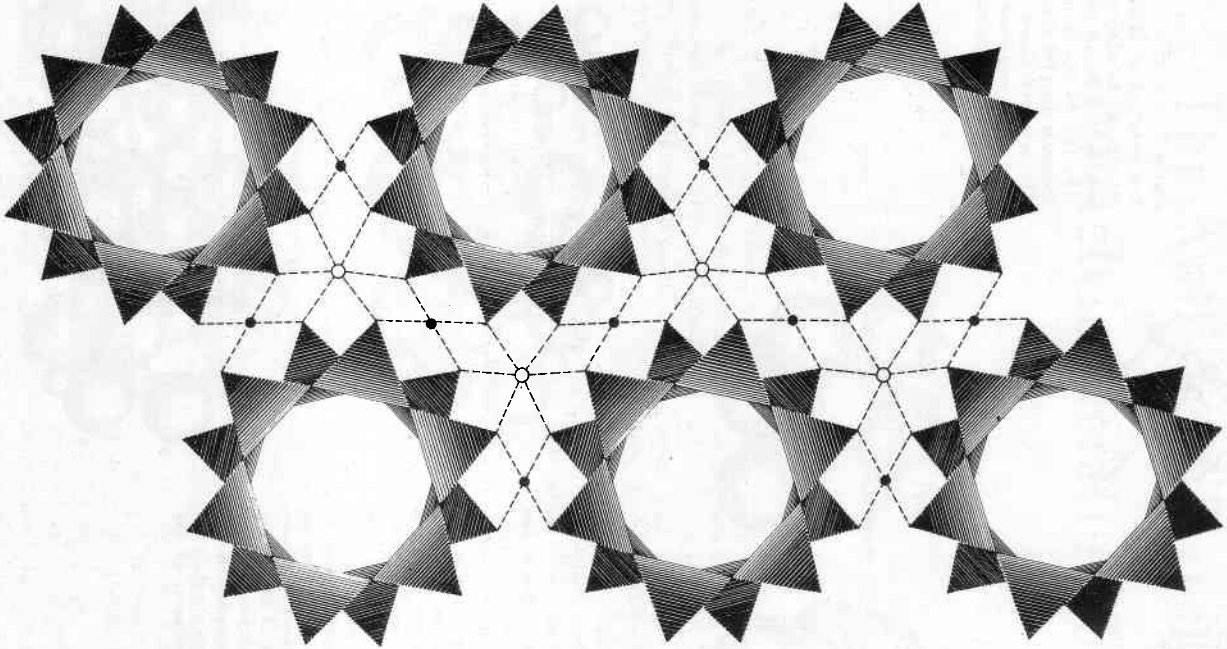


Figure 8

The structure of beryl, $Be_3Al_2Si_6O_{18}$, projected to a plane perpendicular to the c-axis. Each SiO_4 group is represented diagrammatically by a ruled triangle, and each ring of six triangles represents an Si_6O_{18} group like that shown in the right-hand part of *Figure 6* (Spring 1958). The stacks of Si_6O_{18} rings are joined together by beryllium ions (small solid circles) and aluminum ions (larger open circles).

After R. C. Evans.

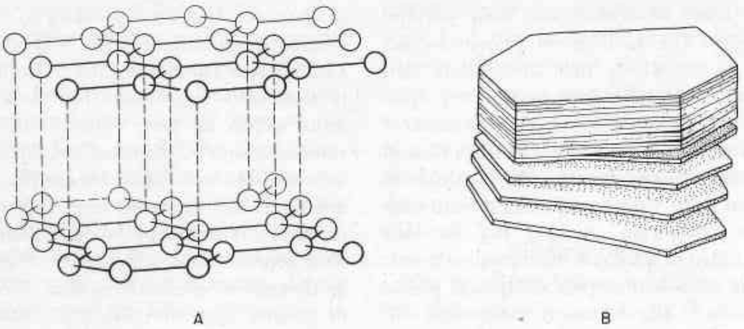


Figure 11

The structure, crystal form and cleavage of graphite. Covalently bonded sheetlike molecules of carbon atoms are held together by weak residual bonding (dashed lines in A), and hence cleaved apart in a direction parallel to the sheets (B).

In many instances, however, the geometric relations are made more clear by means of so-called lattice diagrams, in which the atoms and ions are correctly positioned but are drawn to a scale much smaller than that of the structure as a whole *(Figures 5, 8, and 11 in this issue and Figure 10 in Spring 1958)*. The units are connected by lines in order to indicate the major geometric elements of the assemblage. Most of the lines represent bond directions, but they may not be elements of a true line lattice for the crystal.

Atomic and Ionic Size

A crystal of a covalent substance such as diamond must have an internal structure that is compatible with the specific bond directions of its constituent atoms. However, such specification exists for crystals that have other types of bonding (Table II, Spring, 1958), in which the participating units* generally are packed together in three-dimensional arrangements that require a minimum of space. The nature of these space-conserving arrangements obviously is governed in part by the respective sizes of the various constituent units.

Neither atoms nor ions are strictly limited in space. and their effective size is merely a measure of the space they require when they are bound to other atoms or ions, either tangentially or with some interpenetration. This size is variable for the unit of a given element, and depends upon factors such as the nature of the bonding it forms with its neighbors in a given structure and the number and positioning of these neighbors. Thus an atom in a metallically bonded substance generally is of comparable but significantly greater size than an atom of the same element in a covalently bonded substance. A greater change in effective size accompanies a gain or loss in electrons to form anions and cations, respectively, so that anions are much larger than the corresponding atoms and cations much smaller.

The sizes of ions ordinarily are expressed in terms of *ionic radii*, which are very useful

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* The chemical units of crystalline substances are properly referred to as molecules, atoms or ions, depending upon the nature of the bonding involved. Thus a crystal of sodium chloride is *ionic*, and consists of electrostatically bonded sodium ions and chlorine ions *(Figure 3, Spring, 1958)*; the entire crystal can be thought of as a single gigantic molecule. A crystal of diamond is *covalent*, and consists of carbon atoms bonded by means of shared electrons *(Figure 10, Spring, 1958)*; it, too, can be regarded as a single gigantic molecule. In contrast, a crystal of graphite is *molecular*, since it is an assemblage of sheetlike molecules stacked together *(Figure 11)*. Each sheet is made up of carbon atoms that are covalently bonded, and the sheets themselves are bound together by relatively weak residual bonding.

in the study of crystals and their physical properties. The radii of many ions, for occurrences in which they are closely surrounded by six other ions, are shown graphically in *Figure 2 (Spring, 1958)*. Some of these ions occur rarely or not at all in natural substances, chiefly because the elements in question show strong tendencies toward nonionic bonding (e.g., Au, Hg, Bi), but they are included to illustrate the consistent trends in ionic sizes within each group and period of the chart. The cations of comparable valence state, for example, decrease progressively in radius within each period of the chart from Group I to Group V, from Group Ia to Group VIIa, and from Group Ib to Group Vb.

Arrangements of Atoms and Ions

The simplest three-dimensional arrangements of spherical or nearly spherical units are those in which all the units are equal in size. Space-conserving arrangements are more complex in crystals that contain atoms of unlike size. The effect of size differences is well illustrated by the contrasting structures of NaCl and CsCl *(Figure 5)*. The sodium ions in a crystal of NaCl achieve a close packing with the chlorine ions through a simple cubic arrangement in three dimensions. This arrangement, in which every ion is surrounded by six others of opposite charge, is not satisfactory for the much larger cesium ions in the compound CsCl; relatively close packing of Cs^+ and Cl^- ions is accomplished instead by means of a somewhat more complex type of cubic arrangement, in which every ion is surrounded by eight others of opposite charge. Both of these structures fulfill the second major requirement for stability: the essential balancing of the gross positive and negative electrical charges among the participating ions. Other requirements also must be met, but these can be neglected in this discussion.

In simplified treatments of crystal structure, the great majority of gem-forming minerals can be regarded as dominantly ionic in character, despite, for example, the large covalent contributions to the Si-O bonding in silicates and aluminosilicates. The term *ion* is reasonably appropriate for the chemical units within all these minerals except the sulfides, graphite, diamond and a few others in which the binding forces are prevailingly non-ionic. The relatively large O^{2-} ion is by far the most abundant unit in crystals of the most common minerals, which therefore can be thought of as closely packed assemblages of oxygen ions with interstitial cations of various kinds.

The *coordination number* of a given cation denotes the number of anions (ordinarily O^{2-} ions in minerals) that are grouped about it as immediate neighbors *(Figure 2, Spring, 1958)*. With respect to a given kind of anion, it follows that this number increases with increasing size of the cation. For a cation in threefold coordination, the surrounding anions generally are disposed at the corners of an enclosing equilateral triangle, for one in fourfold coordination at the corners of a regular tetrahedron *(Figure 6, Spring, 1958)*, for one in sixfold coordination at the corners of a regular octahedron *(Figure 5)*, for one in eightfold coordination at the corners of a cube *(Figure 5)*, and for large cations in higher orders of coordination they are disposed at the corners of more complex polyhedra.

The size of the Si^{4-} ion is almost ideal for fourfold coordination with respect to 0^{2-} ions, as already noted, and it is not surprising that tetrahedral SiO_4 groups *(Figure 6, Spring, 1958)* are formed in overwhelming preference to alternative arrangements between these two kinds of ions. Many other cations also occur in one particular coordination with respect to oxygen, especially where the coordination number is six or less. Larger cations are less likely to be restricted in this way *(Figure 2, Spring 1958)*, partly because increasing coordination number permits alternative arrangements whose gross space requirements do not differ so greatly from one another.

Structural Defects

It is doubtful whether any natural crystal is absolutely perfect in the sense that every theoretical position in its structure is occupied precisely by the kind of atom or ion that belongs there, and various types of departures from the ideal arrangement are known. A few atoms or ions may occur interstitially within the structure, for example, thereby slightly displacing the adjacent units from their normal positions. Small-scale distortion of the lattice also occurs in the neighborhood of impurity atoms or ions, whether they are distributed interstitially or occupy regular sites for which they are not well suited dimensionally. Another type of defect results when some of the regular sites, ordinarily a very small percentage of the total number in the crystal, are not occupied at all.

The crystals of some substances are characterized by larger scale departures from ideal and specific arrangements. Atoms or ions of one kind may be distributed essentially at random within a definite framework of other units, or they may not be present in sufficient numbers to fill all of the regular sites available for them. In some substances this deficiency is rather large. Finally, numerous foreign constituents can occupy structural sites normally taken by other atoms or ions of similar size. This type of substitution is common among minerals, and is discussed farther on in connection with isomorphism.

Many crystals are marred by dislocations and by voids that correspond to large numbers of atoms or ions. A distinct cloudiness or lack of transparency, especially in thick slices or larger masses of the material, is the most obvious result. Some of these imperfections are large enough to be seen without the aid of a microscope. Sets of subparallel dislocations commonly divide crystals of some substances into mosaics of structural blocks that differ slightly from one another in their alignment. This type of imperfection, which can be likened to the distribution of trees in adjacent orchards that were laid out independently according to slightly differing plane, is commonly developed over a wide range of scales, chiefly as a result of growth accidents in the history of a given crystal. It is variously referred to as *gross dislocation, block structure* and *mosaic structure.*

Silicate Structures

The most abundant minerals, the silicates and aluminosilicates, serve to illustrate the most important of the structural relationships that are fundamental to any mineralogic studies. Their chemical composition, physical properties and responses to changes in their physical and chemical environment are easily understood when viewed in terms of crystal structure. The basic geometry in each type of structure is defined by tetrahedral SiO_4 groups; AlO_4 groups also are present in the aluminosilicates, but for ordinary spatial considerations the behavior of the Al^{3+} ion in these groups is analogous to that of the Si^{4+} ion.

Where the SiO_4 groups occur as individual $[SiO_4]^{4-}$ ions, they tend to be oriented and positioned in some regular pattern that permits their electrostatic binding into a stable structure by means of cations that have appropriate size and charge. The most common arrangement of independent SiO_4 groups requires two cations in sixfold coordination for each $[SiO_4]^{4-}$ ion, and cations with a charge of 2 are thus best suited to the structure *(Figure 7).* This yields compositions such as Mg_2SiO_4 and Mn_2SiO_4, which characterize the olivine group of minerals (including the gem peridot).

In most silicate structures the SiO_4 groups do not occur as separated individuals, but instead are bound together by the *sharing* of oxygen ions to form more complex groups *(Figure 6, Spring, 1958).* The simplest of these is the Si_2O_7 group, or $[Si_2O_7]^{6-}$ ion, in which one oxygen ion links two SiO_4 groups by serving as a part of each. Linking of three or more SiO_4 groups can form ring-like asemblages with the general composition Si_nO_{3n}. The largest of these is the complex $[Si_6O_{18}]^{12-}$ ion, which comprises six linked groups *(Figure 6, Spring 1958)*. Anions of this general type can be stacked on top of one another or arranged in other ways that permit their binding together by a wide variety of cations. This results in the formation of so-called *ring-structure minerals,* typical examples of which are tourmaline and beryl *(Figure 8)*.

Linear linkage of SiO_4 groups provides the basic element of *chain-structure minerals.* Independent chains of infinite extent and with the composition Si_nO_{3n} are bonded together by means of cations to form the pyroxene group of minerals (e.g., diopside, bronzite, spodumene, jadeite). Another group of minerals, the amphiboles, has structures whose governing elements are paired chains with the composition $Si_{4n}O_{11n}$ (e.g., anthophyllite, hornblende).

A logical extension of the sequence from independent chains to double chains leads to planar structures characterized by sheets, or multiply-paired chains, whose composition is $Si_{2n}O_{5n}$. Three of the four oxygen ions in each SiO_4 group within such a continuous sheet are shared by three other groups, and the fourth is available for binding to additional cations that can tie the sheets together. This is the general basis for producing the *sheet-structure minerals,* of which the micas and clay minerals are typical examples.

Three-dimensional linkages of SiO_4 and AlO_4 groups yield minerals with so-called *framework structures.* Every oxygen ion is shared between two groups, and if only SiO_4 groups are present in a given linkage it has the composition Si_nO_{2n}. The electrical charges of the Si^{4+} ions balance those of the O^{2-} ions, and the structure requires no additional ions to achieve stability. Thus the chemical composition of quartz and the other silica minerals can be expressed simply as SiO_2. If some AlO_4 groups participate in the framework linkage, whose composition then becomes $(Si,Al)_nO_{2n}$, the Al^{3+} ions do not compensate for all of the negative charges of the adjacent O^{2-} ions, and other cations of appropriate size are needed to provide gross electrical neutrality for the structure. Where the ratio of AlO_4 groups to SiO_4 groups in the framework is one to three, for example, the charges can be balanced by the addition of one K^+ ion for every Al^{3+} ion; this results in formation of a potassium feldspar whose structure can be expressed by the formula $K_n\ [(3Si,\ 1\ Al)_n\ 40_{2n}]$, in which the ions that define the framework are enclosed within the brackets. The K^+ ions occupy regular positions within this framework. The structural formula reduces to the conventional and more simple chemical formula $KAlSi_3O_8$.

Polymorphism

A substance that can exist in two or more different forms, each with a different crystal structure, is said to be *polymorphous.* Thus two such forms, or *polymorphs,* of a given substance are alike in chemical composition, but differ in their physical properties as a result of their contrasting structures. These differences vary in their nature and magnitude from one substance to another. The two quartz polymorphs of SiO_2 differ only slightly in their physical properties, for example, whereas the differences between the carbon polymorphs graphite and diamond are extreme.

Two types of polymorphism can be distinguished on the basis of whether or not the transformation from one form to another is reversible and occurs at a definite temperature and pressure for a specific composition of the substance in question. Irreversible transformations convert substances from one form that is inherently unstable to one that is stable, and can take place over a considerable range of conditions. Reconversion to the original form, however, cannot be accomplished without an intervening change in state of aggregation of the sub-

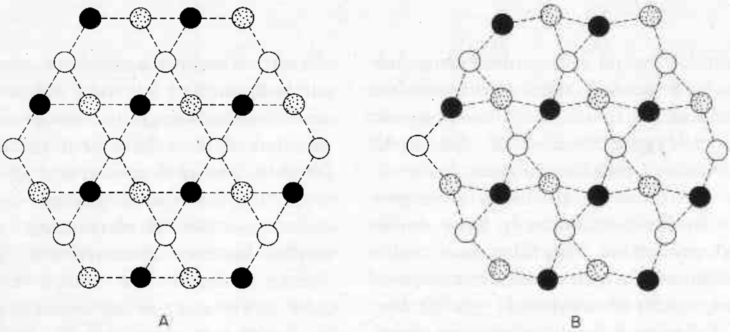

Figure 9

The structures of high-temperature quartz (A) and low-temperature quartz (B), projected to a plane perpendicular to the c-axis. Different levels of silicon atoms are indicated by differences in shading. The oxygen atoms, which are not shown, lie between the pairs of silicon atoms, one between each pair.

stance; i.e., either solution, melting or conversion to a gas. Thus aragonite, an orthorhombic polymorph of $CaCO_3$, can change at an extremely slow rate into calcite, a rhombohedral polymorph, under normal conditions at the earth's surface, but calcite cannot change into aragonite in the solid state.

Two common types of *reversible transformations* are known among the rock-forming minerals. One of these involves relatively slight shifts in the arrangements of atoms or ions within the structure, but does not require the breaking of bonds. As one might expect, such changes proceed easily and quickly in either direction under the appropriate boundary conditions. They are referred to as *high-low transformations* because they typify the shifts between high- and low-temperature forms of many minerals. Thus low-temperature quartz, a rhombohedral polymorph of SiO_2, changes almost instantaneously at about 573° C. to high-temperature quartz, a different rhombohedral polymorph of greater symmetry and approximately two percent greater volume *(Figure 9)*. The reverse change takes place just as readily when the temperature is reduced to points below 573°.

Reçonstructive transformations are those in which the rearrangements of atoms or ions require the breaking of bonds in the structure and the establishing of new bonds in other positions. As might be expected, many of these polymorphic changes are very sluggish, and may require periods of time that are long even in geologic terms. Some can be speeded up, however, in the presence of other substances that act essentially as solvents within a given crystal structure. The change from high-temperature quartz to tridymite (orthorhombic SiO_2) is of the reconstructive type. The inversion occurs at 870° C., but ordinarily is so sluggish that tridymite persists as such to much lower temperatures and can be observed in many rocks at the earth's surface. A second extremely sluggish inversion, from tridymite to crystobalite (SiO_2 with pseudo-isometric symmetry), occurs at 1470° C. Both the temperatures and rates of these transformations can be changed significantly by the occurrence of impurity ions in the structure.

Other types of polymorphic transformations can be distinguished on the basis of different kinds of structural changes within crystals, but these need not to be considered here.

Isostructuralism

Two different substances that have analogous crystal structures are said to be *isostructural* or *isotypic*. Isostructural substances have similar crystal lattices, but many substances with similar crystal lattices are not isostructural, inasmuch as a lattice is only a geometric generalization of the crystal structure. As opposed to polymorphous substances, isostructural substances are compositionally unlike but ordinarily have similar physical properties. They also have analogous chemical formulas, and are composed of atoms or ions of comparable *relative* sizes. Many of these substances have strong chemical resemblances, as illustrated by NaCl and KCl, PbS and MnS, and $CaCO_3$ and $FeCO_3$. Others are less closely related chemically, as illustrated by NaCl and PbS, and by $CaCO_3$ and $NaNO_3$. A given structural position may be occupied by a simple ion in one isotype and by a complex ion in another. For the isostructural compounds KH_2PO_4 and $(NH_4)\ H_2PO_4$, which furnish a classic example of this relationship, the $(NH_4)^+$ ion can be treated as a sphere comparable in size to the K^+ ion.

An impressive example of isostructural compounds that are chemically different but physically similar is provided by the mineral pair quartz (SiO_2) and berlinite ($AlPO_4$). Al^{3+} and P^{5+} ions in the berlinite structure are distributed in framework positions like those of the Si^{4+} ions in the similar quartz structure, and the resultant analogy in formulas becomes clearer when they are written Si_nO_{2n} and $Al_1/_{2n}P_1/_{2n}O_{2n}$. or in chemical terms, $SiSiO_4$ and $AlPO_4$. These two minerals, one a silicate and the other a phosphate, have remarkably similar properties. Both exhibit hexagonal trigonaltrapezohedral symmetry and are similar in their optical properties, crystal habit, range in color, and other physical characteristics. Moreover, both undergo polymorphic transformation of the high-low type, quartz at 573° C. and berlinite at 583° C.

Isomorphism and Solid Solution

The term *isomorphous* is employed in the same sense as the term *isostructural* by many investigators, particularly chemists, but an alternative and more restricted usage is commonly applied to minerals. In the narrower sense, two substances can be considered isomorphus if they have analogous chemical formulas and anologous crystal structures in which the corresponding atoms or ions are of comparable *absolute* sizes and have similar bonding characteristics. Such substances ordinarily are capable of forming *solid solutions* or *mixed crystals,* which can be regarded as a criterion for isomorphism. This constitutes only one of the necessary conditions for isomorphism, however, since many substances that can form solid solutions are not isomorphous.

A solid solution of two isomorphous components AX and BX has the formula (A,B) X, which implies a "mixing" of the two components in various proportions. AX and BX are termed *end members,* and if they are miscible in all proportions they are said to define a complete *isomorphous series,* or a series of *substitutional solid solutions.* The two end members, however, are really not present *as such* in any intermediate compound, but instead are theoretical contributors to crystals in which atoms or irons of A and B are distributed among sites corresponding to the A sites in the AX structure and the B sites in the analogous BX structure.

This distinction can be illustrated by the isomorphous series Mg_2SiO_4—Fe_2SiO_4, one of those that constitute the olivine minerals. All members of this series have independent SiO_4 groups as a basic structural element, and these groups are arranged in a consistent pattern. They are bound together by Mg^{2+} ions in pure Mg_2SiO_4 and by Fe^{2+} ions in pure Fe_2SiO_4. Both kinds of cations participate in this role for all intermediate members of the series, whose compositions are expressed collectively as $(Mg,Fe)_2SiO_4$. Thus the formation of intermediate members should be considered in terms of substitution of Fe^{2+} ions for Mg^{2+} ions, or of Mg^{2+} ions for Fe^{2+} ions, in the general olivine structure. The well-established terms solid solution and end member should not be taken to indicate that two separate compounds, Mg_2SiO_4 and Fe_2SiO_4, are dissolved in each other as such.

The degree to which one ion can substitute for another in a given structure without seriously impairing its stability is governed chiefly by their respective sizes and electrical charges, the nature of the structure, and the chemical environment during formation of the structure. It should be emphasized that in many geologic processes this "substitution" is partly a purely theoretical concept, since the guest ions not only displace some host ions during growth of a given crystal, but also are initial occupants of structural positions that otherwise would be available to the "host" ions.

The German geochemist V. M. Goldschmidt showed by empirical means that considerable substitution can be expected if the radii of the two kinds of ions do not differ by more than fifteen percent. Thus the Sr^{2+} ion (radius 1.13 Å) can substitute rather freely for the Ca^{2+} ion (0.99Å) in minerals, but there is little substitution of Ba^{2+} (1.35 Å) for Ca^{2+}. Ions of different charge can substitute for each other if concomitant substitutions take place between two other kinds of ions in order to balance the gross electrical charges in the structure. A common example among the silicate minerals in the substitution of Fe^{3+} (0.67 Å) for Mg^{2+} (0.65 Å), accompanied by the substitution of Al^{3+} (0.50 Å) in positions of fourfold coordination normally occupied by Si^{4+} (0.41 Å). Little substitution takes place if ions of appropriate size differ in charge by two units, as Li^+ (0.60 Å) and Fe^{3+} (0.67 Å) or Mg^{2+} (0.65 Å) and Ti^{4+} (0.68 Å). Where the difference in charge is greater, as between Ta^{5+} (0.71 Å) and Mg^{2+} (0.65 Å), substitution is negligible, mainly because it is not possible to compensate for the large differences in charge by other substitutions elsewhere within the structure. This accounts for the essential absence of elements like tantalum from the common silicate minerals.

Most minerals are formed in chemically complex environments, and hence it is not surprising that they generally contain guest-ion impurities of various kinds. These impurities in a sense represent isomorphous series, many of which are incomplete. Thus impurity ions M and N in a mineral of composition AX represent series (M,A) X and (N,A) X, respectively. These formulas might hold only for small values of M and N (incomplete series), or they might hold for all values (complete isomorphous series).

In general, isomorphism and solid solution are favored by high temperatures, which tend to increase the tolerance of a structure for ions of differing size. The framework structure of an alkali feldspar (amazonstone, for example) makes little distinction at high temperatures between K^+ ions and Na^+ ions, which differ in radius by considerably more than 15 percent. A given crystal at these temperatures thus has a composition expressed in general terms by the formula $(K,Na)\ AlSi_3O_8$, and the permissible ratios of K^+ ions to Na^+ ions in the Si-Al-O framework have the widest possible range. As the temperature is decreased, however, the crystal can no longer retain large percentages of both kinds of alkali cations and yet remain stable. These ions begin to order themselves by migrating within the framework until two separate mineral phases appear; one of these is a potassium feldspar, $(K,Na)\ AlSi_3O_8$, in which the K^+/Na^+ ratio is very large, and the other is a sodium feldspar, $(Na,K)\ AlSi_3O_8$, in which the Na^+/K^+ ratio is very large. Thus typical amazonite consists of numerous thin plates of white albite, the sodium feldspar, in a host of green microcline, the potassium feldspar. This solid-state development of two phases from one is known as *unmixing* or *exsolution.*

Solid solutions of the isomorphous type are of great mineralogic importance, and if one considers them in terms of the ionic substitutions that are involved he will understand the complex chemical composition of most gem materials, and many of the reasons for the varieties in their physical properties. Two other types of solid solution also are well known. In one type, termed *interstitial solid solution,* additional atoms or ions are present in the host structure, not in regular structural positions but interstitially between such positions. In the other type, termed *omission solid solution,* some of the regular structural positions are vacant. Both kinds of non-substitutional solid solution are related to structural defects discussed earlier.

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counter.

Instead of grading from flawless to I_2 (imperfect) we could use I.C. (identification characteristic) 1 to 9, or possibly just the letter C (clarity) 1 to 9. Or we may reverse the numerical sequence and use the number 9 for the best grade and 1 for the I_2 grade. The latter seems to be in keeping with the GIA color-grading scale, possibly not so far fetched as to be impractical at that.

I mentioned the word clarity in connection with one of the lists; this might be the key to the solution. Use C_1 for the GIA grade (I_2) to describe a "good" stone and C_9 (flawless) to describe the best. Possibly I am too liberal, or possibly the suggestion does not differ enough from the one now in use. There is no particular objection to the *grades* we use, but they should be *named* differently. The expression *clarity grading* would be better than *imperfection grading;* at least it gets away from negative terms.

When buying diamonds it is essential to know the grades that are being offered and to know how they compare with our standards. But when describing a stone to a customer, the jeweler does not have to use the same terminology. Surely he does not explain his cost code to his customer, nor does he need to go into as much detail when selling to most people.

There are exceptions, of course. Each presentation must be fitted to the customer. The salesman should study his customer as thoroughly as time and circumstances will permit. This is done by the salesman, not the customer, asking questions. It can be done in such a way as to convince the customer that he is sincerely interested in serving him in the best possible manner. Here, then, is the time to start avoiding the use of any *negative* expressions, even though they be *very very slight.*

I do not feel that this paper has solved a problem; rather, it has posed a question. Can we in our trade meet this question? Must we go on using negative terms to describe the most popularly accepted symbol of enduring beauty and love?

In describing a colored stone, we no longer say "This is a semiprecious stone." Then why must most diamonds, good diamonds, be described in terms that imply imperfections?

Not long ago I visited a clinic for the physically handicapped. One group of children had hairlips and cleft palates. The purpose of the class was to teach these children not only to improve their speech but, what was more important, how to live in a society in which they were different. I had the greatest admiration for the lady who was achieving so much success in accomplishing this difficult task. To revise our thinking on diamonds is a much lesser task. Surely it is a challenge, but it can succeed if enough of us who want to be up to date will work together toward that end.

It has been said that the only difference in the mentality of people is that some think more quickly and more clearly than others. Clarity in diamonds and clear thinking may have more in common than just a play on words. After all, it is clear thinking that makes more sales. If we think of our product in positive terms, we will overcome an objection that very often exists only in our own minds.

BOOK REVIEW

ROCKS AND GEMS, A Handbook, by DeWitte Hagar, Trend Book 164. Published by Trend Books, Inc., Hollywood, California. 128 pages, well illustrated (paper bound). Price $.75.

Rocks and Gems is written in nontechnical terms essentially for the hobbyist. It furnishes the potential hobbyist-collector with the necessary information concerning various collection areas in the U. S., how to recognize minerals in their natural formations, where to search for them, procedures for cutting them and methods of cataloging them. The subject material is presented in a simplified manner that should appeal to the neophyte and hold much interest for the more experienced hobbyist as well. All technical descriptions such as chemical formulas and optical and physical properties have been omitted, since the author believes that technical information belongs to a more advanced branch study. In the reviewer's opinion the brown-tone photographs detract appreciably from the overall appearance of the book. The value of the otherwise excellent illustrations would of been enhanced if they had been printed in black and white.

CINNABAR, A GAME OF ROCKS AND MINERALS, by Vinson Brown. One of a series of the Nature Games published by Naturegraph Company, San Martin, Calif.

Cinnabar, A Game of Rocks and Minerals, is composed of a 56-piece set of playing cards that are divided into 12 separate categories, each of which represents a mineral family; e.g., the silicates, the oxides, the sulphides, etc. Each face card has a color photograph of one of the minerals in the family it represents, and also lists the names of a few of the other minerals of the same family. An important characteristic of one of the minerals is listed. The idea of the game is to draw cards from other players, the winner being the one who completes the most families. It is a game for both old and young. Several methods of playing the game are included with the instructions. Even a small child can play the game by recognizing the photos and numbers on the cards. It provides an easy method for the novice to learn more about rocks and minerals through play.

ABOUT THE AUTHOR

William C. McConahay, gemologist-jeweler, Salt Lake City, Utah, has spent most of his 58 years in the jewelry business in Salt Lake City. Even during high school and his college years at the University of Utah he understudied the engraver, the manufacturing jeweler and the sales people in his father's jewelry store. His inquisitive mind also prompted him to digress from the jewelry profession at times, but only for short periods. During these intermissions he was variously employed in a sugar factory, a dry-cleaning establishment, and in the selling of electric refrigeration. He served in both World Wars in combat units in Europe in the first and in the Pacific in the second. One of his hobbies is Scout work. To quote Mr. McConahay, ". . . since most of our four children are boys, I became involved in Boy Scout work." He is presently a member of the Executive Board of the Great Salt Lake Council and is the district governor of the State of Utah. His interest in and love of diamonds led him to write the provocative article, *Clarity,* that appears on page 174 of this issue of GEMS & GEMOLOGY. It was submitted to the GIA as his thesis in fulfillment of the requirements for the Gemologist Diploma.