UBIQUITOUS QUARTZ

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WHERE WOULD WE BE WITHOUT QUARTZ? It is one of the most common minerals in the Earth's crust and is an important constituent of many igneous, sedimentary, and metamorphic rocks. It occurs in many hydrothermal veins which carry precious metals and valuable sulfides. It is a major constituent as well in most pegmatites, including those that contain significant gem minerals. Because of quartz's prevalence in so many environments, it can be thought of as Nature's canvas upon which she paints her final vapors into the solid crystals and gems we prize so much.

At any major mineral and gem show look around, and you will see fine quartz crystals, specimens and gems. Many of the more spectacular specimens will be quartz upon which there is perched gem tourmaline, fiery red rhodochrosite, gemmy fluorite, and other mineral crystals, perhaps even gold. And the lapidary would be lost without quartz, both as a medium for practice while learning and as a source of fine gems to blend with other stones in jewelry.

tourmaline embedded in quartz crystal

If that isn't enough to show the importance of quartz, look at its impact on science. It was quartz that Nicolaus Steno studied to discover the Law of Constancy of Angles in 1669. As the first formulated law governing how crystals form, this law laid the basis for later work by Romé de l'Isle and others in establishing the science of crystallography.

In more recent times, the search for quartz with electrical properties applicable to communications led to the discovery of many Brazilian specimen and gem deposits and also to the successful synthesis of quartz. The latter was also an important step in the realm of electronics and related fields.

Nassau (1980) credits H. de Senarmont with the first successful growth of quartz; he used a hydrothermal method in 1851. Nassau also describes the work of Giorgio Spezia of Turin, Italy, who published a series of papers from 1889 to 1908 telling how to grow quartz from seed crystals. Preceded by Verneuil's successful work in ruby, made public in 1902, quartz became the second gem material synthesized in useful quantities (Nassau, 1980).

fine colored Laguna Agate from Chihuahua, Mexico

One of the keys to quartz's common natural occurrence is its ability to form under many conditions. It can grow from fairly cold solutions; a good example is revealed by the work of Keller (1977) on the lovely agates of Chihuahua, Mexico. Chemically quartz is silicon dioxide. Quartz is called alpha– or low-quartz when formed below 573°C. Above that temperature it can be formed as beta– or high-quartz up to a temperature of 870°C. Both belong to the hexagonal system, but the alpha form has only threefold symmetry whereas the beta form has sixfold symmetry.

There are also other mineral species that are silicon dioxide like quartz. They include tridymite, crystobalite, coesite, and stishovite. Opal is sometimes grouped with quartz, as it is composed of submicroscopic spheres of silicon dioxide. However, it also contains some water in the structure ans should be treated separately.

The habits of quartz are many, particularly if one also considers the twinning forms it assumes. There are the Japan-Law twins that commonly look like two rabbit ears or, less commonly, like a heart. There are the Dauphiné-law and Brazil-law twins, difficult to recognize for the amateur although extremely common. Both are internal twinning that show only minor, if any, external signs of their presence. For the electronic expert, however, thisinternal twinning is a pariah to be avoided. It is, in fact, a condition that prompted scientists to search for and discover how to grow untwinned forms of quartz in the laboratory. There is a host of other laws, which are described in, for example, Frondel (1962).

Japan-Law twin crystal habit

Just as there is a host of twin forms, so there seems to be a host of color varieties of quartz. There are, however, only four major varieties of coarsely crystalline quartz: *citrine*-a lovely yellow color, *amethyst*-violet in hue, *smoky*-ranging from light gray to brownish black, and *rose*-a delicate pink color. Among the cryptocrystalline varieties, most of which are chalcedonic, there is an array of colors great enough to please anyone's senses. Fiery red carnelians and bright red and yellow jaspers are particularly popular. So are the multi-hued and varied forms of agate, some displaying a veritable riot of colors. Even without one slice of agate you can see a rainbow of colors, thanks to inclusion of, for example, manganese oxides, hematite, and other iron oxides. Such coloration turns common chalcedony into a very attractive and eagerly sought gem that remains relatively inexpensive. Added to the colors of agate are the less common but attractive forms of quartz including *aventurine* which can be green, yellow or brown due to included mica; *chrysoprase* which is green due to the inclusion of hydrated nickel silicate; *plasma* which is a similar green due to other included minerals; and historically important names assigned in the literature to the diversely colored and patterned quartzes and agate that they are mond boggling. Frazier (personal communication, 1986) in checking the literature while preparing his forthcoming book on quartz has come across literally hundreds of terms applied to the mineral. Ransom (1974) and Frondel (1962) also cover this topic in depth.

colorful Montana Moss Agate from the Yellow-stone River in Eastern Montana

When quartz replaces other substances, it creates yet another group of gemstones. Prime examples are *tiger's eye* (golden brown) and *hawk's eye* (shimmering blue). Each was originally a fibrous asbestiform amphibole.

Even organic materials have not escaped being replaced by quartz. The world-renown picture woods of Arizona, so precious as decorative stone, are a good example. These replaced

tiger's eye and hawk's eye

woods were so highly prized in the early days of Western migration that the huge logs were regularly blasted to bits to get at the better gems and amethyst crystals inside (Funsten, 1986). Such vandalism contributed to the push that created the Petrified Forest National Park in 1906.

Arizona Petrified wood

The literature is replete with information and descriptions of classic sources of fine quartz specimens. Colorless rock crystal, usually referred to simply as quartz, is found in many kinds of environments. It can be late-forming in sedimentary rocks, filling seams and cavities formed by secondary action. It is significant as crystal specimen material in many ore veins throughout the world. Pegmatites constitute another major source of fine specimens. Miarolitic cavities are yet another source of specimen quartz. And, keep in mind it often is quartz's close association with other species that make it even more desire.

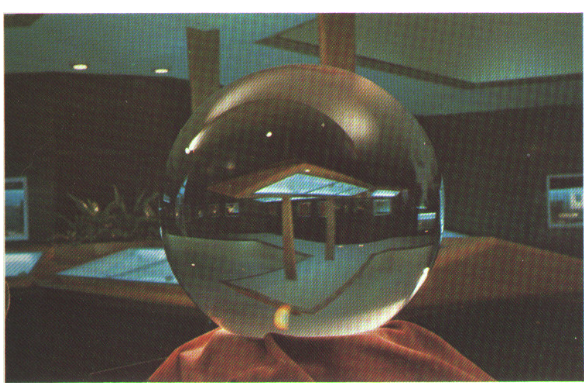
clear example of Arkansas quartz (tabular)

The following are a few classic sources for quartz and also some of the recent and exciting sources in Brazil, peru, and Mexico.

Madagascar, now called the Malagasy Republic, has been a major source of coarsely crystalline quartz for centuries. Many of the beautiful carved Roman and Greek *objets d'art* seen in museums were made of quartz from here (Frondel, 1962). The quartz occurs in large crystals from two major sources. Some large, clear quartz crystals have been found in cavities in quartzite, and other fine crystals have come from the famous pegmatites of the island. Although little quartz comes from Malagasy Republic today, some ten or fifteen years ago a selection of extremely fine crystal groups with individual prisms up to ten inches long were being offered for sale in this country.

Madagascar quartz cluster

Another historically important source of quartz was at Sakangyi, Katha District, Burma. Frondel (1962) mentions clear quartz masses weighing up to 1,500 pounds from a pegmatite there. The large quartz sphere displayed at the Smithsonian Institute comes from this source. Made into a sphere in China, it measures 13 inches in diameter and weighs 107 pounds (Hurlbut, 1970).



quartz sphere displayed in Smithsonian

For sheer vibrant beauty the water-clear tapering prisms from LaGardette, near Bourg d'Ouisans, Dauphiné, France, are hard to match. Perhaps those from Ellenville, New York, come closest. The French specimens grace fine museum displays around the world. The Dauphiné-law twin draws its name from this locality. This twin consists of two intergrown prisms, one rotated 180 degrees from the other. Outwardly, the specimen appears as one crystal. Both crystals are of the ame hand-that is, the internal silica-tetrahedron spirals of both crystal units rotate in the same direction. If the two internally twinned crystals rotate in opposite directions, the twin is accorded to the Brazil law, named for a major source of such twinned quartz (Gait, 1973).

Arkansas cluster with visible phantom from Ron Coleman Mine

A major source of quartz crystal groups in this country is in Arkansas. The lovely and popular specimens from the Ouachita Mountains were used by Indians, who chipped them into arrowheads. Such artifacts were first found by the Spaniard DeSoto in 1541 (Engel, 1952). As Americans entered the region, quartz crystals were found and saved, and as settlements developed, particularly around the Hot Springs area, the sale of quartz crystals to tourists had already become a brisk trade in the 1800's. Mining of optical quartz in the area has also been important in the past.

The quartz in Hot Springs is found in a variety of environments. The better crystallized material tends to be found as cavity fillings, with quartz comprising 90 percent of the filling, probably derived from hydrothermal solutions of relatively low temperature. The cavities occur in both sandstone and shale formations with the sandstone formations yielding the better quality quartz (Engel, 1951). Today you can go into the region and, for a fee, dig at a number of mines. There are plenty of retail sources as well. It is this writer's opinion that Arkansas quartz has not been given the same respect or esteem granted quartz of similar quality elsewhere. Accessibility, abundance of material, and other factors probably have contributed to this lack of respect. The fact that what is found here is just plain quartz, no twins, nothing exotic, may have also been a factor. Recently, you may have seen some deeply colored smoky quartz from Arkansas for sale. Apparently they are not naturally occurring smoky quartz. Rumor has it that they are dug up, put in food store shopping baskets, and run through a gamma radiation source at a meat packing plant to give them the smoky appearance.

typical Arkansas quartz

Some eastern collectors might challenge the suggestion that Arkansas is North America's premier quartz locality. After all, the beautiful doubly terminated euhedral quartz crystals from Little Falls, Herkimer, and other localities in central New York State certainly deserve recognition. Surely, these attractive crystals deserve a high ranking on North America's quartz list. Individual crystals and groups of crystals occur in open pockets in a gray dolomite and in the soil mantle of the area. Groups of crystals are rarely seen, however, because the crystals tend to separate easily. But finely reconstructed groups are most attractive. The crystal concentrations are centered around the Herkimer-Middleville region along the Erie (Barge) Canal. The crystals occur in cavities in a calcareous gray dolomite which is tough and difficult to break (Sinkankas, 1959). Diggers pay for the joy (?) of breaking rock here. They set up camp and sunshade awnings, and get serious when they search for and work the pocket zones. The rewards can be little or great. Some pockets produce hundreds of crystals while others may contain just a crystal or two. The smaller crystals tend to survive frost and other damage better than the larger ones. The larger ones are up to more than two inches in length.

Herkimer Diamond crystal from Ace of Diamonds Mine, Middleville, New York

There is little argument about the best sources of smoky quartz. Premier specimens have been coming from the alpine cleft zones of Switzerland for centuries. They tend to be uniform in overall appearance with the color pale enough to preserve the transparent condition of the quartz. Smoky quartz crystals from Colorado, Scotland, and elsewhere tend to be so dark that they lose their effect.

smoky quartz cluster from Chamonix, France

For sheer beauty, crystal form, mineral association, and rarity the Swiss smoky quartz is top drawer. The alpine cleft environment is of interest to serious collectors. Learning just how these fine crystals formed has been difficult to determine. One current hypothesis on the origin of the left deposits holds that the minerals we treasure formed from solutions that moved during metamorphic activities associated with mountain building (Weibel, 1966). An earlier, long-prevailing view held that the crystals formed from action of late residual solutions emanating from some deep seated body of magma.

Swiss crystals are typically simple hexagonal prisms, clear, and perfectly terminated; they range in size from micro to huge masses weighing hundreds of pounds. Accounts of pockets yielding tons of crystals are in the literature —e.g., Wilson (1984), Weibel (1966), and Dake (1935). Along with the limpid beauty of these crystals from Switzerland, there comes a variety of habits and forms worth mentioning. Some show a form called the Dauphiné habit, not to be confused with the similarly named twin form. There are scepters wherein one fatter crystal has overgrown the termination end of another crystal.

Some crystals are skeletal featuring hollow crystal faces not completely filled during the growth cycle. Still others show the gwindel ("twisted") form that reflects a slight offset of each stacked crystal unit (Sinkankas, 1976). There is also a form designated Tessin that makes one think of a blimp because of the unusual sloping or curving terminations. Inclusions are also common in Swiss quartz. These include: rutile, jamesonite, epidote, anhydrite, actinolite, and chlorite.

Swiss smoky quartz displaying the "gwindel" form. This specimen is from St. Gotthard, Switzerland

In this country, the miarolitic cavities of the Pike's Peak Granite of Colorado and the White Mountains of

New Hampshire contain superb smoky quartz crystal groups. The former occur with amazonite of excellent blue green color. Those from New Hampshire are best seen where associated with white to cream-colored microcline and snowy albite blades.

smoky quartz on amazonite from Pike's Peak, Colorado

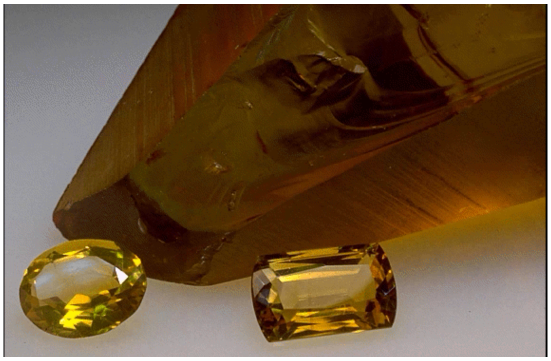
Smoky quartz that exhibits Japan-like twins has been found as superb specimens at the El Tigré claim, El Capitan Mountains, New Mexico. Discovered by Dick Jones, now deceased, this claim produced very dark, superb twins up o two inches on a crystal side. Jones (personal communication) explained that the presence of highly radioactive minerals in the pockets along with the smoky crystals were good evidence of the cause of the dark color. Now we know that radioactivity can be a cause of the smoky color of quartz (Nassau, 1980). The best specimen from the El Tigré claim is currently in the collection of Thomas McKee of Scottsdale, Arizona.

The cause of color in rose quartz is not completely understood. One recent study suggests that in at least one case the cause of the color in rose quartz is dependent upon a displaced electron in the molecular structure (Maschmeyer and lehmann, 1983). The rarity of rose quartz was such that as recently as fifty years ago some writers did not even acknowledge its existence (Hurlbut, 1970). The earlier collected rose quartz of note was from several Maine pegmatite localities, including Newby. Tiny prisms that occur in vugs there are of pale color and are not worthy as collector specimens, except for their rarity. More recently, Brazil has become a major source of superb rose quartz. Fine prisms of rich rose color that occur here range up to an inch or more long, and also comprise sub-parallel groups commonly as crests or crowns on other crystals. The best older source was Galilea, Minas Gerais, Brazil. Some fifteen years ago, a major source was found on a small island in the Jequitinhonha River, near Taquaral.. Known as the Lavra da Ilha pegmatite, this source produced superb groups of pink, sometimes purplish hued crystal groups and aggregates of crystals in radial clusters (Cassedanne, 1973). Another noteworthy Brazilian source has been Sapucaia, Minas gerais (Groben, 1985). Little rose quartz is available in the current marketplace.

rare example of naturally crystalline rose quartz

Natural citrine, which has a beautiful canary yellow color, is even rarer than rose quartz. A visit to a lapidary show would seem to contradict this statement because dealer after dealer offers small crystallized plates of Brazilian yellow to amber brown citrine for sale. These pieces, however, are all heat treated amethyst, rather than true citrine.

Citrine has never had a significant impact on the specimen market because there are no major or regular sources. A few specimens have come from Brazil, for example, from lead-zinc deposit on the Fazenda do Cedro (Cassedanne, 1975). Schumann (1977) mentions citrine as coming from three different states in Brazil as well as from several sources in the United States. One of the listed sources probably refers to Gunnison County, Colorado,



natural citrine crystal shown with faceted stones

where excellent pale yellow crystals up to two inches long have occurred. An example is in the Yale University collection.

Specimens and gems of a bi-colored quartz showing distinct amethyst/citrine zoning are currently on the market. Some of this beautiful material is apparently natural, but some is also treated. More studies remain to sort this out. Just as amethyst and smoky quartz, amethyst and citrine occur as lovely zonned and twinned crystals. However, the quantity and uniformity of quality seen in such stones on the market today suggest that a considerable effort in treating stones is taking place.

Work done by Nassau (1981) indicates possible causes of both the amethyst and citrine colors. He examined both natural and synthetically produced amethyst-citrine. From his studies it is clear that naturally occurring amethyst-citrine quartz does occur. He also shows how such material can be made in the laboratory. The problem as he defines it is that he was unable to determine a test to distinguish between the two.

ametrine (amethyst/citrine) from Bolivia

Amethyst is probably the most popular of the quartz varieties because it is available, colorful, and occurs in spectacular crystal groups. The most important source of amethyst for the lapidary and the collector is from the Rio Grande do Sul area of Brazil and Uruguay. Volcanic rocks there contain enormous cavities, some as large as small caves, that are lined with amethyst crystals. Curving sections, even tube sections and huge geode forms broken open to reveal the colorful purple lining of crystals, are offered at all major shows, usually by many dealers. Large pieces are used as office and home décor, while crystal-lined cavities are sometimes artfully lighted to make attractive window display or a setting for fine jewelry being offered for sale.

In the United States, many amethyst deposits provide fine specimens. The miarolitic cavities in the White Mountains of New Hampshire have already been mentioned.

Pockets large enough to crawl into and mine have been found at Kearsarge and elsewhere near North Conway. Equally attractive, richly colored crystal groups come from North Carolina. The trap rock quarries of northeastern North America contain vugs lined with pale to good amethyst upon which superb zeolite minerals are found. At the top of Four Peaks Mountain, Arizona, there is a fine deposit that has produced superb gem-quality red violet amethyst that rivals the world's best, which is from Russia. In Canada, there are some rich deposits, particularly around Thunder Bay on Lake Superior. Fine gems have been cut from material there (Jones, 1985), and American collectors find the region very productive when the weather is kind!

Two deposits in Mexico have been significant in recent years. Each is unique. Each provides beautiful specimens, pale to violet prismatic crystals of amethyst that are truly lovely come from Las Vigas, near Veru Cruz in the state Vera Cruz. Some crystals are virtually colorless at the base, grading upward into a lovely rich amethyst color near their terminations. The termination sections are often of gem quality. Other specimens are more uniformly colored. Most have a brilliant luster, and the crystal form is typically candlelike with the crystals tapering into gracefully beautiful forms. The fact that these amethyst crystals occur with and on microcrystals of pistachio-gren epidote provides an aid in identifying them as from Las Vigas. The crystals tend to be less than two inches long and commonly occur in diverging sprays a few inches across. Crystals up to four inches long also occur.

amethyst cluster from Vera Cruz, Mexico

Mexico's other major amethyst crystal source is the Valenciana mine, near Amatitatlan, in the state of Guererro. Amethyst there can be distinguished from the las Vigas material in several ways. Much of it is deep amethyst color at the base of the crystal and clear or white tipped at he termination. It does not occur with epidote in the matrix. Crystals tend to be thick in the middle, having an almost Tessinlike habit. Some Guererro amethysts are much larger than those from las Vigas. Crystals to six inches long atop a base of massive zoned amethyst have been mined at this locality. The huge masses have even been carved into spectacular human profiles representing, for example, one of the major gods of Mexico.

amethyst cluster from Guererro, Mexico

In the United States, the most recently discovered source of noteworthy quartz came as a delightful surprise. The Denny Mountain region of Washington has produced some superb rock crystal groups, sharp free-standing quartz exhibiting Japan-law twins, and spectacular scepters, some with amethyst tops. A few fine quartz groups with bright cubes of pyrite among and even impaled by the quartz crystals have been mined. This region and thedifficulty in collecting there is well documented by Ream (1977) and Medici et al. (1978)

The Denny Mountain occurrence as described by ream is a quartz– and iron-rich skarn. It produces marvelous amethyst scepters with the promary crystal consisting of white quartz and the scepter a lovely reddish violet color. Bright flecks of red, probably hematite, are easily seen in some of these specimens. The popular designation for these crystals is strawberry quartz. They tend to be modest in size, few exceeding an inch in length. Nice plates of crystals also have been recovered and make fine display pieces. The same deposit has, in addition, produced good clear quartz exhibiting Japan-law twins, some more than an inch long. They occur nested in among crystals of regular habit. A final note on the scepters from here: Some are "reverse scepters" with the more slender prism jutting out from the larger-radius part on the bottom.

The Medici et al. (1978) article describes a collecting trip to Spruce Peak in the same region of Washington. The described quartz crystals are large prisms of common habit, some of which are more than three inches long. Japan-law twins along with scepters are found. Sharp cubes of pyrite crystals also occur with the quartz at this locality. The quartz-pyrite specimens make spectacular display pieces, and, because collecting in the region is difficult, if not hazardous, fine groups from this locality are not easy to obtain.

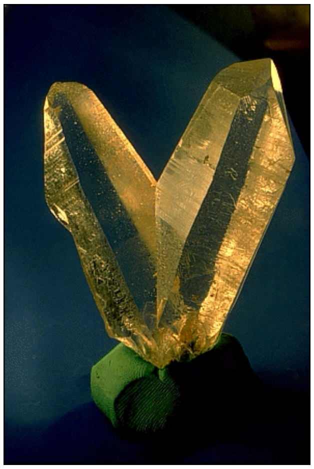
Near the beginning of this publication, we mentioned quartz as a constituent of ore veins. As such, it is considered a gangue mineral. One prime area for good hydrothermal vein quartz is the San Juan Mountain region in Colorado. Several mines—the Campbird, the American Tunnel and others—have been excellent sources for snow-white prisms of quartz, some in plates a foot or more across. Here and elsewhere in Colorado, quartz has been found with fine red rhodochrosite rhombohedrons; these are particularly highly prized by collectors (Kosnar and Miller, 1976). Caution is offered here, however, for those buying the quartz groups said to be from Ouray *if* the specimens have native gold on them. No valid specimen with this association, gold on quartz, is known to this writer from here. I have seen, however, dozens of such specimens over the years (I visit this region every summer), and all have appeared to be fake, with the gold having been implanted.

Quartz scepter on pyrite from Spruce Peak, Washington

Except for the mine at Silverton, formerly called the American Tunnel mine, the Colorado sources for quartz are no longer active. Therefore, the supply from Colorado is dwindling dramatically. Ore vein quartzes from Peru, however, are available, and some are fantastic groups of crystals. The quartz occurs as a gangue mineral in silver/lead/zinc veins there. The most noteworthy specimens are those that have fiery red rhodochrosite crystals impaled or perched upon the quartz. These specimens are from the Huallopon mine, near Pasto Bueno. Quartz from the mine also occurs with bournonite, brilliant tetrahedrites, fine pyrite, and several silver minerals. Fine specimens from here command high prices. Nothing currently available compares ith the quality of the best specimens from Peru. In fact, even the fine quartz pieces associated with apatite, ferberite, and arsenopyrite from Panasquiera, Portugal, that were so common a few years ago pale by comparison.

No article about quartz would be complete without some mention of the spectacular pegmatite sources in Brazil. So many spectacular quartz groups, the best associated with superb gem-quality crystals of tourmaline or beryl, have been recovered that all other sources pale by comparison. With the rising demand for optical grade and electronic grade quartzduring World War II, Brazilian localities have become world leaders in quartz and gem mineral production. Huge quartz crystals weighing hundreds of pounds have come from Brazil. Beautiful quartz has come from several pegmatite pockets in the state of Minas Gerais, and the state of Bahia has yielded some lovely Japan-law twinned crystals as well.

The association of Brazilian quartz with virtually every rare and beautiful pegmatite


Brazilian quartz crystals

mineral species known is especially noteworthy. Spectacular quartz/ tourmaline masses, topaz on quartz, eosphorite on quartz, rose quartz on clear quartz, rare radioactive minerals on quartz, heliodor on quartz, aquamarine on quartz, morganite on quartz, etc., have been found during the last few decades. It was with the Brazilian pegmatites in mind that we earlier alluded to Mother Nature's ability to use quartz as a canvas upon which to deposit her final mineral vapors as lovely crystals.

There are some Brazilain deposits, which are not pegmatitic, that deserve mention here. The deep Morro Velho gold mine has produced some exceedingly fine quartz crystals with associated siderite, lovely pink apatite, and some sulfides. These specimens are particularly appealing to thespecimen collector.

One recent find of quartz in Brazil was displayed at the 1986 Tucson gem and Mineral Show. The display consisted of an excellent array of quartz crystals, each hosting an inclusion. Some were distinctly phantoms with chlorite or other minerals as the outlining material. Others had included pyrite crystals, rutile in lovely six-rayed patterns, carbonate minerals, limonite pseudomorphs, even enclosed clays. The owner of the display, Ed Swoboda, has recorded the occurrence of this quartz array, which is from the Cata Rica mine, near Francisco Dumont, Minas Gerais (Swoboda, 1985).

One nice thing about being a collector of quartz is that you never run out of varieties to collect or of localities to explore. The association of other minerals with quartz and the various forms and habits of quartz also seem infinite. In addition, there are such things as: pseudomorphs after quartz and replacements by quartz; fluid inclusions in quartz; and other aspects not described herein.

REFERENCES

Cassedanne, J.J. 1973. Minerals from the Lavre da Ilha pegmatite, Brazil. *Mineralogical Record* 4:207-213.

Cassedanne, J.J. 1975. Minerals from the lead-zinc localities of Brazil. *Mineralogical Record* 6:282-291.

Dake, H.C.: Flener, F.L.: Wilson, B.H. 1938. *Quartz family minera*ls. New York: Whittlesey House.

Engel, A.E.J. 1952. *Quartz crystal deposits of western Arkansas*. Washington, D.C.: U.S.G.S. Bulletin #973-E.

Frondel, C. 1962. The system of mineralogy, Vol. III, 7th Edition. New York: Wiley and Sons.

Funsten, K. 1986. Adam Clark Vroman and the forest of stone, Phoenix, Arizona. *Arizona Highways* 62:28-33.

Gait, R.I. 1973. Quartz, quartz, quartz. *Mineralogical Record* 4:7-14.

Groben, M.M. 1985. *Mineralogical record Index*, Vol. I-XIV, Livermore, California: Friends of Mineralogy.

Hurlbut, C.S. 1970. Quartz, New York. *Mineral Digest* 1:62-74

Jones, R.W. 1985. Thunder bay amethyst. *Rock and Gem* 15:8-12.

Keller, P.C. 1977. *Geology of the Sierra del Gallego area*, Chihuahua, Mexico. Austin: University of Texas.

Kosnar, R., and Miller, H. 1976. Crystallized minerals of the Colorado mineral belt. *Mineralogical Record* 7:278-307.

Maschmeyer, D., and Lehmann, C. 1983. A trapped hole center causing rose quartz coloration of natural quartz. *Zeitschrift für Kristallographie* 163:181-196.

Medici, J.; Ludlam, N.; Pfaff, N.; Hawes, W. 1978. Quartz and pyrite from Kings County, Washington, *Mineralogical Record* 9:349-358.

Nassau, K. 1980. *Gems made by man*. Radnor: Chilton Books.

Nassau, K. 1981. Natural, treated and synthetic amethyst-citrine quartz. *Lapidary Journal* 35:52-60.

Ransom, J.E. 1974. *Gems and minerals of America*. New York: Harper & Row Publishing Co.

Ream, L.R. 1977. Denny Mountain quartz. *Mineralogical Record* 8:14-18.

Schumann, W. 1977. *Gemstones of the world*. New York: SterlingPublishing Co.

Sinkankas, J. 1959. *Gemstones of North America*. New York: Van Nostrand Reinhold Publishing Co.

Sinkankas, J. 1976. *Gemstones of North America*, Vol. II. New York: Van Nostrand Reinhold Publishing Co.

Swoboda, E.R. 1986. The wonders of quartz. *Lapidary Journal* 39:19-24.

Weibel, M. 1966. *A guide to the minerals of Switzerland*. New York: Interscience Publishers.

Wilson, W.E. 1984. Great pockets: the tiefenglatscher quartz grotto. *Mineralogical Record* 15:253-255.