September 2004 Mineral of the Month: Japan-Law Twinned Quartz

> "Of the various twin laws exhibited by quartz, few are more desirable or interesting to the collector than the Japan law. Such specimens are generally attractive, normally available from only a few locations worldwide, and often expensive." --Robert B. Cook, *Mineralogical Record*, May-June 1979.

PHYSICAL PROPERTIES

Chemistry: SiO_2 Silicon Dioxide
Class: Silicates Subclass: Tectosilicates Group: Quartz
Crystal System: Hexagonal (Trigonal)
Crystal Habits: Usually long, prismatic crystals, striated crosswise and frequently terminated by double rhombohedrons shaped like hexagonal pyramids; less frequently, short prisms to nearly bipyramidal; sometimes distorted, skeletal, and drusy; also granular, disseminated, and massive (microcrystalline). Twinning relatively common.
Color: Colorless, white, and many shades, often with varietal names such as rose quartz, pink to rose-red; amethyst, purple; rock crystal, transparent and colorless; smoky quartz, pale brown to near-black; milky quartz, milk-white; citrine, yellow. Twinned crystals are usually colorless; may be smoky or amethyst in rare instances.
Luster: Vitreous to slightly greasy
Transparency: Transparent to translucent
Streak: White
Refractive Index: 1.55
Cleavage: Generally none; occasionally exhibits indistinct rhombohedral parting
Fracture: Conchoidal to subconchoidal
Hardness: Mohs 7.0
Specific Gravity: 2.65
Luminescence: Triboluminescent (luminescence caused by friction)
Distinctive Features and Tests: Best field marks are vitreous to greasy luster, crosswise-striated hexagonal crystals, and hardness.
Dana Classification Number: 75.1.3.1

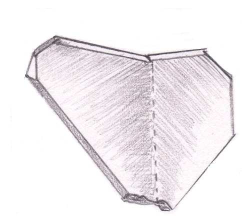

Figure 1 Japan-Law twinned quartz

NAME

The English word "quartz" derives from the German *Quarz*, which in turn may have originated from the archaic Slavic word *kwardy*, meaning "hard." It is correctly pronounced KWÔRTZ. Quartz-variety names are often based on color (see "Color" under *Physical Properties* above). Inclusions and crystal shapes are also criteria for varietal names, and include scepter, faden, and specific types of twinned crystals. Japan-law twins, a type of symmetrical twinning found in quartz, are named for Japan, the nation in which the modern type locality, the Otome Mine, is located (see "History and Lore").

COMPOSITION

The mineral quartz, in its seemingly infinite forms and colors, must truly be one of our Creator's greatest gifts to mankind! Many beginning collectors (including us) are drawn to the study of minerals by the sharp angles and faces and the remarkable clarity of quartz crystals, so abundant in the Earth that all can afford them. Some experienced collectors devote their collections to the countless forms quartz takes, while others devote a special section, such as noted mineral writers Si & Ann Frazier, who have undertaken to examine and chronicle this remarkable mineral, and who provided us with some special information on Japan-law twins.

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Last year in June, we examined the phenomenon of scepter quartz, when we sent specimens from the new find at the Lilliana Mine, near the city of Chihuahua, Mexico, and in March of this year, we focused on the unique formation of “Cactus” quartz from the new find at Boekenhout, South Africa. And this month, we get to highlight another unique formation peculiar to quartz. We hope to make the explanation of their formation deep enough to get to the core understanding, but simple enough to understand.

First, some of the oft-repeated background of this marvelous mineral. Quartz’s chemical formula, SiO_2, tells us that it consists of the elements silicon and oxygen. Within the quartz molecule, the cationic silicon ion (Si^{+4}) is drawn to the combined -4 charge of two oxygen (O^{-2}) ions. The total atomic weight of quartz, or silica, consists of 53.26 percent oxygen and 46.74 percent silicon.

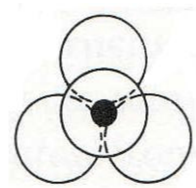

Figure 2 Silica tetrahedron. Image courtesy of Mineralogy by John Sinkankas, used by permission.

Silicon and oxygen are the most abundant elements in the Earth’s crust, together comprising 75 percent of total crustal weight. Quartz is the most abundant mineral and silicates are the largest class of minerals. Despite its chemical simplicity, quartz has a somewhat complex atomic structure. Quartz is a tectosilicate or “framework” silicate, in which the basic structural unit is the tetrahedral configuration SiO_4. Each silica tetrahedron shares the oxygen ions at its corners with another tetrahedron to form a repeating, rigid, compact, three-dimensional framework. The silicon ions lie on interpenetrating hexagonal lattices, surrounded by oxygen ions in a tetrahedral configuration. This so-called “hexagonal, close-packed” crystal lattice is a very dense form of atomic packing that fills three-quarters of the space within the lattice.

Quartz’s dense, rigid crystal structure determines its physical properties. Like non-crystalline glass, the quartz lattice has neither a center of symmetry nor any significant cleavage planes. Because of quartz’s repeating tetrahedral structure and absence of well-defined cleavage planes, quartz has a relatively high Mohs hardness of 7.0 and resists abrasion well. Despite close atomic packing, the relative lightness of its elemental components accounts for its low density (specific gravity 2.65).

There are three basic ways in which quartz crystals grow: as a component of crystallizing magma; by the crystallization of silica-rich, hydrothermal fluids; and by the downward percolation of silica-rich, meteoric (ground) waters. In all growth environments, the crystal grows by adding layers of atoms, one layer at a time. This crystallization process begins when a tiny crystal, called a “seed” crystal, forms from solution. Growth occurs as the seed crystal accumulates more of the same mineral constituent from its fluid environment. In the growth of quartz crystals, silica-rich fluids continuously deposit more silica to form new tetrahedra on growing crystal lattices and faces. With space for growth, slow cooling, and a steady supply of silica-rich fluid nutrients, the growing quartz crystals almost always adhere closely to the basic hexagonal crystal form, developing as single, independent crystals unrelated to other quartz crystals, even those that are adjacent or directly adjoining. However, errors that occur in this methodical and repetitive crystal-growing process sometimes produce variant crystal forms, such as the symmetrical “double” crystal arrangement called “twins,” in which two crystals appear to be growing into, or out of, each other.

TWINNED CRYSTALS

Twinned crystals, or simply “twins,” are among the more interesting and unusual crystal forms. Twins are not to be confused with crystal clusters or pairs, in which single crystals exhibit a random alignment of crystallographic axes as a result of coincidental growth. True twinned crystals are much rarer and form from the orderly, symmetrical intergrowths of crystals. By definition, twinned crystals are rational, symmetrical intergrowths of two or more individual crystals of the same mineral species. In crystallography, “rational” means that the twins share common lines, planes, or points; “symmetrical” indicates that the twins are related by crystallographic symmetry. The terms “individual” or “component” refer to one crystal of a twin; the term “single,” or “single crystal,” refers to an untwinned crystal. In a discussion of twinned crystals, “symmetry” is defined as a correspondence of size, shape, and relative position of parts on opposite sides of a dividing line or median plane or about an axial center.

Because twinning increases a crystal’s symmetry by adding new symmetrical elements, it is usually defined by the symmetry operations involved. Important symmetry operations include:
1. **Reflection across a mirror plane**, in which the added mirror plane is called a “twin plane.” This is often a good way to identify twins, as two faces, one on each twin, are exactly opposite from each other and mirror each other.
2. **Rotation about an axis** within the crystal, in which the double rotation axis is called a “twin axis.” An example of this is the Dauphiné-law quartz crystal described under Transformation twins.
3. **Inversion through a common point**, in which the added center of symmetry is called a “twin center.”

The rule that governs a specific twinned crystallographic relationship is called “twin law.” Twin law specifies the symmetry operation and its orientation, as well as the type and orientation of the compositional surface or plane which joins the twins. In the lexicon of crystallography, the term “operation” refers to a mathematical or logical process that derives one entity from another according to a rule.

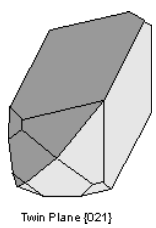

Figure 3
Orthoclase crystals twinned on the Braveno-law

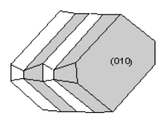

Figure 4
Plagioclase feldspar crystals twinned on the Albite-law

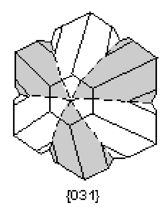

Figure 5
Chrysoberyl cyclical twins. All drawings on this page courtesy of Stephen A. Nelson, Tulane University

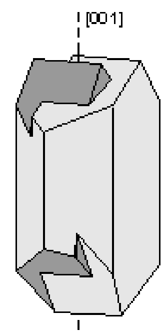

Figure 6
Orthoclase twinned on the Carlsbad-law

The general types of twinned crystals include:

1. **Contact twins,** which have a planar composition surface between the two individual crystals. These are usually defined by a twin law that expresses a twin plane, such as an added mirror plane. Examples are the Braveno-law orthoclase twins found in Figure 3. Contact twins can also occur as repeated or multiple twins. If their compositional surfaces are parallel to one another, they are called **polysynthetic twins**, an example of which are Albite-law plagioclase twins in Figure 4. Multiple contact twins, in which the compositional surfaces are not parallel to one another, are called **cyclical twins**, an example of which are cyclical chrysoberyl twins, seen in Figure 4.
2. **Penetration twins**, unlike contact twins, have an irregular composition surface between two individual crystals. The Carlsbad-law orthoclase twins in Figure 6 are a familiar example.

Twinned crystals are also categorized by the nature of their origin:

1. **Growth twins**, or primary twins, develop when errors occur during crystal growth causing a new crystal to be added to the face of an existing crystal. Twinning occurs when the new crystal shares lattice points with the existing crystal, but has a different orientation. Growth twins may be either contact or penetration twins. Japan-law quartz twins are classic examples of growth-contact twinning.

2. **Transformation twins** develop when an existing crystal undergoes a transformation due to a change in pressure or temperature. This commonly occurs in minerals that have different crystal structures (and thus different symmetries) at different temperatures and pressures. When temperatures and pressures change during the crystal-growth process to levels in which other crystal structures and symmetries become stable, different parts of the crystal arrange themselves in different symmetrical orientations, thus creating an intergrowth of one of more crystals. Dauphiné-law and Brazil-law quartz twins commonly form in this manner when temperatures decrease during the growth process.

3. **Deformation twins**, or glide twins, develop when mechanical stresses displace atoms from their normal positions to new positions within the crystal lattice. Deformation twins, most common in calcite, grow when these new atomic positions are symmetrically related to the original crystal lattice.

Twinning is often a valuable diagnostic feature in mineral identification. While many twins are immediately and outwardly identifiable, others are not. Some twinned crystals can be positively identified only by such laboratory methods as etching. Crystals in question are immersed briefly in appropriate chemical reagents (hydrofluoric acid or ammonium bifluoride in the case of quartz), then examined. Because the basic atomic structure imparts specific and diagnostic differences in chemical resistance on parts of the crystal faces, etching produces thin, wormy lines called "etch figures." Comparison of the orientation of etch-figure patterns on the corresponding faces of individual crystals can confirm whether or not a crystal is indeed twinned.

JAPAN-LAW TWINNED QUARTZ CRYSTALS

Quartz forms at least six several different types of twinned crystals, the most common of which are the Brazil-law and Dauphiné-law varieties. But Japan-law quartz twins, while much less common, are nevertheless more familiar due to their characteristic and easily recognizable "V" shape. Japan-law twins are growth-type contact twins that share a common basal point and are symmetrically inclined to each other at a precise angle of 84 degrees and 33 minutes (slightly more acute than a right angle). Brazil-law and Dauphiné-law quartz twins are more difficult to recognize. Unlike Japan-law contact twins, these are penetration twins which intergrow around a common, main longitudinal axis that produces only an unusual arrangement of crystal faces.

Technically, Japan-law quartz twins include four distinct subtypes which are difficult to distinguish visually. All are contact twins with the c-axes (in quartz crystals the c-axis is the longest axis) of the two individual crystals precisely aligned at the 84-degree, 33-minute angle. Just one of these four subtypes has a true mirror plane, however. The other three have pseudotwin planes which only express the angular relationship between the axes of the twinned parts.

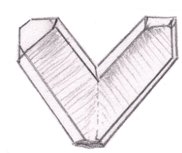

Figure 7 Japan-law twin quartz crystals

Japan-law twinned quartz crystals have two general appearances. One twin looks like a "V" with the individual crystals, or "wings," either slightly tabular (flattened) or distinctly prismatic, as seen in Figure 7. In the other twin, both individual crystals are tabular and have a heart- or butterfly-like shape (Figure 8). In the "V" twin, the contact area, or compositional plane, between the two individual crystals is relatively small. But with heart- or butterfly-shaped twins, the contact area is much larger. This contact area, which actually forms a rare trigonal dipyramid, is most often irregular and shows a zigzag or "squiggly" pattern, but can sometimes be planar (straight). Japan-law twins also have a tendency to break along this compositional plane.

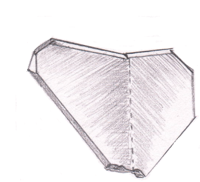

Figure 8 Japan-law twin quartz crystals

September 2004 Mineral of the Month: Japan-Law Twinned Quartz

The relative scarcity of Japan-law twinned quartz crystals is belied by the great abundance of quartz. Although twins are often seen at shows and exhibits, they are nevertheless very rare when compared with single quartz crystals. Of the huge number of quartz-crystal deposits worldwide, less than 100 have yielded Japan-law twinned crystals. Even within these specific deposits, Japan-law twins account for only a tiny fraction of the crystals present.

Apart from their distinctive shapes and symmetries, Japan-law twins differ from single quartz crystals in other ways. While single quartz crystals can measure many feet in size, Japan-law twins are, on average, much smaller. While the "wings" of a few Japan-law quartz twins measure about one foot, most measure less than one inch. Another interesting feature of Japan-law twinned quartz crystals is that they usually lack color. Single quartz crystals typically occur in a wide range of colors, the familiar varieties of which include smoky quartz, rose quartz, amethyst, and citrine. But most Japan-law twins occur only in the colorless, rock-crystal variety of quartz. This observation infers that the trace presence of chromophoric (color-forming) elements such as iron, which imparts colors to quartz, inhibits the growth of twinned crystals on the atomic level.

Twinned quartz crystals are sometimes confused with distorted single crystals or even with pairs of adjoining single crystals that appear symmetrically aligned. However, study of the crosswise striations on prism faces, one of quartz's most important diagnostic features, can often identify true twins. At the contact between two twinned individual crystals, the striae on the adjoining prism faces of the individual crystals meet at nearly right angles. This relationship is absent in distorted single crystals and in pairs of adjoining single crystals that sometimes "masquerade" as twins.

COLLECTING LOCALITIES

Although single-crystal quartz is abundant and occurs worldwide, Japan-law crystal sources are quite limited. Some of the best recent specimens have come from the Tentadora Mine, Pampa Blanca, in the Castrovirreyna (spelled Castrovirreña on our labels) Province of Peru's Huancavelica Department, as detailed under *About Our Specimens*. Another prominent South American locality is the Chicote Grande Mine in Bolivia's La Paz Department. In Africa, Japan-law quartz twins, some with a faint amethyst coloration, are collected at Andilamena, Toumasina, Madagascar. Sites near the modern type locality, the Otome Mine in Japan's Yamanashi Prefecture, continue to provide a few specimens. Another Japanese source is Narushima Island in the Nagasaki Prefecture.

In North America, Japan-law quartz localities include several sites in the Valhalla Mountains of British Columbia, Canada; Spruce Ridge, North Bend, King County, Washington; the Washington Camp-Duquesne area in Santa Cruz County, Arizona; Mina Tiro Estrella in the Capitán Mountains of Lincoln County, New Mexico (possible smoky coloration); the PC Mine in Jefferson County, Montana; and at several Arkansas rock-crystal sites.

JEWELRY & DECORATIVE USES

Small Japan-law quartz twins are occasionally mounted for wear as pendants, most often for use in a metaphysical context. Twinned crystals, especially Japan-law quartz twins, have developed their own following among mineral collectors, some of whom specialize in twinned specimens. In the collectors' market, twinned crystals are considerably more valuable than single crystals of the same mineral. The popularity of twinned crystals, including Japan-law quartz twins, among collectors is reflected in the selection of twinned crystals as the theme of the 1999 Munich (Germany) Gem and Mineral Show.

September 2004 Mineral of the Month: Japan-Law Twinned Quartz

HISTORY & LORE

Twinned quartz crystals have probably been known, though not understood, since antiquity. Efforts to explain twinned crystals date back to the time of the earliest morphological crystal observations, such as those made in 1669 by Danish geologist and physician Nicolaus Steno (Niels Stensen, 1638-1686). The German crystallographer and mineralogist Christian Samuel Weiss (1780-1856) first formally described Japan-law twinned quartz crystals in 1829. This twin law was initially known as "Weiss' law," or the "La Gardette law," the latter after France's La Gardette gold mine, which provided the best specimens at the time. These names persisted until the early 20th century, shortly after quantities of superb, larger specimens became available from the Otome Mine in Japan's Yamanashi Prefecture. In 1905, the prominent, Swiss-born crystallographer and mineralogist Victor Moritz Goldschmidt (1853-1933) published this particular twin law in German as *Japaner Gesetz*, literally "Japanese order," or "Japanese law." Although "La Gardette law" is still used in France and several other parts of Europe, "Japan law" is the term that most of the world now uses to describe these particular twinned quartz crystals.

Because of quartz's abundance and familiarity to most researchers, the study of Japan-law twins took on a special significance and led the way to the identification and study of the twinning phenomenon in other mineral species. Although confusion about twinning initially delayed the definition and organization of the basic crystal systems, understanding the twinning phenomenon and the ability to identify twinned crystals eventually aided the advancement of crystallography. By 1900, the study of twinned crystals had evolved into a specialized branch of crystallography. Today, this branch is sometimes known among some researchers as "geminography," literally the "study of twins."

Those interested in twinned crystals will enjoy a visit to the Janet Annenberg Hooker Hall of Geology, Gems, and Minerals at the Smithsonian Institution's National Museum of Natural History in Washington, D.C., where exhibits include spectacular specimens of twinned crystals of many different mineral species, as well as specimens representing all six laws of twinned-quartz crystals.

For metaphysical purposes, Japan-law quartz twins are said to aid in healing and uplifting the mind, body, and soul. They are also believed to promote the establishment of relationships and to stabilize emotions, dispel anger, and direct the energy of two individuals toward the same purpose.

TECHNOLOGICAL USES

Although Japan-law twinned quartz crystals have no direct technological or industrial applications, knowledge derived from their study has contributed to crystallography, specifically to the understanding of how crystals deviate from the norm. The ability to identify twinning in natural quartz is important in the commercial synthesis of quartz. Today, synthetic quartz "wafers" have electronic uses as filters, frequency controls, and timing components in such products as communications equipment, televisions, watches, computers, and electronic games. This synthetic, or "cultured," quartz must be electronically perfect and able to conduct and modify electrical current in a highly predictable and reliable manner. Such properties are found only in perfect, single quartz crystals and never in twinned crystals. Thus, natural quartz used as seeds in hydrothermal synthesizing processes must first be positively identified as single, and not twinned, crystals.

ABOUT OUR SPECIMENS

Back in July 1997, when we had only about 100 members, we were offered a lot of very fine epidote crystals from Peru, groups of needle-like green crystals without matrix. Little did we know at the time that seven years later, we would be featuring outstanding twinned quartz crystals from the other side of the highway! The mine name we had then for the epidote was Mina Provincia Mabel, now more correctly known as Mina Rosario Mabel. (We are trying to accumulate enough epidote from this mine in order to feature it again in the future.)

Our Japan-law twinned crystals come from the Tentadora (Spanish for "Temptress") Mine, in the steep cliffs near the small village known of Pampa Blanca ("White Prairie"), about 90 kilometers east of Pisco, which is about 200 kilometers south of Lima, Peru. The mine is located in Castrovirrena Province, a province being roughly the equivalent of a county, and Huancavelica Department, a department being the equivalent of a state, close to the border of Ica Province.

Peru, which has been one of the world's most prolific sources of mineral specimens for the past twenty years, is a nation of 23.4 million people of Indian and mixed European and Indian descent. The third largest nation in South America, almost twice the size of Texas, it sits along the western coast of South America, The Andes Mountains split the nation into three major regions: a narrow coastal belt occupied by a barren desert, the jagged snow-covered peaks on the Andes mountains in the center, and the tropical rain forests of the Amazon basin to the east. Tourists visit colonial cities that preserve the legacy of the Spanish conquistadors, visit the ancient Incan capital of Cuzco, and explore the lost city of Machu Picchu.

Figure 9 Cliffs at Pampa Blanca, Peru

Figure 10 Collector/dealers holding a specimen at Pampa Blanca

The 1979 *Mineralogical Record* lists more than 70 worldwide localities for Japan-law twinned quartz, including one in Peru. The Tentadora locality was not known at the time. It also did not finds its way into the special 1997 issue on "Mines and Minerals of Peru," though to confuse matters, there is another Tentadora Mine listed in the Julcani district of Huancavelica.

However, the update on Peruvian minerals in the May-June 2003 *Mineralogical Record* does comment on our wonderful pieces, starting with a description of the epidote locality and then moving onto our site:

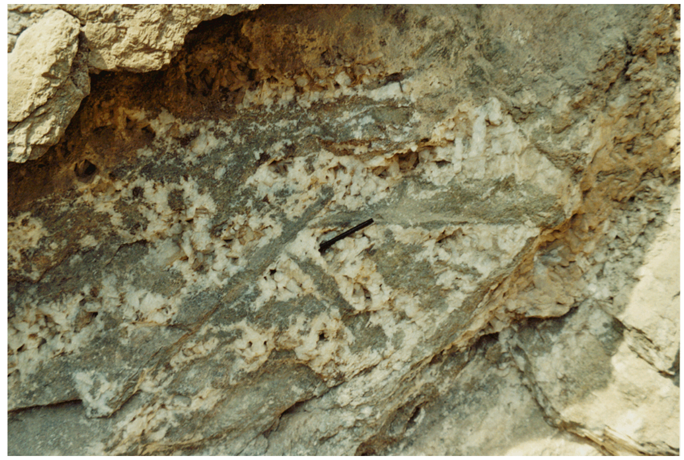

Figure 11 Vein containing Japan-law twinned quartz. Note the pen placed in the center for scale.

"The first Japan-law twinned quartz specimens from southern Peru appeared on the market around 1997. Secretive local suppliers have given various locality names, but the source is the Rosario Mabel claim near Pampa Blanca in Castrovirreyna Province, Huancavelica Department. Between 1995 and 1996 this claim also produced huge quantities of fine epidote specimens. In 1999 the claim was sold to a new owner, G. Russo, who renamed it 'Flor de Peru II.' The occurrence is a contact between granite and carbonate rocks, where abundant andradrite garnet, rarely in crystals to 2 cm, has been found with epidote. The epidote characteristically forms sprays of thin needles up to about 10 cm long; thick terminated crystals are quite rare. Japan-law twinned quartz here is rarer than at Ullpac Mountain; the crystals are similar in habit to the Ullpac specimens, but are transparent and thus much more attractive. The biggest specimen to reach the Lima market in 2001 weighs about 200 kg and contains at least 10 japan-law twins, each twin about 10 cm across. A huge 49-cm twin was found at Pampa Blanca in 2002. Rarely, calcite crystals occur on the quartz twins.

"Probably the world's most productive locality for Japan-law twinned quartz at present is the 'Flor de Peru I' claim at Ullpac Mountain, situated about 3 km north of Pampa Blanca; this abandoned copper (?) mine (which was called the Tentadora mine when it was active) began to produce specimens in 1999. The crystals come from simple quartz veins and are rarely accompanied by epidote, green platy vesuvianite, small scheelite crystals, and pale amethyst. Quartz here forms crystals to about 20 cm long. Japan-law twins are very common, averaging about 5 cm, occasionally reaching 10 cm. The twins are almost always flattened, and range in shape from the typical 'V' through heart-shaped to very rare 'closed squares.' The twins are usually accompanied by untwinned quartz crystals, but one part of the vein produced a limited number of groups to more than 30 cm in size, composed entirely of large Japan-law twins. Unfortunately, Ullpac quartz twins are usually rendered milky by a thin crust of younger, white quartz. Very rarely the twin shows green chlorite phantoms or are terminated by amethyst scepters."

We received a nice mixture of what is mentioned here, most being long thin twinned crystals on matrix, with a few of the highly flattened heart or butterfly shaped twins. Some were fairly square, but no matter what the form, we could always pick out the precise angle of 84 degrees and 33 minutes between the twins. We are very happy to be able to add such a wonderful specimen to our collection!

References: *Dana's New Mineralogy*, Eighth Edition; *Encyclopedia of Minerals*, Second Edition, Roberts, et al, Van Nostrand Reinhold Company; *1999 Glossary of Mineralogical Species*, J. A. Mandarino; *Mineralogy*, John Sinkankas, Van Nostrand Reinhold Company; "Peruvian Minerals: an Update," Jaroslav Hyrsl and Zolina Rosales, *Mineralogical Record*, May-June 1973; "Mines and Minerals of Peru," Jack A. Crowley, Rock H. Currier, Terry Szenics, *Mineralogical Record*, July-August 1997; "The Occurrence of Japan-law Twinning in Quartz," R. B. Cook, *The Mineralogical Record*, May-June 1979; "Twinning in Minerals," A. Blount and W. Shulman, *The Mineralogical Record*, September-October 1977; "Washington Japan-law Twins and Scepter Quartz Localities," Lanny R. Ream, *Rocks & Minerals*, November-December 1991; "Quartz Crystal (Industrial)," United States Geological Survey *2002 Mineral Commodity Summaries*; "The Frequency of Twin Types in Quartz Crystals," H. R. Gault, *American Mineralogist*, Volume 34, 1949; "The Genesis of Twin Crystals," M.J. Buerger, *American Mineralogist*, Volume 30, 1945. Special thanks to Professor Stephen A. Nelson, Tulane University.