

Mineral of the Month Club May 2016

QUARTZ var. TESSIN

This month our featured mineral is the Tessin variety of quartz from Peru's Pachapaqui mining district. Our write-up discusses the characteristics of this rare quartz habit and explains why quartz occurs in such an unusually broad variety of forms and colors.

PHYSICAL PROPERTIES:

Chemistry: SiO₂ Silicon Dioxide

Class: Silicates

Subclass: Tectosilicates

Group: Quartz

Crystal System: Hexagonal

Crystal Habits: Macrocrystalline quartz usually occurs as hexagonal prisms with crosswise striations and hexagonal or dihexagonal (12-sided) pyramidal terminations, and less frequently as short to nearly bipyramidal prisms. Crystals can also be distorted, skeletal, and drusy. Twinning is common. The rare Tessin habit is characterized by nonparallel, prismatic crystal faces that taper or converge from the base toward the termination, and that exhibit mosaic-like, striation patterns.

Color: The Tessin variety of quartz is usually colorless or white, but occasionally exhibits pale shades of purple (amethyst) or golden-yellow (citrine).

Luster: Vitreous to greasy

Transparency: Transparent to translucent

Streak: White

Refractive Index: 1.544-1.553

Cleavage: None

Fracture/Tenacity: Conchoidal/brittle to tough.

Hardness: Mohs 7.0

Specific Gravity: 2.65

Luminescence: Impurities sometimes create a pale, greenish-white fluorescence.

Distinctive Features and Tests: The best field marks for quartz are hardness; vitreous-to-greasy luster; distinct conchoidal fracture; and hexagonal crystals with crosswise striations and pyramidal terminations. The field marks for Tessin quartz are hexagonal crystal form with nonparallel prismatic faces that taper or converge from the base toward the termination and unusual, mosaic-like striation patterns.

Dana Classification Number: 75.1.3.1

NAME: The word "quartz" (pronounced KWORTZ) is derived from the German *Quarz*, which stems from the Slavic *kwardy*, meaning "hard." In European mineralogical literature, quartz appears as *Quarz*, *kwartz*, and *cuarzo*. The Tessin (pronounced TESS-in) variety of quartz is named for a locality in Tessin (Ticino), Switzerland, where this habit was first described. Tessin quartz is also known as "Tessiner quartz," a German name; "Binntal quartz," after a Swiss locality; and "Penninic quartz," after an occurrence in Switzerland's Pennine Alps.

Mineral of the Month Club May 2016

COMPOSITION & STRUCTURE: Quartz consists of 46.74 percent silicon (Si) and 53.26 percent oxygen (O). Silicon and oxygen are the most abundant elements in the Earth's crust; more than 2,000 silicate minerals make up 75 percent of the crust's total weight. The basic building block of all silicate minerals is the silica tetrahedron $(\text{SiO}_4)^{4-}$, in which four equally spaced oxygen ions 4O^{2-} positioned at the corners of a tetrahedron (a four-faced polyhedron) surround a silicon ion Si^{4+} . Quartz, a framework silicate or tectosilicate, occurs in both macrocrystalline and microcrystalline forms. As an allochromatic (other-colored) mineral, quartz is colorless when pure, but traces of nonessential, color-producing elements called chromophores create a wide range of colors. Quartz is found in virtually all igneous, metamorphic, and sedimentary rocks. It forms as a component of crystallized magma in intrusive and extrusive (volcanic) rocks; and also from crystallization of silica-rich, hydrothermal fluids and groundwater. Tessin quartz most commonly forms in alpine-type fissures, which are vugs within granitic rocks that are created when tectonic uplifting stretches and bends igneous rock formations. These fissures later fill with silica-rich hydrothermal solutions or groundwater that crystallizes in the form of quartz. Unlike the crystals in geodes, mariolitic (gas-formed) cavities, and pegmatite vugs that develop within concentric zones of alteration or on secondary mineralization, the crystals in alpine-type fissures form directly on the host rock. Mineralogists believe that Tessin quartz grows very slowly in high temperatures around 500°C . (932°F .) and forms from the crystallization of silica-rich solutions that contain significant quantities of dissolved carbon dioxide. The Tessin variety of quartz is among the rarest of all quartz habits.

COLLECTING LOCALITIES: Although quartz is very abundant, the rare Tessin variety is found in relatively few localities. Tessin quartz occurs in Peru, Switzerland, Nepal, Spain, Japan, Colombia, Madagascar, Ukraine, Greece, and the United States (Colorado, Arkansas, Connecticut, North Carolina, New Hampshire).

HISTORY, LORE & GEMSTONE/TECHNOLOGICAL USES: Various forms of quartz have been collected since antiquity and used as gemstones and ornamental stones, and as materials for flaking into tools and weapons. Metaphysical practitioners have traditionally used spherical "crystal balls" fashioned from colorless, transparent quartz for divining purposes. Medieval physicians prescribed the ingestion of powdered quartz generally to relieve pain and specifically to alleviate renal and intestinal ailments. Until synthetic quartz became available in the 1960s, crystallographically perfect forms of natural quartz served in many optical and electronic uses. Tessin quartz was identified as a rare, unusual habit of quartz in the mid-1800s after study of specimens obtained from alpine fissures in the Swiss Alps. The crystallography of the Tessin habit was formally described in 1952 by the German mineralogist Carl Friedlaender. Modern metaphysical practitioners consider quartz to be the "universal crystal" because of its purported abilities to sharpen insight, enhance spiritual development, improve concentration, refine focus, energize the mind, and facilitate channeling and astral travel. They also believe that Tessin quartz is an "unlocking" stone that accesses hidden realms of the mind to encourage the exploration of spiritual mysteries and to speed astral movement in psychic journeys. Tessin quartz has no technological uses.

Mineral of the Month Club May 2016

ABOUT OUR SPECIMENS: Our specimens of the Tessin variety of quartz were collected at the Pachapaqui mining district near the village of Pachapaqui in the Pachapaqui District, Bolognesi Province, Ancash Department, Peru. The Pachapaqui District covers 168 square miles and has an average elevation of 10,948 feet. It is 80 miles east of the Pacific Coast and 150 air miles due north Peru's capital city of Lima. Mineralization at Pachapaqui was emplaced following the crustal fracturing that accompanied the Andean Orogeny (mountain-building episode) some 60 million years ago. Multiple phases of mineral-rich, hydrothermal solutions surged upward into fractures within quartz-monzonite and granitic country rock where they precipitated an array of minerals in complex vein systems. These multimetal deposits contain economic quantities of zinc, silver, lead, molybdenum, copper, and manganese minerals; although small and erratic, the veins are extraordinarily rich. The Pachapaqui mining district is located in a remote and isolated part of the high Andes. The village of Pachapaqui, population 1,000, rests at an elevation of 12,467 feet; its nearby mines are considerably higher. At Pachapaqui, Tessin quartz is not directly associated with the mineralized vein systems, but is recovered from alpine-type fissures within the adjoining, granitic host rock. Our specimens of Tessin quartz were recovered by miners who drove exploration tunnels through the host rock in search of mineralized veins. Tessin quartz crystals do not have parallel prismatic faces, but taper or converge from the base toward the termination. Tessin quartz crystals also lack the simple, transverse, linear striations that are characteristic of most other forms of quartz. Instead, their striations appear as blocky, mosaic-type patterns that are unique to Tessin quartz. Your specimen of Tessin quartz formed during or shortly after the uplift of the Andes, but before the emplacement of mineralization in the Pachapaqui mining district.

COMPREHENSIVE WRITE-UP

COMPOSITION & STRUCTURE

Quartz [silicon dioxide, SiO_2] contains two elements: the semimetal silicon (Si) and oxygen (O). Silicon and oxygen are the most abundant elements in the Earth's crust; more than 2,000 silicate minerals make up 75 percent of the crust's total weight. The molecular weight of quartz consists of 46.74 percent silicon and 53.26 percent oxygen. All molecules are made up of positively charged cations that are bonded to negatively charged anions. The cation in the quartz molecule is the silicon ion Si^{4+} with its +4 charge. The anion consists of two oxygen ions 2O^{2-} with their collective -4 charge. The balance of the +4 cationic and -4 anionic charges provides the quartz molecule with electrical stability.

Chemically, quartz is classified as an oxide, a mineral in which metals or semimetals combine with oxygen. But in terms of structure, which is the basis of modern mineral-classification systems, quartz is considered a silicate, a mineral in which the basic building block is the silica tetrahedron $(\text{SiO}_4)^{4-}$. In the silica tetrahedron, four equally spaced oxygen ions 4O^{2-} positioned at the corners of a tetrahedron (a four-faced polyhedron) surround a silicon ion Si^{4+} . In the quartz-crystal lattice, all four oxygen ions in each silica tetrahedron bond covalently with the silicon ions of adjacent tetrahedra. In this configuration, four oxygen ions surround each silicon

Mineral of the Month Club May 2016

ion, while two silicon ions surround each oxygen ion. Because this “four-oxygen-coordination” arrangement satisfies the -4 charge of each individual tetrahedron, no other ions are needed for electrical stability. The result is quartz’s infinite, three-dimensional structure, in which each electrically balanced molecular unit is described by the formula SiO_2 .

Repeating chains of silica molecules form seven types of structures: independent tetrahedral silicates (nesosilicates); double tetrahedral silicates (sorosilicates); single- and double-chain silicates (inosilicates); ring silicates (cyclosilicates); sheet silicates (phyllosilicates); and framework silicates (tectosilicates). Quartz is a framework silicate or tectosilicate that occurs in both macrocrystalline and microcrystalline forms. Macrocrystalline quartz appears as large, individual, transparent-to-translucent crystals or crystal groups. Microcrystalline quartz (chalcedony) is a compact or massive form that consists of interlocked, microscopic silica grains and includes such varieties as chert, jasper, and agate. Quartz, which is found in virtually all igneous, metamorphic, and sedimentary rocks, forms as a component of crystallized magma in both intrusive and extrusive (volcanic) rocks; by crystallization of silica-rich, hydrothermal fluids; or, in the case of our specimens of Tessin quartz, by crystallization of silica-rich groundwater.

Quartz crystallizes in the hexagonal system, which has four axes. Three are of equal length and lie on a plane; the fourth, which is unique to the hexagonal system, is perpendicular to the plane of the other three axes and is of variable length. The most common quartz habit is the hexagonal or six-sided prism, in which all six prismatic faces are parallel to the unique axis. Quartz crystals are terminated by hexagonal or dihexagonal (12-sided) pyramids. Atomic bonding within the quartz lattice is exclusively covalent. Because covalent bonding exerts omnidirectional strength, quartz crystals exhibit no cleavage. This lack of cleavage and the high bonding strength resulting from close atomic packing account for quartz’s great durability and for its substantial hardness of Mohs 7.0. Yet despite quartz’s close atomic packing, the low atomic weights of its essential elements silicon (28.09) and oxygen (16.00) result in a relatively low specific gravity of 2.65. Although most minerals eventually abrade into fine particles and eventually become chemically disassociated, huge quantities of hard, durable, chemically stable quartz sand accumulate as beaches, deserts, sea bottoms, and dune fields. These granular silica deposits sometimes lithify into sandstone, a common sedimentary rock that often subsequently metamorphoses into quartzite, a tough, hard, compact rock that can survive most weathering and erosion processes to form large geological features such as plateaus, mesas, and cliffs.

Quartz is an allochromatic (other-colored) mineral, meaning its colors are caused by traces of nonessential, color-producing elements called chromophores. Pure or nearly pure quartz is colorless and often highly transparent, but the presence of chromophores creates a road range of colors (see “*Quartz: Many Colors, Many Forms*”).

The Dana mineral classification number 75.1.3.1 first identifies quartz as a tectosilicate or framework silicate (75). The subclassification (1) next defines it by the chemical formula SiO_2 and by its four-oxygen coordination within the lattice configuration in which four oxygen ions are bound to each silicon ion. Quartz is then assigned to the quartz group (3) as the first (1) and only member. Quartz also occurs in several polymorphic forms which have identical

Mineral of the Month Club May 2016

chemistries, but different crystal structures. These include cristobalite (tetragonal), tridymite (triclinic), coesite (monoclinic), and stishovite (tetragonal).

Tessin quartz differs structurally from other types of macrocrystalline quartz. The most common mineralogical environment in which Tessin quartz forms is alpine-type fissures. These are vugs that are usually, but not always, found in granitic rocks. The origin of alpine-type fissures is unlike that of geodes, mariolitic (gas-formed) cavities, and pegmatite pockets. Alpine-type fissures are created during tectonic uplifting and the subsequent stretching and bending of igneous rock formations. These fissures later become filled with silica-rich groundwater that crystallizes in the form of quartz. Also unlike geodes, mariolitic cavities, and pegmatite vugs, alpine-type fissures have no concentric zones of alternation or associated, secondary mineralization; the crystals within alpine-type fissures form directly on the host rock.

Mineralogists believe that Tessin quartz grows very slowly in high temperatures around 500° C. (932° F.) from the crystallization of silica-rich solutions that contain significant quantities of dissolved carbon dioxide. The presence of carbon dioxide is thought to interfere with the development of the normal quartz crystal lattice, thus producing the rare Tessin habit. Tessin quartz is similar in color and degree of transparency to other forms of macrocrystalline quartz. It is visually distinguishable only by its prismatic faces that taper or converge from the base toward the termination, and by its distinctive, mosaic-type striations. When thin sections of Tessin quartz are viewed through polarizing microscopes, their internal, mosaic-type structure becomes visible.

COLLECTING LOCALITIES

Tessin quartz is rare and has relatively few collecting localities. Our specimens are from the Pachapaqui mining district in the Pachapaqui District, Bolognesi Province, Ancash Department, Peru. The leading sources of Tessin quartz are the Bedretto and Vergeletto valleys at Leventina, Tessin (Ticino), Switzerland. Another important Swiss source of Tessin quartz is Turbealp, Binntal, Wallis. Other localities include the Dharding region and Ganesh Himal, both in Nepal; Almuñicar, Granada, Spain; Namarasawa, Nikko, Tochigi Prefecture, Kanto Region, Honshu Island, Japan; the San Cristobal pegmatite, Suaita, Santander Department, Colombia; the Itremo Massif, Ambotofinandrahana District, Amoran'i Mama Region, Fionarantsoa Province, Madagascar; Volodarsk-Volynskii, Zhytomyr Oblast', Ukraine; and Serifos Island, Kykládes Islands, Kykládes Prefecture; Aegean Islands Department, Greece.

In the United States, Tessin quartz is found near Lake George in Teller and Park counties, Colorado; Garland County, Arkansas; Becker's Quarry, West Willington, Tolland County, Connecticut; Cary in Wake County and Hiddenite in Alexander County, both in North Carolina; and Spruce Hill at Fremont, Rockingham County, New Hampshire.

JEWELRY & DECORATIVE USES

Mineral of the Month Club May 2016

Although many forms of macrocrystalline and microcrystalline quartz serve as gemstones and ornamental stones, Tessin quartz is too rare for such uses. Specimens of Tessin quartz are collected for their rarity; unusual, tapering prismatic faces; and distinctive, mosaic-like striations.

HISTORY & LORE

Although most forms of quartz have been known since antiquity, Tessin quartz was discovered only in the mid-1800s after crystallographers had sufficiently defined the basic structure of quartz and realized that the Tessin variety represented a crystallographic anomaly. Tessin quartz is named for a locality in Tessin (Ticino), Switzerland. It is also known as “Tessiner quartz,” a German name; “Binntal quartz,” after a Swiss locality; and “Penninic quartz,” for localities in the Swiss Pennine Alps. German mineralogist Carl Friedlaender published the first formal description of the Tessin habit in 1952. Tessin quartz most commonly occurs in alpine-type fissures. These vug-type mineralogical environments were originally called “alpine fissures” because they were first identified and studied in the European Alps. Mineralogists now prefer the term “alpine-type,” because such fissures are also found in other mountain ranges, including the Urals and Himalayas, as well as in relatively low mountain ranges.

Modern metaphysical practitioners consider quartz to be the “universal crystal” because of its purported abilities to sharpen insight, enhance spiritual development, improve concentration, refine focus, energize the mind, and facilitate channeling and astral travel. They believe that Tessin quartz is an “unlocking” stone that accesses hidden realms of the mind to encourage the exploration of spiritual mysteries and to speed astral movement in psychic journeys.

Although Tessin quartz has no technological uses, it has served as the model for its own laboratory synthesis, a process that supports the theory that in natural mineralogical environments it forms very slowly in unusually high temperatures (see “*Composition & Structure*”).

QUARTZ: MANY COLORS, MANY FORMS

Tessin quartz, this month’s featured mineral, is one of many quartz varieties. In fact, quartz has more varieties, subvarieties, habits, forms, and colors than any other mineral, for four basic reasons.

1: Quartz is very abundant and occurs in every mineralogical environment and virtually every type of rock. This means that quartz has the capability of developing in a broad range of pressures, temperatures, and chemistries, all of which modify its growth in various ways to create many forms and habits.

2/ Quartz occurs in two radically different crystalline forms: macrocrystalline and microcrystalline, both of which develop in a variety of mineralogical environments and thus have many different habits and forms.

Mineral of the Month Club May 2016

3/ The quartz crystal lattice accommodates many accessory elements that produce an almost limitless range of colors.

4/ Because quartz develops in so many different mineralogical environments with varying chemical and physical conditions, it often occurs with foreign minerals included within its crystal structure, or coated onto its crystal faces. Both inclusions and coatings produce their own range of colors and a variety of optical effects.

When we consider the possible number of combinations of these four factors, it becomes easy to understand why quartz has such a wide range of form and color. As an example, we have featured quartz as our Mineral of the Month 18 times—all with different colors, crystalline structures, or habits. And there are still many types of quartz that we have yet to feature.

Naturalists and early scientists could not understand how so many different types of quartz could all be varieties of the same mineral. Accordingly, until the late 1700s, many forms of quartz that we now classify as varieties were considered to be separate species. The first step toward defining the true nature of quartz and understanding its large number of varieties was taken in 1780 by the Swedish chemist and naturalist Torbern Olaf Bergmann (1735-1784), who noted that, while visually quite different, rock crystal, amethyst, citrine, flint, agate, and jasper all had an apparent chemical similarity. But it was not until 1823 that the Swedish chemist Jöns Jacob Berzelius (1779-1848) decomposed quartz into oxygen and a previously undiscovered element, silicon, to demonstrate that quartz consisted of silicon dioxide or SiO_2 . Only after other researchers had decomposed other types of quartz to yield identical proportions of silicon and oxygen, did scientists realize the true number of quartz varieties.

Scientists then classified the forms of quartz based on the general appearance of their crystal structures into three groups: macrocrystalline, microcrystalline, and cryptocrystalline. “Macrocrystalline quartz” (macro—“large”) consisted of visible, individual crystals; “microcrystalline quartz” (micro—“small”) consisted of compact material composed of tiny individual crystal grains that were discernible under optical microscopes; and “cryptocrystalline quartz” (crypto—“hidden”), consisted of dense, crystalline grains too small to be discerned by optical microscopy. This classification system has been simplified today into two general categories: macrocrystalline, which includes such varieties as rock crystal and amethyst; and microcrystalline, which includes all forms other than macrocrystalline, such as agate, jasper, and flint, all of which are grouped under the umbrella term “chalcedony.”

Macrocrystalline quartz and microcrystalline quartz develop in entirely different ways. Macrocrystalline quartz, which occurs as transparent-to-translucent, individual crystals or crystal groups, grows by adding individual molecules of silica that collectively form new layers on a crystal surface. Conversely, microcrystalline quartz, or chalcedony, which consists of compact, interlocked, microscopic silica grains or fibers, forms when microscopic particles of silica from weathered silicate minerals are transported by groundwater in colloidal suspensions called silica

Mineral of the Month Club May 2016

gels. In mineralogical environments with lower temperatures and decreased pressures, these silica gels solidify or “freeze” into solid masses of chalcedony.

The colors seen in the various forms of quartz can have four different origins, or combinations thereof. Quartz readily accepts many chromophores (coloring agents) that alter its crystal lattice and thus the manner in which it reflects and absorbs light. Exposure to natural geophysical radiation also alters the light-absorption properties of quartz to produce colors. Quartz frequently contains tiny or microscopic inclusions of liquids, gas bubbles, and foreign minerals that impart colors or unusual optical effects; it is also sometimes coated with colorful, particulate minerals.

The main color varieties of macrocrystalline quartz are colorless, transparent rock crystal, which is essentially pure silica; transparent-to-translucent, purple-to-lilac amethyst that is colored by traces of iron and manganese; transparent, golden-yellow citrine with traces of iron; transparent-to-translucent, pink rose quartz with traces of titanium; and brown, gray, or near-black smoky quartz, which has been naturally irradiated. Translucent, white milky quartz contains tiny inclusions of gases and liquids; the varied colors in translucent cat’s-eye quartz are due to inclusions that also produce a chatoyant effect; opaque tiger’s-eye quartz has dense inclusions of asbestos fibers that create a banded chatoyancy and a silky luster; green quartz contains inclusions of chlorite-group minerals; and red or orange quartz is colored by inclusions or coatings of particulate hematite [iron oxide, Fe_2O_3].

The many forms of macrocrystalline quartz include drusy quartz, which occurs as coatings of numerous tiny, individual prisms; and stalactitic quartz, which consists of compact clusters of quartz crystals that grow downward in icicle-like shapes. Primary quartz crystals covered with smaller, secondary crystals create “cactus” quartz; individual quartz crystals overgrown by larger terminations are called “scepters”; gwindel quartz exhibits parallel or “stacked” structures created by opposing electrical charges that modified growth patterns; and floaters are distorted, “free-form” crystals that grow while unattached to a base or matrix. And the rare Tessin variety is the only form of quartz with nonparallel prismatic faces and mosaic-type, prismatic striations.

Chalcedony also assumes many forms and colors. As examples, translucent-to-opaque, multicolored agate exhibits banded or layered patterns; opaque jasper can be singularly colored or multicolored; translucent chrysoprase is colored apple-green by traces of nickel; and opaque carnelian exhibits rich, reddish colors caused by microscopic particles of hematite.

For many collectors, the most fascinating aspect of quartz is not individual form or color, but the variety and combinations of forms and colors. So great are the numbers of quartz varieties, that it is unlikely that anyone will ever amass a complete collection. And, incredibly, new types of quartz seem to be described almost every year.

TECHNOLOGICAL USES

Mineral of the Month Club May 2016

Unlike other forms of quartz, Tessin quartz, because of its rarity and modified crystal lattice, has no technological uses. It has, however, served as the model for its own laboratory synthesis.

ABOUT OUR SPECIMENS

Our specimens of Tessin quartz were collected at the Pachapaqui mining district near the village of Pachapaqui, Pachapaqui District, Bolognesi Province, Ancash Department, Peru. Ancash, one of Peru's 21 departments (political divisions comparable to American states), is located in northwestern Peru and extends from the Pacific coast eastward into the high elevations of the Andes. Covering 13,866 square miles, Ancash is about as large as the combined states of Massachusetts, Rhode Island, and Connecticut. Ancash Department is administratively divided into 20 provinces (comparable to American counties). Located in southeastern Ancash and the Cordillera Blanca, an Andean sub-range, sparsely populated Bolognesi Province has a rugged mountain topography. Bolognesi Province is divided into 15 administrative districts (comparable to American townships). The Pachapaqui District, which covers 168 square miles and has an average elevation of 10,948 feet, is 80 miles east of the Pacific Coast and 150 air miles due north Peru's capital city of Lima.

The Andean Orogeny (mountain-building episode) that uplifted the Andes Mountains some 60 million years ago accounts for Peru's contorted geology, dramatic topography, and abundant mineralization. Peru, one of the Earth's most tectonically active regions, lies directly on the contact of two tectonic plates: the Nazca Plate and the South American Plate, the common interface of which follows the Peruvian coast. At a rate of about two inches per year, the Nazca Plate is grinding over the South American Plate. For millions of years, this tectonic interaction has strained the regional crust and triggered a continuing succession of major earthquakes. The fractured and unstable regional crust has enabled magmatic intrusions and associated mineral-rich fluids to emplace rich mineral deposits. Mineralization at Pachapaqui was emplaced following the Andean Orogeny. Multiple phases of mineral-rich, hydrothermal solutions surged upward into fractures within quartz-monzonite and granitic country rock, creating vein-type, multimetal deposits rich in zinc, silver, lead, molybdenum, copper, and manganese minerals. Although small and erratic, these veins are often extraordinarily rich.

The remote and isolated village of Pachapaqui, population 1,000, rests at an elevation of 12,467 feet; its mines are considerably higher. Despite its lofty alpine elevation, Pachapaqui, which is only 750 miles south of the equator, enjoys a temperate climate. During the winter months of June, July, and August, light frost and clear, pleasant days are common; December through March marks the foggy, rainy season. The local economy is based on sheep and cattle herding; because mining activity is now limited to exploration, few mining jobs are currently available.

Details of early mining activity at Pachapaqui have been lost in history. Despite rich outcrops of silver, the Incas, the dominant culture in Peru when the Spanish arrived in 1532, did not mine them because of the high elevation and remoteness. Spanish prospectors made important, regional silver discoveries at Huallanca, Potosí, Huancavelica, Hualgoyoc, Castrovirreyna,

Mineral of the Month Club May 2016

Huancapeti, and Cerro de Pasco. By 1630, Spain's mines in the Viceroyalty of Peru were turning out five million troy ounces of silver per year. Although local oral tradition indicates that the Spanish mined silver at Pachapaqui, confirming documentary evidence does not exist.

Peruvian prospectors knew of the rich mineralization at Pachapaqui by the 1880s. But when Peru legalized foreign mine ownership in the 1890s to attract development capital and technical expertise, development at Pachapaqui was delayed by remoteness, poor roads, and high elevations until 1910. The first mines were shallow underground workings that followed only the richest silver veins; miners employed archaic, manual drilling techniques, then hand-cobbed (manually concentrated) the ore before hauling it to distant mills and smelters. Production remained limited for the next 40 years. In 1950, United States Geological Survey economic geologists surveyed the district and noted that only two of two dozen small mines were operating, and two antiquated, hydro-powered generators powered a crude concentration mill. The geologists also reported rich mineralized veins at elevations as high as 14,500 feet, while noting that the district had never been explored by modern core-drilling methods.

A Canadian company finally began a core-drilling exploration program in 1998. In 2007, when high metal prices encouraged development, a British company acquired and consolidated the Pachapaqui properties into a 5,360-acre tract. A major exploration program followed and 45,000 feet of drill-core samples revealed veins containing more than 15 million tons of mineralization with an average per-ton grade of 5.8 troy ounces of silver, 4.31 percent zinc, 2.69 percent lead, 0.73 percent copper, and small amounts of gold.

During the last decade, many old workings have been reopened and miners have driven several thousand feet of new workings. The primary ore minerals at Pachapaqui are sphalerite [zinc sulfide, ZnS] and galena [lead sulfide, PbS], both containing significant amounts of silver. Other ore minerals are tetrahedrite [copper iron zinc antimony arsenic sulfide, $\text{Cu}_6\text{Cu}_4(\text{Fe,Zn})_2(\text{Sb,As})_4\text{S}_{13}$]; chalcopyrite [copper iron sulfide, CuFeS_2]; bournonite [lead copper antimony sulfide, PbCuSbS_3]; and tennantite [copper iron zinc arsenic antimony sulfide, $\text{Cu}_6\text{Cu}_4(\text{Fe,Zn})_2(\text{As,Sb})_4\text{S}_{13}$]. The gangue minerals include quartz, pyrite [iron disulfide, FeS_2]; calcite [calcium carbonate, CaCO_3], and rhodochrosite [manganese carbonate, MnCO_3]. The mineralized veins sometimes contain pockets filled with collectible crystals of quartz, rhodochrosite, bournonite, pyrite, and pink, manganoan calcite. Composite specimens with crystals of three or more species are common. Miners collect these crystals to sell to dealers from Lima who visit Pachapaqui periodically. These specimens are then exported to markets in the United States and Europe.

Pachapaqui has only recently become a source of Tessin quartz. In 2010, miners driving exploration tunnels through granite adjacent to mineralized vein systems encountered vugs filled with milky quartz crystals—a quartz variety previously unknown at Pachapaqui. The miners sold these crystals to Lima dealers who exported them to the United States, where a dealer recognized them as the rare Tessin variety. Needing confirmation about their source, he contacted a knowledgeable dealer in Lima, asking him to investigate the actual vug where the crystals had been found. When the Lima dealer next visited Pachapaqui, miners showed him the

Mineral of the Month Club May 2016

source of the crystals. The dealer identified the host rock as granite and recognized the source of the crystals as an alpine-type fissure—the first ever found in Peru. Several other alpine-type vugs have since been found and are the source of our specimens of Tessin quartz.

As you study your Tessin quartz specimen, notice that some individual crystals do not have parallel prismatic faces, but taper or converge from the base toward the termination. This tapering may be difficult to observe in compound crystals. Notice also that the prismatic faces lack the simple, transverse, linear striations that are typical of most forms of quartz. Instead, they exhibit the blocky, mosaic-type pattern characteristic of Tessin quartz. To view this mosaic-striation pattern, slowly rotate the specimen until a specular (mirror-like) reflection illuminates a prismatic face, which clearly exhibits this distinctive, mosaic-striation pattern. Your specimen also includes secondary, recently formed crusts of off-white-to-tan calcite. Remember that your Tessin quartz specimen is not related to the multimetal mineralization at Pachapaqui, but was collected in alpine-type fissures in the adjacent, granitic host rock.

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Mineral of the Month Club May 2016

Pachapaqui Mine Location Map

The Pachapaqui Minesite is located near the town of Pachapaqui, Peru, 240 kms north of Lima in the province of Bolognesi, department of Ancash.

