December 2009 Mineral of the Month: Lazurite

From one of the world's oldest mines in one of the world's most remote and dangerous localities comes one of the best loved gemstone minerals, straight to your door! Our write-up explains the relationship of lazurite and lapis lazuli, Afghanistan's legacy of lapis, and the fascinating history of its ancient mines.

OVERVIEW

PHYSICAL PROPERTIES

Chemistry: $(Na,Ca)_8Si_6Al_6O_{24}[(SO_4),S,Cl,(OH)]_2$ Basic Sodium Calcium Aluminum Sulfate Chlorosilicate (Sodium Calcium Sulfate Chloroaluminosilicate Hydroxide)
Class: Silicates
Subclass: Tectosilicates
Group: Sodalite
Crystal System: Isometric (Cubic)
Crystal Habit: Usually dodecahedral, occasionally cubic; most often in granular, compact, or massive form.
Color: Azure-blue to violet-blue, occasionally greenish-blue.
Luster: Dull to greasy
Transparency: Usually opaque; occasionally translucent.
Streak: Pale blue
Refractive Index: 1.502-1.522
Cleavage: Poor in six directions
Fracture: Uneven, brittle
Hardness: 5.0-5.5
Specific Gravity: 2.4-2.5
Luminescence: None
Distinctive Features and Tests: Best field marks are deep-blue color and association with pyrite [iron disulfide, FeS_2]. Can be confused visually with sodalite [sodium aluminum chlorosilicate, $Na_8Al_6Si_6O_{24}Cl_2$], which has coarser grain and paler color, and lazulite [basic magnesium aluminum phosphate, $MgAl_2(PO_4)_2(OH)_2$], which is softer and more dense.
Dana Classification Number: 76.2.3.4.1

NAME The name "lazurite," pronounced LAH-zhur-ite, stems from the Arabic *lazaward*, variously meaning "sky," "heaven," or "azure," in reference to the mineral's blue color. Lazurite has also been known as "cyaneus," "ultramarine," "lasurite," "Lasurstein," "lapis lazuli," "lapis stone," "sapphis," and "sapphirus." In European mineralogical literature, lazurite appears as *lazurit* and *lazurita*. Lazurite is often confused phonetically with such similarly named minerals as lazulite [basic magnesium aluminum phosphate, $MgAl_2(PO_4)_2(OH)_2$] and azurite [basic copper carbonate, $Cu_3(CO_3)_2(OH)_2$]. It is also confused with lapis lazuli, a blue gemstone and decorative rock in which it is the primary mineral component. The term "lapis lazuli," meaning "blue stone," was introduced into English in the 15th century and stems from the Latin word *lapis*, meaning "stone," and the Medieval Latin word *lazulum*, meaning "blue."

COMPOSITION: The chemical formula $(Na,Ca)_8Si_6Al_6O_{24}[(SO_4),S,Cl,(OH)]_2$ shows that lazurite contains sodium (Na), calcium (Ca), silicon (Si), aluminum (Al), sulfur (S), chlorine (Cl), oxygen (O), and hydrogen (H). Lazurite's molecular weight is made up approximately of 13.5 percent sodium, 7.8 percent calcium, 15.8 percent aluminum, 16.3 percent silicon, 6.0 percent sulfur, 38.1 percent oxygen, and small percentages of chlorine and hydrogen. Lazurite is a framework silicate or tectosilicate, a classification that includes quartz and the feldspar-group minerals. The lazurite crystal lattice is based on a modified tectosilicate structure, in which alumina ions alternate with silica ions to form an aluminosilicate. Lazurite forms from the high-grade, contact metamorphism of silica-poor, marine limestone that contains available

sulfur and chlorine. The host rock of lazurite is usually marble; associated minerals are pyrite, calcite, and diopside. Lazurite rarely forms crystals and occurs most often in massive form as a component of lapis lazuli, which is a rock consisting of a number of minerals.

COLLECTING LOCALITIES: The world's premier source of lazurite is the Kokcha Valley, Badakhshân Province, Afghanistan. Lazurite also occurs in neighboring Tajikistan. Russia's two localities, both near Lake Baikal in Irkutskaya Oblast' in the Eastern-Siberian region, are the Tuluti and the Malo-Bystrinkoye lazurite deposit in the Tounkinskaya Valley, and the Slyudyanskoe lazurite deposit at Slyudyanka. Chile's two sources are the Flor de Chile Mine along the Cazedero River near Ovalle, and the Flor de los Andes Mine near El Polvo on Mount Patria, both in Lamari Province in the Coquimbo Region. In the United States, lazurite occurs on Italian Mountain in Gunnison County, Colorado, and in Cascade Canyon in San Bernadino County, California.

HISTORY, LORE, & USES: Lapis lazuli, or "lapis" for short, is a rock consisting of an indeterminate mixture of minerals that contains 20 to 40 percent lazurite, with the higher percentages producing the most intensely colored and valuable material. Known since antiquity, lapis was perhaps the first gemstone ever mined in quantity. Afghanistan's lapis deposits were known in prehistory and have been systematically mined since about 4000 B.C. Afghan lapis was widely traded, first to the Sumerians and Assyrians, then to the Chinese, the Egyptians, and later to the Europeans. Although pure lazurite is not used as a gemstone, it is the primary mineral and the cause of the blue color in lapis lazuli, which is highly valued in jewelry and decorative objects. As a refined powder, lazurite is natural ultramarine, an intense blue pigment used in specialty inks, lacquers, and paints. Modern metaphysical practitioners believe that lapis strengthens the physique and spirit, aids in spiritual evolution, and enhances love and fidelity to strengthen the bonds of marriage.

ABOUT OUR SPECIMENS: Our specimens were collected in the Sar-e-Sang district in the Kokcha Valley, Badakhshân Province, Afghanistan. The Kokcha Valley lapis mines, among the world's oldest gemstone mines, are located in northeastern Afghanistan at an elevation of 9,000 feet in a remote and rugged section of the Hindu Kush range. This politically unstable region is controlled by Northern Alliance guerrillas who tax mine production and use revenues to fund military activities. The mines are located on the side of a steep cliff on Lapis Wash Mountain at elevations between 9,000 and 10,000 feet (1,500 to 2,500 vertical feet above the Kokcha River) and are accessible only by a dangerous, steep foot trail. The district has seven mines, all consisting of narrow tunnels or declines leading to underground galleries. Only one mine is currently active and consists of two access tunnels and an underground gallery 150 feet high. Although mechanical rock drills have been used in the past with limited success, most mining is still conducted by manually drilling with hammers and hand steels to prepare the marble host rock for blasting. After blasting, the miners, who earn about $10 for a long shift, carefully search the marble for faint blue coloration that might indicate a nearby lapis-bearing lens. During each mining season, which extends only from late June through early November, more than 10 tons of lapis lazuli are recovered and shipped. Our specimens from the Kokcha Valley mines include both lazurite crystals in matrix and lapis lazuli. Gold- and Platinum-level members received 12-sided dodecahedral lazurite crystals in a matrix of coarse-grained, white marble; Silver-level members received specimens of lapis lazuli—gemstones in the rough which contain a high percentage of lazurite and appear exactly as mined.

10 YEARS AGO IN OUR CLUB: Native gold, Jamestown Mine, Jamestown District, Tuolomne County, California. We obtained gold on quartz specimens for Gold-level members, and gold flakes mounted in magnifier boxes for Silver-level members, from Ed Coogan, a collector/dealer from the Gold Country. (We didn't have a Platinum-level then.) Ed has since retired, and we know of no similar supplier where we could hope to feature gold again. It was the same story for our diamond supplier in March 2003.

December 2009 Mineral of the Month: Lazurite

COMPREHENSIVE WRITE-UP

COMPOSITION

As shown by its chemical formula $(Na,Ca)_8Si_6Al_6O_{24}[(SO_4),S,Cl,(OH)]_2$, lazurite contains the elements sodium (Na), calcium (Ca), silicon (Si), aluminum (Al), sulfur (S), chlorine (Cl), oxygen (O), and hydrogen (H). Its molecular weight is made up of approximately 13.5 percent sodium, 7.8 percent calcium, 15.8 percent aluminum, 16.3 percent silicon, 6.0 percent sulfur, 38.1 percent oxygen, and small percentages of chlorine and hydrogen. As will be explained, the exact percentages cannot be stated because of the variable elemental compositions of the compound cation and anion within the lazurite molecule.

Lazurite is not to be confused with lazulite [basic magnesium aluminum phosphate, $MgAl_2(PO_4)_2(OH)_2$], our Mineral of the Month for February 2007. Although both are blue minerals, they have entirely different chemistries, structures, and origins. Lazurite is a member of the silicate mineral group, in which silicon and oxygen are combined with metals or nonmetals. The basic silicate structural unit is the silica tetrahedron $(SiO_4)^{4-}$, in which a silicon ion is surrounded by four equally spaced oxygen ions positioned at the four corners of a tetrahedron (a four-faced polyhedron). In the silicates, silica anions and metal cations join together in repeating chains to 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). Lazurite is a framework silicate or tectosilicate, a classification that includes such minerals as quartz [silicon dioxide, SiO_2] and the feldspar group of complex aluminosilicates containing potassium, calcium, and/or sodium. The lazurite crystal lattice is actually based on a modified tectosilicate structure, in which aluminum ions Al^{3+} alternate with silica ions Si^{4+} to form the aluminosilicate tetrahedra $[(Si,Al)O_4]^{4-}$. This arrangement is reflected in lazurite's chemical formula $(Na,Ca)_8Si_6Al_6O_{24}[(SO_4),S,Cl,(OH)]_2$, in which the aluminosilicate radical $(Si_6Al_6O_{24})^{6-}$ consists of six $[(Si,Al)O_4]^{4-}$ tetrahedra.

Because of lazurite's chemical complexity, its chemical formula $(Na,Ca)_8Si_6Al_6O_{24}[(SO_4),S,Cl,(OH)]_2$ can appear daunting. But remember that all molecules are composed of cations (positively charged ions) and anions (negatively charged ions). Lazurite's compound cation and compound anion both contain radicals, which are groups of atoms of different elements that act as entities in chemical reactions. With this in mind, it is easy to understand lazurite's chemistry and structure by breaking down its formula into three main groups: the compound cation $(Na,Ca)_8^{14+}$ and the two compound anions $(Si_6Al_6O_{24})^{6-}$ and $[(SO_4),S,Cl,(OH)]_2^{8-}$. Notice that the total +14 cationic charge balances the total -14 anionic charge to provide the lazurite molecule with electrical stability. However, the balance within this ideal formula is not rigid. In the cation, the symbols for sodium and calcium are separated by commas, indicating that the proportions of the sodium ion Na^{1+} and the calcium ion Ca^{2+} are variable. The actual cationic charge varies between +8 and +16. Because the proportions of the radicals within the $[(SO_4),S,Cl,(OH)]_2^{8+}$ anion are also variable, its anionic charge varies from -2 to -10. (If you try to calculate this collective charge, remember that the sulfur in the sulfate ion $(SO_4)^{2-}$ is present in the +6 oxidation state, but in the elemental sulfur ion S^{2+} it is present in the +2 oxidation state). Because the compositions and thus the collective cationic and anionic charges vary proportionately with each other, the lazurite molecule is always electrically stable. Lazurite's precise chemistry is determined by the chemical environment and physical conditions that existed when it was formed.

Within the lazurite lattice, the silica $(SiO_4)^{2-}$ and alumina $(AlO_4)^{5-}$ tetrahedra covalently share all four of their oxygen ions to create a repetitive, three-dimensional framework of alternating four- and six-membered rings that form hollow cavities. Within these cavities, the negative charge of the combined aluminosilicate radical $(Si_6Al_6O_{24})^{6-}$ ionically attracts and holds positively charged sodium and calcium ions to form the

incomplete lazurite molecule $[(Na,Ca)_8Si_6Al_6O_{24}]^{8+}$. This positively charged, incomplete molecule then ionically attracts the negatively charged, complex radical $[(SO_4),S,Cl,(OH)]_2^{8-}$, which has formed during metamorphism from the sulfur, chlorine, and water present in a marine-sediment environment. This completes the lazurite molecule $(Na,Ca)_8Si_6Al_6O_{24}[(SO_4),S,Cl,(OH)]_2$. By building the lazurite molecule up from its aluminosilicate core, we see that, despite its complexity, it consists of just three basic parts.

Because the strong covalent bonding of shared oxygen ions is equal in three directions, the lazurite lattice has no pronounced cleavage planes and a considerable hardness of Mohs 5.0-5.5. Lazurite's low specific gravity of only 2.4-2.5, unusual for a dark-colored mineral, is due both to its hollow, intermolecular cavities and to the light atomic weights of its elemental components. The basic structure of alternating four- and six-membered rings causes lazurite to crystallize in the isometric or cubic system, with three mutually perpendicular axes of equal length. Chemically simple minerals usually crystallize in the isometric system, but lazurite is an exception. Because its complex, variable chemistry often disrupts its crystal lattice, lazurite most often occurs in granular, compact, and massive forms. It only rarely occurs as crystals, and then usually as crudely formed, 12-sided dodecahedrons and also occasionally as six-sided cubes.

As an idiochromatic (self-colored) mineral, lazurite's color is caused by its essential composition and the light-reflecting properties of its crystal lattice. Lazurite absorbs most white-light wavelengths, reflecting only a narrow band of blue wavelengths to create its distinctive, deep-blue color. The intensity of this blue color is primarily dependent upon the amount of sulfur present, and to a lesser extent upon the amount of calcium present. Common trace impurities such as iron, magnesium, and potassium have little effect on this basic color.

Lazurite forms as a product of the high-grade, contact metamorphism of silica-poor, marine limestone that contains available sulfur and chlorine. Lazurite's host rock is marble; associated minerals include pyrite [FeS_2], calcite [$CaCO_3$], and diopside [$CaMgSi_2O_6$]. Lazurite most often occurs as a mineral component of lapis lazuli (see "Jewelry & Decorative Uses").

The Dana mineral classification number 76.2.3.4 identifies lazurite as a tectosilicate with an aluminosilicate framework (76). The subclassification defines it as a member of the feldspathoids (2), a group of aluminosilicate minerals having less silica than the closely related feldspar-group minerals. Lazurite is then assigned to the sodalite group (3) as the fourth (4) of eight chemically similar members. This group's most abundant member is sodalite [sodium aluminum chlorosilicate,$Na_8Al_6Si_6O_{24}Cl_2$], which is similar in color and form to lazurite.

COLLECTING LOCALITIES

Our specimens were collected in the Sar-e-Sang district in the upper Kokcha Valley, Badakhshân Province, Afghanistan, which is both the type and classic locality for lazurite. Lazurite also occurs in neighboring Tajikistan along the Lyadzhavadara River in the Viloyati Mukhtori region. Russia's two lazurite localities, both near Lake Baikal in Irkutskaya Oblast' in the Eastern-Siberian region, are the Tuluti and the Malo-Bystrinkoye lazurite deposits in the Tounkinskaya Valley, and the Slyudyanskoe lazurite deposit at Slyudyanka. Chile also has two sources of lapis lazuli that yield occasional lazurite specimens: Both are in Lamari Province in the Coquimbo Region and include the Flor de Chile Mine along the Cazedero River near Ovalle, and the Flor de los Andes Mine near El Polvo on Mount Patria. Swedish specimens come from the Sunnerskog Mine at Vetlanda in Småland. Italian localities include Ariccia in the Alban Hills, Roma Province, Latium; the Novelle and San Vito mines in the Somma-Vesuvius Complex in Naples Province, Campania; and the Foldite and Tephrite outcrops at Mt. Vulture, Potenza Province, Basilicata.

Lazurite is relatively rare in North America. Canadian specimens come from Kimmirut on Baffin Island in

December 2009 Mineral of the Month: Lazurite

Nunavut Territory. Notable sources in the United States are the Blue Wrinkle lapis mine on Italian Mountain in Gunnison County, Colorado; the Bighorn lapis deposit in Cascade Canyon in the San Gabriel Mountains of San Bernardino County, California; the Edwards Mine at Edwards and the St. Joe No. 3 and ZCA No. 4 mines at Balmat, both in the Balmat-Edwards zinc district of St. Lawrence County, New York; and Granite Mountain near Little Rock in Pulaski County, Arkansas.

JEWELRY & DECORATIVE USES

Although lazurite itself is not a gemstone, it is the primary mineral and the cause of the blue color in lapis lazuli (LAP-iss LAH-zhu-lee), one of the most ancient of all gemstones. The term "lapis lazuli," meaning "blue stone," was introduced into English in the 15th century and stems from the Latin word *lapis*, meaning "stone," and the Medieval Latin word *lazulum*, meaning "blue." Lapis lazuli, or "lapis" for short, is a rock consisting of an indeterminate mixture of minerals. Lazurite makes up 20 to 40 percent of lapis, with the higher percentages producing the most intensely colored and valuable material. Other mineral components of lapis are calcite [$CaCO_3$], sodalite [$Na_8Al_6Si_6O_{24}Cl_2$], haüyne [$Na_6Ca_2Al_6Si_6O_{24}(SO_4)_2$], diopside [$CaMgSi_2O_6$], pyrite [$FeS_2$], augite [$(Ca,Na)(Mg,Al,Fe,Ti)(Si,Al)_2O_6$], muscovite [$KAl_3Si_3O_{10}(OH)_2$], enstatite [$Mg_2Si_2O_6$], and nosean [$Na_8Al_6Si_6O_{24}(SO_4)\cdot H_2O$].

Lapis lazuli is a compact or massive form of its constituent minerals. It has no crystal structure or cleavage, an uneven fracture, dull luster, generally fine grain, light-blue streak, and a specific gravity between 2.6 and 2.9. Its considerable hardness of Mohs 5.0-5.5 enables it to take a fine polish. The most desirable lapis is opaque, with an even, intense, "royal" blue color that is speckled with small, glittering bits of brass-yellow pyrite. Top-grade material has no streaks of calcite or other light-colored minerals to detract from or lighten its basic blue color. Lapis lazuli is cut and polished both as a gemstone and as a decorative stone. For jewelry, lapis is fashioned into beads for necklaces, earrings, and bracelets, and cabochons for mounting in rings and pendants. As a decorative stone, it is made into figurines, sculptures, amulets, ornaments, trinket boxes, vases, goblets, and inlays for floor and wall mosaics. Lapis prices vary widely by grade. The lowest grades have pale-blue, mottled colors and are priced by the ounce. Higher grades are sold on a per-gram basis and can easily cost more than $1 per gram (about $28 per ounce). Superfine material can retail for $100 per gram or more, a remarkable price for what is considered a semiprecious gemstone. The retail cost of four-inch-high carvings fashioned from top-grade lapis ranges well into the thousands of dollars.

Lower grades of lapis lazuli with an abundance of white calcite streaks are often color-enhanced by immersion in ferrocyanide or organic blue dyes. Lapis imitations such as "Swiss lapis" and "German lapis" are white or gray chalcedony [microcrystalline quartz, SiO_2] or white howlite [basic calcium borosilicate, $Ca_2SiB_5O_9(OH)_5$] that has been dyed blue. A popular lapis imitation introduced in the 1950s consists of a mix of fragmented, synthetic blue spinel [magnesium aluminum oxide, $MgAl_2O_4$], blue cobalt oxide, and pyrite sintered together under heat and pressure. In the 1970s, French chemist Pierre Gilson (1900-1997) introduced a lapis imitation made of synthetic ultramarine pigment mixed with hydrous zinc phosphates and bits of pyrite. "Reconstructed lapis" is made by cementing together chips of natural lapis.

Mineral collectors value lazurite crystals for their rarity. The most desirable collector pieces are lazurite dodecahedrons in a snowy-white, marble matrix. Although lazurite crystals have been found up to two inches in size, these are extremely rare; most lazurite crystals are much smaller. Crystals only one inch in size can cost more than $1,000 each. Specimens of rough lapis lazuli are collected because this gemstone is not often seen in its natural, unfinished state.

December 2009 Mineral of the Month: Lazurite

HISTORY & LORE

Known since antiquity, lapis lazuli was perhaps the first gemstone ever mined in quantity. Until the 19th century, the lapis deposits in Afghanistan's Kokcha Valley were the only significant source of the stone. These deposits have been mined sporadically since prehistory and systematically since about 4000 B.C. Afghan lapis was widely traded, first to the Sumerians and Assyrians, then to the Chinese and Egyptians, and finally to the Europeans. Most was fashioned into jewelry and decorative pieces; the Egyptians also ground it into a fine powder for use as eye shadow. During Roman times, when lapis was known as *sapphirus,* Pliny the Elder (Gaius Plinius Secundus, A.D. 23-79) described it as "a blue stone sprinkled with specks of gold" and "a fragment of the starry firmament." The Romans considered lapis to be a powerful aphrodisiac. During medieval times, physicians used powdered lapis in various elixirs to keep the limbs healthy, heal ulcers and boils, and free the soul from envy and fear.

In the 7th century A.D., Afghan artists began using finely powdered lapis as the pigment for blue paints to decorate temples and mosques. Lapis pigment was later introduced to Europe where it became known as "ultramarine"—literally "beyond the sea," a reference to its exquisite, deep-blue color. During Europe's Renaissance, ultramarine colored the blue paints applied to the finest frescoes and panel art, as well as the blue inks that were applied to illuminated manuscripts. Extracting ultramarine, which is essentially pure lazurite, from powdered lapis lazuli was extremely difficult. Simple gravitational separation was ineffective because of the similar densities of the mineral components in lapis. Over the centuries, chemists and alchemists devised many complex separation methods that employed various oils, waxes, and chemical reagents, but with only limited success. During the Renaissance, the scarcity of pure ultramarine made the pigment literally worth its weight in gold and created a huge demand for the highest grades of lapis. Ultramarine, derived from the finest Afghan lapis and known as "blue gold," remained exorbitantly priced until the early 1800s, when synthetic ultramarine was produced in France by roasting a mixture of kaolin clay, sodium sulfate, and charcoal.

Lapis lazuli was originally thought to be its own mineral until 1890, when Norwegian geologists Waldemar Christopher Brøgger (1851-1940) and Helge Bäckström (1865-1932) determined that lapis was actually a rock that consisted of a number of minerals. Brøgger and Bäckström also demonstrated that the blue color of lapis was due to a previously unknown mineral which they named "lasurite." In 1892, the American mineralogist Edward Salisbury Dana (1849-1935) changed this name to "lazurite" in his landmark 6th edition of *Systems of Mineralogy*. In 1929, Dutch chemist Frans Maurits Jaeger (1877-1945) used X-ray diffraction techniques to establish lazurite's basic atomic structure.

Today, lapis lazuli is an alternate birthstone for the month of December. Modern metaphysical practitioners believe that lapis strengthens the physique and spirit, and aids in spiritual evolution. It is valued as a calming influence in daily life, an aid to organizing routines, and a builder of self-confidence. It is also thought to enhance love and fidelity and strengthen the bonds of marriage. Lapis was featured on the 37-afghani postage stamp of Afghanistan in 1988 and the 150-peso stamp of Chile in 1996.

AFGHANISTAN'S LEGACY OF LAPIS

Throughout the centuries, lapis lazuli and Afghanistan have been synonymous, and for good reason. In both quantity and quality, Afghanistan has produced most of the world's lapis, and the blue stone is entwined throughout its history. But before examining the role of lapis in the fortunes of Afghanistan, let's look first at a thumbnail history of this central-Asian nation. Since antiquity, Afghanistan has been a crossroads of caravan trade and a goal of foreign conquest. Macedonian ruler Alexander the Great (Alexander III of Macedon, 356-323 B.C.) first conquered the region when it was known as Bactria and

December 2009 Mineral of the Month: Lazurite

was part of the Persian Empire. Afghanistan hosted a flourishing Buddhist civilization that was overthrown by Islamic hordes in the 7th century A.D. After Mongol conqueror Genghis Khan (1162-1227) overthrew the Islamic rulers in the 13th century, Afghanistan subsequently fell to the Turkish conqueror Timur (Tamerlane, 1336-1405). The region then became divided among various tribes and petty kingdoms.

Modern Afghan history began with the establishment of a united Arab emirate by Ahmed Shah Durani in 1747. Two British wars in the 19th century left the Afghans unconquered but within the British sphere of influence. When Afghanistan achieved full independence from Britain in 1919, it established a monarchy that lasted until a 1973 military coup initiated a long period of political instability. After a communist coup in 1978, Soviet troops invaded to support the new regime. In the ensuing civil war, the government and its Soviet allies controlled cities and major transportation routes, while Afghan guerrillas controlled most rural areas (See "About Our Specimens"). The Soviets withdrew in 1989, leaving behind a pro-Soviet government that was toppled by rebel troops in 1992. In 1995, the Taliban, a fundamentalist Islamic militia, overran the country and installed a strict fundamentalist regime, while rebel groups retreated to the mountains to unite as the Northern Alliance. In September 2001, the United States demanded that the Taliban turn over terrorist leaders suspected of plotting the attack on New York City's World Trade Center and the Pentagon in Washington, D.C. American troops then intervened, removed the Taliban from power, and installed, and have since supported, the present moderate democratic government.

Throughout this turbulent history, lapis lazuli has never lost its economic importance. The lapis deposits of the Kokcha Valley in Badakhshân Province were known in prehistory. Many anthropologists believe that the Kokcha Valley deposits are the world's oldest commercial gemstone mines. By about 4000 B.C., Afghan lapis had already become a very valuable commodity in the developing caravan system and was being traded extensively. Over millennia, the actual source of the lapis remained a mystery to all but those who actually mined the stone. Passing near the Kokcha Valley mines in 1271, the Venetian traveler Marco Polo (1254-1324), after being denied access to the mines, wrote, "There is a mountain in that region where the finest azure [lapis lazuli] in the world is found. It appears in veins like silver streaks."

Among the first Europeans to visit the upper Kokcha Valley was John Wood, a Scottish naval lieutenant in the service of the British East India Company, in 1838. In an account of his travels titled A Personal Narrative of a Journey to the Source of the River Oxus, published in London in 1841, Wood recounted making his way up the rugged Kokcha Valley to the mines, then entering a narrow, steeply inclined shaft that led to an underground gallery 12 feet in height and width and 200 feet long. Without any ground support, huge blocks of loosened overhead rock posed a terrible risk, and Wood noted that mine sections were named for miners who had been killed in the frequent rockfalls. Wood recounted how miners used an ancient technique to break the rock, heating it first with fires to "soften" it, then hammering it apart. Citing high elevations, bitter winters, dangerous trails and sheer cliffs, and the threat of bandits, Wood concluded: "If you do not wish to die, avoid the narrow valley of the Kokcha."

During the early 19th century, lapis lazuli was one of the few materials with which Afghanistan could earn hard currency in international trade. Lapis then passed through the capital city of Kabul, where it was worked into decorative objects and jewelry or sold as rough. The Afghan monarchy also hoarded a large quantity of fine lapis in a palace reserve similar to the gold treasury reserves of more developed nations. But the 1979 Soviet invasion disrupted this traditional lapis trade. Despite the Soviet military presence, mujahideen nationalist guerillas maintained control of rural areas, including the Kokcha Valley lapis mines. Just prior to the Soviet invasion, the communist government in Kabul, in apparent distrust of its soon-to-be Soviet masters, sold off tons of the palace lapis reserves. Meanwhile, the mujahideen began taxing lapis-

December 2009 Mineral of the Month: Lazurite

mine production, using the proceeds to purchase weapons. The mujahideen no longer sent the newly mined lapis to Soviet-controlled Kabul, but smuggled it instead across the border into Pakistan, a nation then emerging as a major supplier of gemstones and mineral specimens.

Ironically, the Soviet invasion also helped to partly modernize Afghan lapis mining. Previously, Afghan lapis miners had only rarely used costly and difficult-to-obtain explosives. Now they used explosives regularly, thanks to the inexhaustible supply obtained by disassembling countless unexploded Soviet land mines. After the Taliban took control in the 1990s, the mujahideen, now operating as the Northern Alliance, continued to control lapis mining in the Kokcha Valley. Meanwhile, in Kabul, prior to the arrival of American troops in 2001, another ten tons of quality, rough lapis mysteriously disappeared from the remaining palace reserves, stolen either by the Taliban as it vacated Kabul or by the Northern Alliance after it occupied the city. Either way, the lapis, worth several million dollars, is thought to have been loaded on trucks and smuggled across the border to gem markets in Pakistan.

Today, while the U.S.-backed central government controls the Afghan cities, the Northern Alliance controls the Kokcha Valley lapis mines and realizes an estimated $5 million per year from the mining and sale of lapis. Although some lapis is now sent to Kabul, most is still smuggled into Pakistan where it can be sold for higher prices. The central government plans to eventually nationalize the lapis mines, modernize operations, and increase production. The Kabul government is already negotiating with private European and Asian companies, offering potentially lucrative, long-term mineral leases to companies that agree to build mine-access roads and increase lapis production. If this plan succeeds, the central government would reap millions of badly needed dollars each year, while lapis prices on the international markets could decline substantially. But any attempt at nationalization will certainly lead to armed confrontation with the Northern Alliance.

During the 6,000-year history of Afghan lapis lazuli, control of the mines has changed hands many times and production levels have fluctuated dramatically. Still, international demand for high-quality Afghan lapis has never waned. The Kokcha Valley lapis reserves are sufficient for mining to continue well into the future. So when it comes to Afghanistan's legacy of lapis, many more chapters remain to be written!

TECHNOLOGICAL USES

The blue pigment ultramarine (see "History & Lore") is prepared from lazurite. Lazurite is first extracted from high grades of finely ground lapis lazuli by various chemical and physical processes, then refined to high purity. Natural ultramarine is a specialty blue pigment used in traditional artist's paints, special industrial paints, certain plastics, and the metal lacquers found in quality cloisonné jewelry and fine writing instruments. The unique and readily identifiable crystal properties of natural ultramarine also make it the preferred pigment for the security inks used to print currency and certificates.

ABOUT OUR SPECIMENS

Our specimens were collected in the Sar-e-Sang district in the Kokcha Valley, Badakhshân Province, Afghanistan, which is both the type and classic locality for lazurite. Afghanistan, a landlocked, arid nation in central Asia, has an area roughly equal to that of the state of Texas and a population of 27 million. It is bordered by Turkmenistan to the northwest, Uzbekistan and Tajikistan to the north, China to the northeast, Pakistan to the east and south, and Iran to the west. The capital city, Kabul, has a population of about one million. The central and eastern parts of the country are dominated by the rugged topography of the Hindu Kush, one of the world's highest mountain ranges.

December 2009 Mineral of the Month: Lazurite

Badakhshân is the northeasternmost of Afghanistan's provinces. Feyzâbâd, the provincial capital, population 10,000, is located at an elevation of 3,700 feet on the lower reaches of the Kokcha River. The Feyzâbâd economy is based on rice and wheat farming and milling, herding, and weaving. Although only 200 air miles northeast of Kabul, the driving distance over rough, winding roads is more than 400 miles. While summers are hot and dry, winters are bitterly cold and heavy snow often isolates the town. The lapis mines are 50 miles south of Feyzâbâd and much higher in elevation. From Feyzâbâd, a rough vehicle road leads south 20 miles along the Kokcha River to the tiny settlement of Jurm. Beyond Jurm, a track for pack animals continues south for 30 miles, climbing steadily through the narrowing Kokcha River canyon to the camp of Sar-e-Sang, which is not far from the center of the Hindu Kush massif at an elevation of 7,500 feet. Nowshâk, Afghanistan's highest peak with a summit elevation of 24,560 feet, is 12 miles to the south; the Pakistani border is 25 air miles to the east. The rocky, barren, and steep terrain at Sar-e-Sang is habitat for wild hogs, mountain sheep, and wolves.

At Sar-e-Sang, the original basement rock was marine limestone, a sedimentary rock consisting mainly of calcite [calcium carbonate, $CaCO_3$]. During the uplift of the Hindu Kush massif some 30 million year ago, the heat and pressure associated with intrusions of granitic magma caused intensive regional and contact metamorphism that recrystallized the limestone as marble. Within a 1,200-foot-thick, mica-rich stratum of this marble, lazurite occurs in lens-shaped bodies usually between three and six feet thick, and occasionally as thick as twelve feet. Most extend laterally for 60 to 300 feet and are about 400 feet long. Along with calcite and lazurite, these lenses also contain other minerals that are often components of lapis lazuli, including pyrite [FeS_2], forsterite [Mg_2SiO_4], diopside [$CaMgSi_2O_6$], phlogopite [$KMg_3AlSi_3O_{10}(OH)_2$,], sodalite [$Na_8Al_6Si_6O_{24}Cl_2$], haüyne [$Na_6Ca_2Al_6Si_6O_{24}(SO_4)_2$], augite [$(Ca,Na)(Mg,Al,Fe,Ti)(Si,Al)_2O_6$], muscovite [$KAl_3Si_3O_{10}(OH)_2$], enstatite [$Mg_2Si_2O_6$], and nosean [$Na_8Al_6Si_6O_{24}(SO_4)\cdot H_2O$]. Lapis lazuli in a range of commercial grades along with occasional lazurite crystals occur near the core of these lenses.

Sar-e-Sang, located on the Kokcha River, is a crude camp for the lapis miners. Most mines are located on the side of a steep cliff on Lapis Wash Mountain at elevations between 9,000 and 10,000 feet (1,500 to 2,500 vertical feet above the Kokcha River) and are accessible only by a dangerous, steep foot trail. The highest lapis mines, long inactive, are 2,000 feet higher in elevation. The district has seven mines, all consisting of narrow tunnels or declines leading to underground galleries, only one of which is currently active. This mine consists of two access tunnels and an underground gallery 150 feet high—testimony to the vast quantity of rock that has been removed over the centuries. The interior walls are blackened by smoke from fires that were once used to heat and break the rock. Without the benefit of core-drill exploration, lapis mining at Sar-e-Sang is a haphazard venture that depends heavily on luck. Although mechanical rock drills have been used with limited success, most mining is still conducted by manually drilling with hammers and hand steels to prepare the marble host rock for blasting (see "Afghanistan's Legacy of Lapis"). After blasting, the miners, who earn about $10 for a long shift, carefully search the marble for faint blue coloration that might indicate a nearby lapis-bearing lens. More often than not, any blue coloration they find is due only to isolated, trace occurrences of lazurite, and not to nearby bodies of valuable lapis. Because the tunnels open onto the side of a nearly vertical cliff, miners simply dump the waste rock 1,500 feet straight down into the Kokcha River.

When miners do find a lapis-bearing lens, they drill holes in close patterns and blast as lightly as possible to break the lapis into the large, 40- to 50-pound blocks that are easier to transport and preferred by buyers. Miners backpack these lapis blocks down to Sar-e-Sang. Horses and mules then pack the lapis down the Kokcha River canyon to Jurm or Feyzâbâd to be trucked either to Kabul or the gem market at Peshâwar, Pakistan. The journey from the mines to Kabul takes at lest ten days. The business of lapis mining at Sar-e-Sang is rigidly structured. Afghan entrepreneurs first pay the Northern Alliance for mining rights, then hire local workers to do the actual mining. The Northern Alliance also taxes lapis production and charges fees to guarantee its safe shipment. Currently during each mining season, which extends

only from late June to early November, more than 10 tons of lapis are mined and shipped. At the mine, one pound of top-quality, rough lapis is worth about $50. In the gem markets of Kabul and Peshâwar, Pakistan, that same lapis sells for as much as $400.

We met our Afghani supplier a couple of years ago at the Denver Gem & Mineral Show, explaining to him what kind of quantities we needed and what price ranges we could pay in order to feature a mineral in our Club. It was obvious that there was no way to get lazurite crystals in matrix in the price range we need for our Silver-level membership, so it was decided that small pieces of lapis lazuli rough would suffice, and an upgrade could be offered to those who wanted a matrix piece. Last year, he got back to us and said he would be bringing a large lot to the Tucson Show and could supply what we needed. This past February, we went to his booth at Tucson Electric Park, and hunted through everything he had brought. Unfortunately, there weren't enough choice pieces on hand, but he thought he could obtain more on his return to Afghanistan. So we took home what we could use, and waited to hear from him. This summer, he was back in the States with new material, and came by our home in Cambria, where we picked out the rest of what we needed and finalized the transaction. He gave us a fantastic deal to be able to get lazurite on matrix pieces in our price range!

Our crystal specimens are individual lazurite crystals in the 12-sided dodecahedral habit in a matrix of coarse-grained, white marble. Lazurite crystallizes in the isometric (cubic) system, most commonly as dodecahedrons. Although lazurite rarely occurs in well-formed crystals, the blocky, dodecahedral shapes of our specimens can be discerned. Study both the lazurite crystal and the marble matrix closely to note tiny grains of brassy-yellow pyrite, a mineral frequently associated with lazurite. Check the matrix under your UV lamp if you have one–we saw bright yellow under short wave ultraviolet light, and yellow and occasionally orange under long wave!

Our specimens of rough lapis lazuli sent to Silver-level members are gemstones in the rough. They appear exactly as mined and have not been worked in any way. Their deep-blue color indicates high lazurite content. Their hardness of Mohs 5.0-5.5 enables them to take the fine polish that makes finished lapis jewelry and decorative objects so attractive. The small, white areas within the lapis specimen are calcite, the same mineral that makes up the marble host rock. The tiny, glittering, brassy-yellow specks are pyrite. Few of us have the circumstances to visit these ancient mines in the mountains of Afghanistan–how blessed we are to be able to have these wonderful specimens with their ancient history delivered right to our door!

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