Mineral of the Month Club December 2016

DIOPTASE

This month's mineral is dioptase, a hydrous copper silicate that is one of the most intensely colored of all minerals. Our specimens are from the Kaokoveld Plateau in Namibia, and our special section discusses the world-famous mineral-specimen localities of this African nation.

OVERVIEW

PHYSICAL PROPERTIES:
Chemistry: $Cu_6Si_6O_{18} \cdot 6H_2O$ Hydrous Copper Silicate
Class: Silicates
Subclass: Cyclosilicates
Group: Dioptase
Crystal System: Trigonal (Hexagonal)
Crystal Habits: Usually as interconnected groups of distinct, stubby, hexagonal crystals with sharply edged, rhombohedral terminations; crystals are occasionally elongated. Dioptase also occurs in drusy, radiating, botryoidal, encrusting, and massive forms.
Color: Usually intense, emerald green, sometimes greenish-blue.
Luster: Vitreous to adamantine
Transparency: Transparent to translucent
Streak: Green
Refractive Index: 1.652-1.710
Cleavage: Perfect in three directions
Fracture and Tenacity: Uneven to conchoidal; brittle.
Hardness: 5.0
Specific Gravity: 3.3-3.4
Luminescence: None
Distinctive Features and Tests: The best field marks for dioptase are an intense, emerald-green color; distinct hexagonal crystals with sharply-edged, rhombohedral terminations; and its exclusive occurrence in oxidized copper deposits. Dioptase can be confused in both color and nomenclature with the chromium-rich variety of diopside [calcium magnesium silicate, $CaMgSi_2O_6$], which is harder and differs in crystal structure. Malachite [basic copper carbonate, $Cu_2(CO_3)(OH)_2$] and brochantite [basic copper sulfate, $Cu_4(SO)_4(OH)_6$] have similar colors, but different crystal forms and much less hardness.
Dana Mineral-Classification Number: 61.1.3.1

NAME: The word "dioptase" pronounced dye-OPP-tayse, stems from the Greek *dia-*, meaning "through," and *optikos*, meaning "visible." The literal translation, "to see through" or "transparent," alludes to internal cleavage planes that are visible within the mineral's transparent crystals. Dioptase has also been known as "achtrite," "ashtrite," "emerald copper," "emerald copper ore," and "rhombohedral emerald." In European literature dioptase appears as *Dioptas*, *dioptasa,* and *dioptasio*. Dioptase should not be confused with the mineral diopside [calcium magnesium silicate, $CaMgSi_2O_6$].

COMPOSITION & STRUCTURE: The molecular weight of dioptase is made up of 40.31 percent copper, 17.82 percent silicon, 40.60 percent oxygen, and 1.27 percent hydrogen. Dioptase is a member of the silicates, the largest class of minerals, in which silicon and oxygen combine with one or more metals. Dioptase is a cyclosilicate or ring silicate, the most structurally complex of all silicate subclasses. Dioptase crystallizes in the trigonal system, which many crystallographers consider a modification of the hexagonal system. The hexagonal system is characterized by four axes, three of equal length, lying in a common plane, and separated by angles of precisely 120 degrees. In dioptase, the tetrahedral arrangement of the copper ions in the crystal lattice modifies this basic hexagonal structure. Dioptase crystals exhibit a six-sided prismatic form, but their terminations are always sharp-edged rhombohedrons. Diopside is an idiochromatic (self-colored) mineral, meaning that its color is caused by its essential elements and, to a lesser extent, by the nature of its crystal lattice. The essential element copper is a powerful chromophoric (color-causing) agent for the colors green and blue. Because of the intensity of dioptase's emerald-green color, accessory chromophoric elements create very little color shift. Traces of iron occasionally create a slight shift toward greenish-blue. Dioptase usually occurs in arid climates and forms exclusively in the oxidized sections of copper deposits from secondary precipitation of copper-rich groundwater in which acidity is chemically buffered by the presence of calcite [calcium carbonate, $CaCO_3$] from nearby limestone.

COLLECTING LOCALITIES: Dioptase is collected in Namibia, Democratic Republic of the Congo, Republic of the Congo, South Africa, Zimbabwe, Canada, Iran, Kazakhstan, Argentina, Chile, and the United States (Arizona, California, and Pennsylvania).

HISTORY, LORE & GEMSTONE/TECHNOLOGICAL USES: Because of its occurrence in shallow deposits of brightly colored, oxidized copper minerals, dioptase has been known since antiquity. In the late 1700s, copper miners in Kazakhstan encountered vugs within quartz veins that were completely filled with brilliant, intensely colored, green crystals. Assuming that these crystals were emeralds, they sent them to Moscow, Russia, where mineralogists determined that the crystals were actually those of an unknown mineral. These crystals were then brought to the attention of French mineralogist René Just Haüy (1743-1822), who determined that they represented a new mineral which he named "dioptase." Despite its intense, emerald-green color, dioptase has very limited use as a gemstone. With a hardness of Mohs 5.0, it is too soft to withstand the abrasion caused by jewelry wear; because of its brittleness, dioptase gems chip easily. Dioptase is an uncommon mineral that only rarely forms unflawed crystals large enough to be faceted. Dioptase is faceted into collectors' gems that are usually less than one carat in weight. Dioptase specimens are widely collected for their rarity and intense, emerald-green color. Metaphysical practitioners believe that dioptase is a symbol of harmony, sympathy, creativity, and good health, as well as a source of energy to refresh the physical, emotional, and intellectual realms. Dioptase is used in crystal healing for heart ailments and to promote deep healing in general. Powdered dioptase saw limited use as a green pigment in ancient times. It has been milled and smelted in very small quantities along with other copper minerals, thus inadvertently serving as a minor ore of copper.

ABOUT OUR SPECIMENS: Our dioptase specimens were collected at the Omaue Mine near the town of Opuwo in the Kunene Region in far northwestern Namibia. The Omaue Mine is situated on the Kaokoveld Plateau, a mountainous, interior area that is known for such unusual wildlife as cheetahs, black rhinos, and desert elephants. At an average elevation of 4,000 feet, the Kaokoveld Plateau consists of short, rugged mountain ranges covered with sparse grass and occasional dwarf trees. The capital of the Kunene Region is Opuwo, a town of 7,500 residents and the only place within thousands of square miles with basic medical facilities and gas stations, along with auto-repair, shopping, hotel, and telecommunication services. The Omaue Mine is located 44 miles south of Opuwo and is part of Camp Aussicht, a small lodge and way station that serves growing numbers of ecotourists. The Omaue copper deposit, discovered in the early 1900s, consists of oxidized copper minerals within quartz veins in a limestone host rock. The deposit was explored with short tunnels and shallow open pits, but the limited extent of the copper mineralization did not warrant commercial mining. German entrepreneurs Marius and Lottie Steiner acquired the property in the early 1980s as a specimen source. Steiner continues to occasionally conduct small-scale mining operations for mineral specimens, which he sells to his guests and to dealers in the Namibian capital of Windhoek who export the specimens to international markets.

COMPREHENSIVE WRITE-UP

COMPOSITION & STRUCTURE

This is only the second time in our 20-year history that we have selected dioptase as our Mineral of the Month. When we first featured dioptase in September 2001, our specimens were from the type locality at the Altyn-Tyube deposit in Karagandy Province, Kazakhstan. This month our specimens are from the Omaue Mine on the Kaokoveld Plateau in the Kunene Region, Namibia.

Dioptase [hydrous copper silicate, $Cu_6Si_6O_{18}\cdot 6H_2O$] contains the elements copper (Cu), silicon (Si), oxygen (O), and hydrogen (H) in the proportions of 40.31 percent copper, 17.82 percent silicon, 40.60 percent oxygen, and 1.27 percent hydrogen. Like all molecules, those of dioptase are made up of an electrically balanced mix of positively charged cations and negatively charged anions. In the dioptase molecule, the cation consists of six divalent copper ions $6Cu^{2+}$ with a collective +12 charge. The dioptase anion is a radical, which is a group of different ions that behaves as an entity in chemical reactions. This anion is the silica radical $(Si_6O_{18})^{12-}$, in which six silicon ions $6Si^{4+}$ and 18 oxygen ions $18O^{2-}$ provide a -12 anionic charge. This -12 anionic charge balances the +12 cationic charge to provide the dioptase molecule with electrical stability.

The "$\cdot 6H_2O$" in dioptase's chemical formula indicates that it is a hydrous (or hydrated) mineral with six water molecules ($6H_2O$), called "water of hydration," attached to each parent molecule. These attached water molecules are electrically neutral and do not affect the electrical balance of the parent molecule. In the configuration of the water molecule, two hydrogen ions $2H^{1+}$ are grouped closely together on one side of a large oxygen ion O^{2-}. These grouped hydrogen ions retain a small positive charge, while the opposite side of the molecule, dominated by the large oxygen ion, retains a small negative charge. This polarity enables water molecules to behave as tiny dipole magnets that can attach themselves to other molecules by a weak attraction called "hydrogen bonding."

Dioptase is a member of the silicates, the largest class of minerals, in which silicon and oxygen combine with one or more metals. The basic silicate structural unit is the silica tetrahedron $(SiO_4)^{4-}$, in which four equally spaced oxygen ions positioned at the four corners of a tetrahedron surround a silicon ion. These oxygen ions are bound to the silicon ion by strong covalent bonding. In silicate minerals, silica anions and metal cations bond together like polymers (repeating chains) to form seven types of structures: double tetrahedral silicates (sorosilicates); framework silicates (tectosilicates); single-chain silicates and double-chain silicates (inosilicates); sheet silicates (phyllosilicates); independent tetrahedral silicates (nesosilicates); and ring silicates (cyclosilicates).

Dioptase is a cyclosilicate or ring silicate, the most structurally complex of all silicate subclasses. In cyclosilicates, silica tetrahedra share two of their oxygen ions with adjacent tetrahedra. Because each tetrahedra thus effectively loses one of its oxygen ions, this arrangement creates groups of linked $(SiO_3)^{2-}$ units. But rather than forming chain-type structures, these stubby, linked silica units combine into ring structures. In dioptase, each ring consists of six $(SiO_3)^{2-}$ units, creating a six-fold geometry that is reflected in the external, hexagonal shape of its crystals. Within the dioptase crystal lattice, the six-sided rings are arranged in flat sheets. Within this basic structure, tetrahedral silica anions "sandwich" hexagonal rings of attached water molecules. These "sandwich" units of hexagonal silica ions and water rings are interconnected by tetrahedrally coordinated copper ions. This entire arrangement of silica ions, copper ions, and water molecules has been compared to a six-pointed pinwheel that is packed into a trigonal unit cell.

Dioptase crystallizes in the trigonal system, which most crystallographers consider a modification of the hexagonal system. The hexagonal system is characterized by four axes, three of equal length, lying in a common plane, and separated by angles of precisely 120 degrees. The fourth axis, called the unique or hexagonal axis, is perpendicular to the plane of the other three and may be of any length. The most common habit of hexagonal minerals is the hexagonal prism with six faces arranged parallel to the hexagonal axis and with flat or modified-flat terminations. An example of this classic hexagonal form is our August 2016 Mineral of the Month beryl [beryllium aluminum silicate, $Be_3Al_2Si_6O_{18}$]. The tetrahedral arrangement of the copper ions in the dioptase crystal lattice, however, modifies beryl's basic hexagonal structure. Dioptase crystals exhibit a six-sided prismatic form, but their terminations are sharp-edged rhombohedons.

Because intra-sheet distances within the dioptase crystal lattice are very small, the ionic bonding between the copper and silicate ions is unusually strong, explaining dioptase's moderate hardness of Mohs 5.0. With the exception of the emerald variety of beryl and a few other green gemstones, dioptase is among the hardest of all green minerals. Because of its modified trigonal structure, dioptase has perfect cleavage in three directions. The veiled outlines of these cleavage planes are visible within transparent dioptase crystals. Despite its close atomic packing and the presence of a substantial amount of the relatively heavy, essential metal copper (40.31 percent), dioptase has only a moderate specific gravity of 3.3-3.4. This is because of the low atomic weights of its other essential elements: silicon, 21.09; oxygen, 16.00; and hydrogen, 1.01.

Diopside is an idiochromatic (self-colored) mineral, meaning that its color is caused by its essential elements and, to a lesser extent, by the nature of its crystal lattice. The essential element copper is a powerful chromophoric (color-causing) agent for the colors green and blue. Divalent copper ions (cupric, Cu^{2+}) cause dioptase's crystal lattice to absorb all white-light wavelengths except those within a very narrow range of green, which are reflected as its diagnostic, emerald-green color. Because of the intensity of this color, accessory chromophoric elements create very little color shift. Traces of iron occasionally create slight shifts toward bluish-green.

The Dana mineral-classification number 61.1.3.1 first identifies dioptase as a cyclosilicate with six-membered rings (61), specifically with Si_6O_{18} rings (1). Dioptase is then assigned to the dioptase group (3) as the first (1) and only member.

Dioptase occurs in arid regions and forms exclusively in the oxidized sections of copper deposits from secondary precipitation of copper-rich groundwater in which acidity is chemically buffered or tempered by the presence of calcite [calcium carbonate, $CaCO_3$] from nearby limestone. If the acidity is too high, the dissolved copper will precipitate as chrysocolla [basic hydrous copper aluminum acid silicate, $(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$]. Dioptase will precipitate only in conditions of relatively low acidity from solutions with the correct proportions of dissolved copper and silica. Dioptase is associated with such minerals as chrysocolla, malachite [basic copper carbonate, $Cu_2(CO_3)(OH)_2$], plancheite [basic hydrous copper silicate, $Cu_8(Si_4O_{11})_2(OH)_4 \cdot H_2O$], shattuckite [basic copper silicate, $Cu_5(Si_2O_6)_2(OH)_2$], wulfenite [lead molybdate, $PbMoO_4$], descloizite [basic lead zinc vanadate, $PbZnVO_4(OH)$], mottramite [lead copper vanadate, $PbCuVO_4(OH)$], and duftite [basic lead copper arsenate, $PbCuAsO_4(OH)$].

COLLECTING LOCALITIES

Our dioptase specimens were collected at the Omaue Mine on the Kaokoveld Plateau in the Kunene Region of Namibia. Dioptase also occurs at the nearby Old German, Okatumba, Onderra, Otjihowe, and Otjitheka mines. Other Namibian sources of dioptase are the Tsumeb Mine at Tsumeb in the Otjokoto Region and the Kombat Mine at Kombat in the Otjozondjupa Region. Sources in the Democratic Republic of the Congo include the Shinkolobwe, Mutoshi, Mashamba West, and Shangulowé mines in the Katanga Copper Crescent, Katanga Province. In the Republic of the Congo, dioptase occurs at the Songo Quarry and the Kimbanga Mine in the Mindouli District in Pool Department; and at Kenge and M'fouati in Bouenza Department. South African sources include the Vergenoeg Mine in Pretoria District, Gauteng Province; and the Swartberg Mine in the Namakwa District in Northern Cape Province. Localities in Zimbabwe include mines in the Makonde District in Mashonaland West.

Other sources include the Jeffrey Mine at Asbestos, Les Sources Regional County Municipality, Estrie, Québec, Canada; the Sar Cheshma Mine, Rafsanjan County, Kerman Province, Iran; the Altyn-Tyube dioptase deposit (type locality), Kirghiz Steppes, Karagandy Province, Kazakhstan; and the Malpaso Quarry at Dumisnil, Colón Department, Córdoba, Argentina. Chile's localities include Los Tres Presidentes Mine at Caracoles, Sierra Gorda District, Antofagasta Province, Antofagasta Region; and the Delirio and Jardinera No. 1 mines at Inca de Oro, Chañaral Province, Atacama Region.

Most dioptase localities in the United States are in Arizona. These include the Shattuck Mine at Bisbee in the Mule Mountains, Cochise County; the Christmas open pit at Hayden in the Banner district and the Oxbow and Summit mines in the Payson district, both in Gila County; the Eagle Eye Mine in the New Water Mountains, La Paz County; the Ray Mine in the Dripping Springs Mountains and the Mammoth-St. Anthony Mine at Tiger, both in Pinal County; and the Morenci Mine at Morenci in Greenlee County. Dioptase also occurs in the Silver Lake District in San Bernadino County, California; and at Teeter's Quarry at Gettysburg, Adams County, Pennsylvania.

JEWELRY & DECORATIVE USES

Despite its intense, emerald-green color, dioptase has very limited use as a gemstone. With a hardness of Mohs 5.0, it is too soft to withstand the abrasion caused by regular jewelry wear; dioptase gems are also brittle and chip easily. Dioptase is an uncommon mineral that rarely occurs in unflawed crystals large enough to cut. Cutting is risky and difficult because of dioptase's perfect, three-directional cleavage. Specimens of drusy dioptase on quartz are sometimes sized and wrapped in silver wire for wear as pendants, most often for metaphysical purposes.

Dioptase is occasionally faceted into collectors' gems that are usually less than one carat in weight. Note that dioptase gems must not be confused with those of chrome diopside, the chromium-rich variety of diopside [calcium magnesium silicate, $CaMgSi_2O_6$], which has a similar, emerald-green color and is harder than dioptase.

Dioptase specimens are widely collected for their rarity and distinctive color. Dioptase crystals larger than one inch are rare. Cabinet-sized specimens of clustered, one-inch crystals can cost thousands of dollars, while miniature-sized specimens cost at least $500. Most dioptase specimens have an overall size of only one or two inches with very small crystals.

HISTORY & LORE

Because it occurs in shallow deposits of brightly colored, oxidized copper minerals, dioptase has been known since antiquity. Its earliest use was as a powdered pigment to highlight the eyes of the 9,200-year-old, lime-plaster, Pre-Pottery Neolithic B statues that were discovered in 1983 at a cultural site in Amman, Jordan.

In the late 1700s, copper miners at Altyn-Tyube on the Kirghiz Steppes in what is now Karagandy Province, Kazakhstan, encountered vugs within quartz veins that were filled with intensely colored, emerald-green crystals. Assuming that these crystals were emeralds of extraordinary quality and value, the miners sent them to Moscow, Russia, for evaluation. To their great disappointment, Russian mineralogists determined through simple hardness tests that the crystals were not emerald, but those of an unknown mineral.

These crystals then came to the attention of French mineralogist René Just Haüy (1743-1822), now known as the "Father of Modern Crystallography," who confirmed that they represented a new mineral. In 1797, he named this new mineral "dioptase," a word stemming from the Greek *dia-*, meaning "through," and *optikos*, meaning "visible." The literal translation, "to see through" or "transparent," alludes to Haüy's observation that internal cleavage planes were visible within the mineral's transparent crystals.

Dioptase has appeared on the 1.5-escudo stamp of Angola in 1970; the 6-zaire stamp of Zaire (now the Democratic Republic of the Congo) in 1983; the 150-Central African franc stamp of the Republic of the Congo in 1970; the 45-dalasi stamp of The Gambia in 2015; and the 20-cent stamp of Namibia in 1991. Metaphysical practitioners believe that dioptase is a symbol of harmony, sympathy, creativity, and good health, as well as a source of energy to refresh the physical, emotional, and intellectual realms. Dioptase is used in crystal healing for heart ailments and for deep healing in general.

NAMIBIA: LAND OF MINERAL SPECIMENS

Along with China, Brazil, Mexico, Morocco, Pakistan, the United States, and India, Namibia is one of the world's leading sources of mineral specimens. Although Namibia has relatively few collecting sites, it has great mineral diversity and is home to more than 100 type localities—places were mineral species were first discovered. Namibia owes its mineral richness to its geology, specifically to the crustal distortion that accompanied the breakup of the ancient Gondwana supercontinent which separated what are now the continents of South America and Africa. Most Namibian country rock consists of sedimentary and volcanic formations that were laid down or emplaced about 240 million years ago. About 135 million years ago during the mid-Cretaceous Period, the breakup of Gondwana fractured the crust, enabling magma and associated, mineral-rich fluids to surge upward and emplace deposits of such metals as copper, gold, silver, lead, zinc, and uranium. A subsequent uplift of much of southern Africa greatly accelerated surface erosion to expose many of these deposits.

Our dioptase specimens are from Namibia's Kaokoveld Plateau, one of that nation's major mineral-specimen localities. Specimen sources on the Kaokoveld Plateau include the Omaue Mine, the source of our specimens, and the Christoph, Kandesei, Okatumba, and Onderra, Otjitheka, Van der Plas, Otjihowe mines, all of which yield specimens of dioptase, plancheite [basic hydrous copper silicate, $Cu_8(Si_4O_{11})_2(OH)_4 \cdot H_2O$], and shattuckite [basic copper silicate, $Cu_5(Si_2O_6)_2(OH)_2$].

Namibia's most famous specimen locality is the legendary Tsumeb Mine at Tsumeb in the northeastern Otjikoto Region, a multimetal deposit first mined by German colonists in 1905. The name Tsumeb comes from a native word meaning "place of the moss," referring to the area's prominent hill of green, oxidized copper minerals. The Tsumeb deposit is a huge, highly mineralized, nearly vertical geological pipe. More than 30 million tons of Tsumeb ore have yielded 1.7 million tons of copper, 900,000 tons of zinc, 2.8 million tons of lead, 90 tons of the rare element germanium, and substantial amounts of silver and gold. On average, Tsumeb's rich ore contains 10 percent lead, 4.3 percent copper, and 3.5 percent zinc. Flooding closed the underground mine in 1996, but the upper levels were later reopened exclusively for specimen recovery. Tsumeb has large remaining reserves of shallow, oxidized ores and is likely to resume production in the future.

Most collectors consider Tsumeb to be the world's greatest single source of mineral specimens. More than 282 minerals have been identified at Tsumeb, and it is the type locality for 70 minerals, some of which have never been found elsewhere. Many Tsumeb specimens are exceptional in size, color intensity, and degree of crystal development. Tsumeb is best known for specimens of dioptase, azurite [basic copper carbonate, $Cu_3(CO_3)_2(OH)_2$], adamite [basic zinc arsenate, $Zn_2(AsO_4)(OH)$], cerussite [lead carbonate, $PbCO_3$], mimetite [lead chloroarsenate, $Pb_5(AsO_4)_3Cl$], smithsonite [zinc carbonate, $ZnCO_3$], willemite [zinc silicate, $ZnSiO_4$], and wulfenite [lead molybdate, $PbMoO_4$].

Another notable source of Namibian mineral specimens is the Kombat Mine at Kombat in the Otjozondjupa Region not far from Tsumeb. Like Tsumeb, the Kombat Mine began production in the early 1900s and became a major source of copper, lead, and zinc. The Kombat Mine produced nearly 12 million metric tons of copper until lower-level flooding closed the mine in 2008. It may reopen in the future as an open-pit operation. Like Tsumeb, the Kombat Mine is known for specimens of a variety of oxidized copper, lead, and zinc minerals.

Other important specimen localities include the Erongo Mountain, Karibib, Goboboseb Mountains, and Brandberg districts in central Namibia's Erongo Region, where basaltic cavities and pegmatites yield the aquamarine variety of beryl [beryllium aluminum silicate, $Be_3Al_2Si_6O_{18}$], ilmenite [iron titanium oxide, $FeTiO_3$], fluorite [calcium fluoride, CaF], the amethyst variety of quartz [silicon dioxide, SiO_2], topaz [basic aluminum fluorosilicate, $Al_2SiO_4(F,OH)_2$], phenakite [beryllium silicate, $BeSiO_4$], and the tourmaline-group mineral schorl [basic sodium iron aluminum borosilicate, $NaFe_3Al_6(Si_6O_{18})(BO_3)_3(OH)_4$]. The alpine-cleft-type mineralization in the Gambergs area of central Namibia's Khomas Region yields specimens of the amethyst variety of quartz, rutile [titanium dioxide,TiO_2], epidote [basic calcium aluminum iron oxysulfosilicate, $Ca_2Al_2Fe(Si_2O_7)(SiO_4)O(OH)$], scheelite [calcium tungstate, $CaWO_4$], and titanite [calcium titanium oxysilicate, $CaTiOSiO_4$].

Prospectors discovered diamonds in 1908 near the coastal town of Luderitz in southwestern Namibia when the region was still the German colony of South-West Africa. By the start of World War I, German colonists had exported more than seven million carats of diamonds, many gathered by hand from the sandy floors of the desert valleys. Another diamond source was discovered in the 1930s near Oranjemund on the Orange River in the far south of Namibia. After 80 years of continuous mining, this area has yielded more than 65 million carats of diamonds. Namibia now ranks sixth in world annual diamond production, recovering 1.6 million carats of diamonds per year from open-pit, onshore, and offshore mining operations. All Namibian diamonds occur in placer deposits as concentrations of loose diamonds in alluvial gravels and sands. Geologists estimate that at least two billion carats of diamonds, mostly of gem quality, can be recovered from the Namibian sea bottom alone.

Namibia's rapidly growing, small-scale mining sector that produces gemstones and decorative stones is centered in the Erongo-Brandberg region of granite pegmatites and basaltic vugs. The discovery of gem-quality aquamarine and amethyst there in the late 1990s attracted hordes of native diggers. Today, thousands of small-scale miners earn their livings recovering gemstones, decorative stones, and mineral specimens. Compiling accurate production figures for these independent miners is difficult because of incomplete reporting and also because many of these gemstone and minerals are smuggled out of the country to avoid paying high government mineral-production taxes.

To boost its own tax revenues while improving the lives of independent miners, the Namibian government is attempting to restructure the small-scale mining sector by aiding miners's marketing efforts and establishing domestic cutting-and-polishing facilities so that "value-added" gemstone products can be exported at higher prices. The government is also setting up regional organizations, such as the Erongo Small-Scale Gemstone Miners Association of Namibia, to teach advanced mining techniques, disseminate geological information, improve safety, and assist in business planning. Four international specimen dealers now have headquarters in the Namibian capital of Windhoek and regularly send representatives to mines and mining districts throughout the country to purchase specimens.

TECHNOLOGICAL USES

Powdered dioptase saw limited use as a green pigment in ancient times. Dioptase has also been milled and smelted in small quantities along with other copper minerals, thus inadvertently serveing as a minor ore of copper.

ABOUT OUR SPECIMENS

Our dioptase specimens were collected at the Omaue Mine near the town of Opuwo in the Kunene Region, Namibia. Located in southwestern Africa, Namibia adjoins the Atlantic Ocean on the west, Angola on the north, Botswana on the east, and South Africa on the south. Covering 318,259 square miles, Namibia's area is comparable to that of the combined American states of Texas and Oklahoma. Because much of Namibia is arid, inhospitable desert, its population is only 2.2 million, making it the world's second least-densely populated nation after Mongolia. In 1884, Great Britain annexed part of the region to its Cape Colony (now South Africa), while Germany claimed adjacent sections as its Südwestafrika (South-West Africa) colony. During

World War I, South Africa occupied South-West Africa, then assumed regional administration in 1920 before finally annexing South-West Africa in 1946. In 1968, the United Nations changed the name of South-West Africa to Namibia and appointed an international council to supervise its affairs prior to independence. Fighting between South African troops and the South-West Africa People's Organization (SWAPO) rebels continued through the 1980s. In 1992, Namibia adopted a SWAPO-controlled, Western-style, constitutional government and received its independence. Today, Namibia's economy is based on farming and ranching, along with diamond, gold, and uranium mining.

The Kunene Region, one of 14 federal administrative regions, is located in far northwestern Namibia and borders the Atlantic Ocean on the west, Angola on the north, and the Namibian administrative regions of Omujati, Oshana, Oshikoto, Otzondjupa, and Erongo on the east and south. With an are of 44,500 square miles, the arid, mountainous Kunene Region is nearly the size of the American state of Pennsylvania. It has a population of only 88,000 and a population density of just two people per square mile. The region is one of the wildest and least-populated areas of southern Africa. The Kunene Region's unimproved-gravel roads often become impassable during the brief rainy season; the region has only 58 schools and the homes of less than one-quarter of its population have electricity.

Much of the Kunene Region was originally known as the "Kaokoveld," a proposed homeland for the Ovahimba people, the region's dominant indigenous culture. Today, the word "Kaokoveld" refers to both a coastal desert and to a large plateau in the mountainous interior, the latter known for such unusual wildlife as cheetahs, black rhinos, and desert elephants. At an average elevation of 4,000 feet, the Kaokoveld Plateau consists of short, rugged mountain ranges covered with sparse grass and occasional dwarf trees. Local nomadic tribes tend small herds of cattle, sheep, and goats, or engage in subsistence farming using what little water is available.

The capital of the Kunene Region is Opuwo, a town of 7,500 residents that was built as a military headquarters during the SWAPO wars of the 1980s. Despite its unimpressive size, Opuwo has great regional importance as the only place within thousands of square miles with basic medical facilities and gas stations, along with auto-repair, shopping, hotel, and telecommunication services.

The Omaue Mine, the source of our dioptase specimens, is 44 miles (two hours driving time) south of Opuwo along the C43 gravel "highway." The mine is part of Camp Aussicht, a small lodge and way station that serves a growing number of ecotourists. The mine, located at coordinates 18° 41' 37" south latitude and 13° 44' 31" east longitude, is 60 miles south of the Angolan border, 120 miles east of the Atlantic coast, and 400 miles north-northwest of the national capital of Windhoek.

The Omaue copper deposit was discovered in the early 1900s. Over many decades, it was explored with several short tunnels and shallow open pits, but the limited copper mineralization did not warrant commercial mining. It nevertheless became known for its specimens of dioptase, malachite [basic copper carbonate, $Cu_2(CO_3)(OH)_2$], and shattuckite [basic copper silicate, $Cu_5(Si_2O_6)_2(OH)_2$]. German entrepreneurs Marius and Lottie Steiner acquired the property in the early 1980s as a specimen source. A few years later, they opened Camp Aussicht, a campground and primitive lodge that now offers trekking and guided tours to remote native villages, along with opportunities for bird watching, wildlife viewing, and nature photography. Tours of the Omaue Mine are another attraction. Steiner continues to conduct limited mining operations for mineral specimens, which he sells to his guests and to dealers in Windhoek for export to international markets.

At the Omaue Mine, the host rock is the Otavi Group limestone that was laid down some 500 million years ago. About 60 million years ago, solutions rich in copper and silica intruded this limestone to form a complex vein system of quartz and the minerals chalcocite [copper sulfide, Cu_2S] and covellite [copper sulfide, CuS]. Erosion later reduced the surface, exposing the upper veins to groundwater and atmospheric oxygen. The copper-sulfide minerals altered into dioptase, malachite, shattuckite, azurite [basic copper carbonate, $Cu_3(CO_3)_2(OH)_2$], chrysocolla [basic hydrous copper aluminum acid silicate, $(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$], cuprite [copper oxide, Cu_2O], tenorite [copper oxide, CuO], mottramite [basic lead copper vanadate, $PbCuVO_4(OH)$], and plancheite [basic hydrous copper silicate, $Cu_8(Si_4O_{11})_2(OH)_4 \cdot H_2O$].

Your specimen of dioptase from the Omaue Mine on Namibia's Kaokoveld Plateau consists of a coating of small dioptase crystals on a matrix of massive, gray quartz. The dioptase has a characteristic, saturated, emerald-green color. Using a loupe or magnifying glass, you will be able to see that the dioptase forms short, stubby, hexagonal crystals that are doubly terminated with rhombohedral termination faces. The prominent termination faces appear square or rectangular and have a bright, glassy luster. The orange-brown coating seen in cracks within the quartz matrix in some specimens is hematite [iron oxide, Fe_2O_3].

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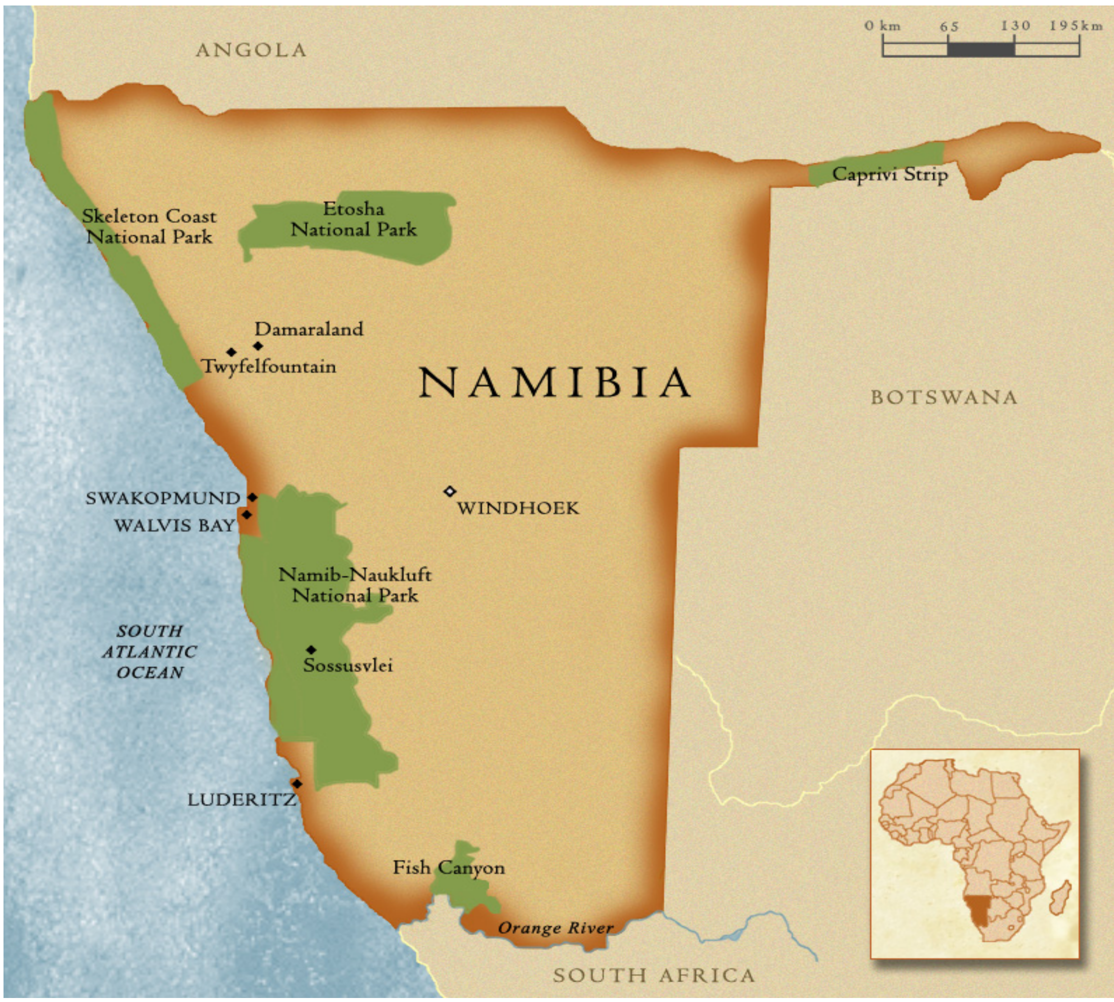
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NAMIBIA
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WINDHOEK
Namib-Naukluft
National Park
SOUTH
ATLANTIC
OCEAN
Sossusvlei
LUDERITZ
Fish Canyon
Orange River
SOUTH AFRICA