

## PROBERTITE

This month we are featuring probertite, a rare borate mineral from the world's largest borate mine in California. Our write-up explains the unusual formation of borate deposits, the history of borate mining, and how our specimens came from a world-class collection.

### PHYSICAL PROPERTIES

Chemistry:  $\text{NaCaB}_5\text{O}_7(\text{OH})_4 \cdot 3\text{H}_2\text{O}$  Basic Hydrrous Sodium Calcium Borate (Hydrrous Sodium Calcium Borate Hydroxide)

Class: Borates

Subclass: Hydrated Borates

Group: Probertite

Crystal System: Monoclinic

Crystal Habits: Usually as flattened, acicular crystals aggregated into rosettes or compact, radial, reticulated masses; individual crystals rare; striations common.

Color: Usually colorless; impurities may create very pale-gray or pale-brownish hues.

Luster: Vitreous

Transparency: Transparent

Streak: White

Refractive Index: 1.514-1.543

Cleavage: Perfect in one direction

Fracture: Irregular, brittle; shatters into needle-like fragments.

Hardness: 3.5

Specific Gravity: 2.14

Luminescence: Exhibits yellow fluorescence under shortwave and long-wave ultraviolet light.

Distinctive Features and Tests: Best field marks are acicular, radiating, transparent, colorless crystals; occurrence in bedded, lacustrine environments; and association with other borate minerals such as colemanite [basic hydrrous calcium borate,  $\text{CaB}_3\text{O}_4(\text{OH})_3 \cdot \text{H}_2\text{O}$ ] and kernite [basic hydrrous sodium borate,  $\text{Na}_2\text{B}_4\text{O}_6(\text{OH})_2 \cdot 3\text{H}_2\text{O}$ ]. Probertite is readily soluble in dilute acids, decomposes slowly in hot water, and fuses Easily into clear, glass-like beads. Can be confused with other borate minerals and sometimes requires laboratory analysis for positive identification.

Dana Classification Number: 26.5.12.1

**NAME:** Probertite, pronounced PRO-bert-ite, is named in honor of American mineralogist Frank H. Probert (1876-1940). Probertite has also been known as “boydite,” “kramerite,” “kramer borate,” and “needle borate.” In European mineralogical literature, probertite appears as *probertit* and *probertita*.

**COMPOSITION:** Probertite consists of 6.55 percent sodium, 11.41 percent calcium, 15.39 percent boron, 63.78 percent oxygen, and 2.87 percent hydrogen. Probertite is a member of the borate class of minerals, a complex class of about 160 members, each of which consists of boron

and oxygen combined with one or more metals. Probertite crystallizes in the monoclinic system, which is characterized by three axes of different length, two of which are perpendicular. Monoclinic crystals tend to elongate along one axis and often produce acicular or long, needle-like crystals. The lattice structure of probertite consists of sheets of molecules. The ionic bonding between these sheets is quite weak, which explains probertite's perfect cleavage in one direction, brittleness, and relative softness of Mohs 3.5. Because of the low atomic weights of its constituent elements, probertite has a very low density (specific gravity 2.14). Probertite is an allochromatic or "other-colored" mineral. When nearly pure, it is colorless and transparent, but traces of impurities, usually of iron substituting for calcium, sometimes create pale-gray and pale-brownish hues and introduce a slight translucency. Probertite is a low-temperature, low-pressure mineral that occurs in sedimentary layers that often underlie playas (intermittent lakes) in arid regions.

**COLLECTING LOCALITIES:** California is by far the world's most abundant source of probertite specimens with notable localities in Kern, Inyo, and Los Angeles counties. Probertite is also collected in Oklahoma. Other sources are located in Turkey, Chile, Argentina, Canada, and Germany.

**HISTORY, LORE & GEMSTONE/TECHNOLOGICAL USES:** Probertite was discovered in 1927 in Kern County, California, by Dr. Frank H. Probert (1876-1940), the dean of the Mining College of the University of California. Although the mineral was recognized as a new species the following year, mineralogists were unable to clearly determine its chemical composition and crystal structure until the 1950s. Because of its softness, probertite has no use in jewelry. Mineral collectors value probertite specimens for their rarity and unusual radial arrangement of acicular crystals. Probertite is a minor ore of borates. Borate minerals and compounds are used to manufacture heat-resistant glassware, fiberglass, fiber-optic cable, advanced fiber-composite materials, detergents, soaps, paints, motor oils, enamels, ceramic glazes, and coated papers. Borates are obtained from open-pit mines and with brine- and solution-extraction methods. After mining, borate ores consisting of several borate minerals are dissolved in water and purified. Borates are among the few minerals in which the United States is self-sufficient. The U.S. has led the world in borate production since the 1880s and now accounts for more than one-quarter of the 4.1 million metric tons of borates mined worldwide each year. Almost all domestic borate production comes from a single mine in California's Mojave Desert.

**ABOUT OUR SPECIMENS:** Our probertite specimens are from the U.S. Borax Corporation's Boron Pit (also known as the Baker Mine and Kramer Mine) near the town of Boron in the Kramer district, Kern County, California. Boron, 40 miles west of Barstow and 140 air miles northeast of downtown Los Angeles, is located at the western edge of the Mohave Desert at an elevation of 2,460 feet. Regional bedrock consists of basaltic lava overlaid by various sediments. During the late Miocene Epoch some 18 to 12 million years ago, hot springs rose through fractured basalt, altered and dissolved anhydrous borate minerals, then concentrated them in the groundwater of a surface playa or intermittent, closed lake. Over a period of six million years, sedimentation created layers of clay, shale, and borate minerals. The Boron Pit ore body is a borate layer more than 1.5 miles long, one-half mile wide, and 200 feet thick that is covered by 400 feet of sandstone and shale overburden. The Boron Pit, California's largest open-pit mine, is 1.5 miles long, 1 mile wide, and 700 feet deep. The Boron Pit produces three

million tons of ore per year, from which one million tons of borate compounds are extracted. The Boron Pit supplies one-quarter of the entire world demand for borates. The mine has already produced for 75 years and its projected operating life, based on the current production rate, is at least another 75 years. Our probertite specimens were collected in the 1980s by the mine manager of the Boron Pit and were formerly part of a world-famous collection of borate minerals.

## COMPREHENSIVE WRITE-UP

### *COMPOSITION*

Probertite, chemical formula  $\text{NaCaB}_5\text{O}_7(\text{OH})_4 \cdot 3\text{H}_2\text{O}$ , contains five elements: sodium (Na), calcium (Ca), boron (B), oxygen (O), and hydrogen (H). Its ideal molecular weight is made up of 6.55 percent sodium, 11.41 percent calcium, 15.39 percent boron, 63.78 percent oxygen, and 2.87 percent hydrogen. Like all molecules, those of probertite are composed of positively charged cations and negatively charged anions. The compound cation in probertite consists of a sodium ion  $\text{Na}^{1+}$  and a calcium ion  $\text{Ca}^{2+}$ , which provide a total cationic charge of +3.

Probertite's compound anion consists of two radicals, which are groups of ions of different atoms that behave as single entities in chemical reactions. The first is the borate radical  $(\text{B}_5\text{O}_7)^{1+}$ , which has five boron ions  $5\text{B}^{3+}$ , seven oxygen ions  $7\text{O}^{2-}$ , and a collective charge of +1. The second radical in probertite's compound anion is the hydroxyl ion  $(\text{OH})^{1-}$ . Four hydroxyl ions  $4(\text{OH})^{1-}$  provide a charge of -4. The total anionic charge of the borate and hydroxyl ions is -3, which balances the total cationic charge of +3 to provide the probertite molecule with electrical stability.

The " $\cdot 3\text{H}_2\text{O}$ " in probertite's chemical formula indicates that it is a hydrous (or hydrated) mineral with three molecules of water ( $3\text{H}_2\text{O}$ ) attached to each parent molecule. Attached water molecules, collectively called "water of hydration," are electrically neutral and do not affect the electrical balance of the parent molecule. Water molecules have an unusual atomic configuration, with two hydrogen ions grouped together on one side of a large oxygen ion. These 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. The resulting polarity enables water molecules to behave as tiny dipole magnets that can attach themselves to other molecules by a weak attraction called "hydrogen bonding."

Probertite is a member of the borates, a complex class of about 160 minerals in which boron and oxygen combine with one or more metals. Many borate minerals also contain water, and some contain hydroxyl and halogen ions. Others are compound borate-phosphates, borate-sulfates, and borate-arsenates. The basic building block of borate minerals is the borate radical  $(\text{BO}_3)^{3-}$ , a triangular structure in which three oxygen ions surround a single boron ion. These borate triangles can link together to form infinite ring and chain structures. By sharing their oxygen ions, borate radicals have many possible arrangements, such as  $(\text{B}_3\text{O}_5)^{1-}$ ,  $(\text{B}_5\text{O}_7)^{1+}$ ,  $(\text{B}_5\text{O}_9)^{3-}$ ,  $(\text{B}_6\text{O}_{11})^{4-}$ , and so forth, thereby making possible the large number of borate minerals. The two general types of borates are anhydrous (without water) and hydrous (with water). Anhydrous borates are rare, chemically stable, and occur in igneous and metamorphic environments.

Hydrous borates, such as probertite, are relatively common and occur in sedimentary environments, often in playas (enclosed, intermittent lakes) in arid regions. The hydrous borates are brittle, soft, low in density, colorless or white, and transparent; anhydrous borates tend to be dark in color and relatively heavy.

Probertite crystallizes in the monoclinic system, which is characterized by three axes of different length, two of which are perpendicular. Many minerals that are chemically complex or that have complex bonding arrangements crystallize in the monoclinic system. Monoclinic crystals tend to elongate along one axis, producing, as seen in probertite, acicular or long, needle-like crystals. The atomic bonding within probertite is both covalent and ionic. Within the borate ion, boron ions and oxygen ions share electrons to bond covalently. Sodium, calcium and hydroxyl ions are joined to borate ions by much weaker ionic bonding. The probertite lattice consists of infinite, stacked, flat sheets of borate radicals  $(B_5O_7)^{1+}$ . Inter-sheet spaces provide room for attachment of water molecules and for the ionic bonding of sodium, calcium, and hydroxyl ions. The inter-sheet bonding is entirely ionic and quite weak, which explains several of probertite's important physical characteristics, such as perfect cleavage in one direction, brittleness, and relative softness of Mohs 3.5. Weak ionic and hydrogen bonding account for probertite's instability in water and solubility in weak acids. When placed in water and acids, ionic and hydrogen bonds slowly part, enabling calcium ions and some hydroxyl ions to leach out. This restructures the borate ion, thus converting probertite into the common borate mineral kernite [basic hydrous sodium borate,  $Na_2B_4O_6(OH)_2 \cdot 3H_2O$ ]. Probertite's very low density (specific gravity 2.14) is due to the low atomic weights of its constituent elements (sodium, 22.99; calcium, 40.08; boron, 10.81; oxygen, 16.00; hydrogen, 1.01).

The Dana mineral-classification number 26.5.12.1 first identifies probertite as a hydrated borate containing either hydroxyl or halogen ions (26) that is grouped into the fifth (5) of six subdivisions. Probertite is then assigned to the probertite group (12) as the first (1) of two members. The only other probertite-group member is the rare mineral tuzlaite [basic hydrous sodium calcium borate,  $NaCaB_5O_8(OH)_2 \cdot 3H_2O$ ], which is similar to probertite in bonding arrangements, chemistry, and general appearance. Laboratory analysis is usually necessary to distinguish probertite from tuzlaite.

Probertite is an allochromatic or "other-colored" mineral. When nearly pure, probertite is colorless and transparent. Traces of impurities, usually of iron substituting for calcium, sometimes create pale-gray or pale-brownish hues and introduce a slight translucency.

Probertite is a low-temperature, low-pressure mineral that occurs in sedimentary layers, often those underlying playas in arid regions. The geochemical mechanism for concentrating borates in shallow deposits begins with tectonic-plate volcanism near major subduction zones. Deep magmas moving upward through volcanic conduits carry small amounts of dark, dense, insoluble, anhydrous borates which crystallize within various igneous rocks, especially basalt. Upon contact with water at elevated temperature and pressure, these anhydrous borates metamorphose into soluble, hydrous borates. Groundwater then dissolves these hydrous borates and transports them to the surface. In arid regions, this borate-rich water sometimes collects in playas. With lengthy, repeated cycles of water replenishment and evaporation, borates crystallize out of solution on the lake bottoms to form bedded, evaporite deposits. The sequential order in the alteration of borate minerals begins when the original anhydrous borates

are metamorphosed into hydrous borates that dissolve and later recrystallize as borax [basic hydrous sodium borate,  $\text{Na}_2\text{B}_4\text{O}_5(\text{OH})_4 \cdot 8\text{H}_2\text{O}$ ] and ulexite [basic hydrous sodium calcium borate,  $\text{NaCaB}_5\text{O}_6(\text{OH})_6 \cdot 5\text{H}_2\text{O}$ ]. Subsequent low-temperature metamorphism can alter borax and ulexite into colemanite [basic hydrous calcium borate,  $\text{CaB}_3\text{O}_4(\text{OH})_3 \cdot \text{H}_2\text{O}$ ] and kernite [basic hydrous sodium borate,  $\text{Na}_2\text{B}_4\text{O}_6(\text{OH})_2 \cdot 3\text{H}_2\text{O}$ ]. A final alteration can sometimes result in the formation of the rarer borate minerals probertite and tuzlaite.

### *COLLECTING LOCALITIES*

Although widely distributed, borate minerals have few collecting localities; large, concentrated deposits suitable for mining are rare. Our probertite specimens were collected at the Boron Pit, a mining operation of the U.S. Borax Corporation, near the town of Boron in the Kramer district, Kern County, California. Among the borate localities in adjacent Inyo County are the Gerstley Mine in the Resting Springs Range, the Upper Biddy Mine in the Furnace Creek district, the Eagle Borax Spring and the Saratoga district mines, all in Death Valley National Park; and the Tecopa district mines in the Black Mountains. Probertite also occurs in the Tick Canyon borate deposit near Lang in Los Angeles County. Other probertite localities in the United States are in Oklahoma and include the U.S. Gypsum Co. quarry in Blaine County and the Universal Atlas quarry in Custer County.

In Turkey, probertite is collected at the Kestelek Mine at Mustafa Kemalpafla, Bursa Province, Marmara Region; and at Doğonlar, Kütanhya Province in the Aegean Region. Chilean specimens come from Zapiga, Iquique Province, Tarapacá Region; and from Canchas, Antofagasta Province, Antofagasta Region. Other localities include the Tincalayu Mine at Salar de Hombre Muerto, Salta, Argentina; the Cheverie prospects in Hants County, Nova Scotia, Canada; and the Kohnstein Quarry at Nordhausen, Harz, Thuringia, Germany.

### *JEWELRY AND DECORATIVE USES*

Because of its softness (Mohs 3.5), probertite is not used in jewelry. Mineral collectors value probertite specimens for their rarity and the unusual, radial arrangement of its acicular crystals.

### *HISTORY AND LORE*

Archaeologists believe that the Babylonians used borate minerals as early as 1600 B.C. Arabian jewelry-makers were employing borates as a bonding flux by the 8<sup>th</sup> century A.D., about the same time that the Chinese began using borates in ceramic glazes. Borate minerals mined in Tibet were introduced to Europe by Venetian traveler Marco Polo (1254-1324). Tibet remained the main source of borates until the early 1800s when small quantities of sassolite [natural boric acid, hydrogen borate,  $\text{H}_3\text{BO}_3$ ] were discovered at volcanic steam vents in Tuscany, Italy. Borates, then considered rare and obtainable only from limited sources in Tibet, Turkey, and Italy, became popular folk remedies (of questionable effectiveness) for a variety of ailments ranging from acne and dandruff to bunions and epilepsy. Borates became readily available in

quantity in the United States and Europe only after large borate deposits were discovered in California's Mojave Desert in the late 1800s (see "About Our Specimens").

Although borate minerals have been known since antiquity, mineralogists only began to differentiate them by species in the late 1700s. Probertite was one of two new borate minerals discovered during the development of the huge borate deposits in the Kramer district, Kern County, California, in the 1920s. As miners sank shafts into these deep, lake-bed deposits in 1925, mineralogists flocked to the site for a rare opportunity to study an in-situ borate occurrence. In 1927, mineralogists recognized one of the district's abundant borate minerals as a new species and named it after Kern County—kernite [basic hydrous sodium borate,  $\text{Na}_2\text{B}_4\text{O}_6(\text{OH})_2 \cdot 3\text{H}_2\text{O}$ ]. Among the mineralogists who visited the Kramer district that year was Dr. Frank H. Probert (1876-1940), then the dean of the Mining College of the University of California. Probert collected specimens of an unfamiliar borate mineral with a distinctive, radiating crystal habit and studied them for more than a year. Although the crystal structure and habit indicated a new borate species, mineralogists were unable to precisely determine the chemical composition.

In 1928, Probert nevertheless proposed that his specimens, which he defined by the formula " $\text{Na}_2\text{CaB}_6\text{O}_{11} \cdot 6\text{H}_2\text{O}$ ," be recognized as a new mineral species. The following year, Arthur S. Eakle (1862-1931), a University of California research mineralogist and a founding member and president of the American Mineralogical Society, agreed and proposed the name "probertite" in honor of Dr. Frank Probert. Probertite was initially classified as a hydrous borate and was assigned Probert's original chemical formula " $\text{Na}_2\text{CaB}_6\text{O}_{11} \cdot 6\text{H}_2\text{O}$ ." But in the 1950s, after advanced methods of quantitative analysis refined its composition and improved X-ray diffraction methods revealed its structural details, probertite was re-described as a *basic* hydrous borate and assigned its current chemical formula  $\text{NaCaB}_5\text{O}_7(\text{OH})_4 \cdot 3\text{H}_2\text{O}$ . Probert's original type specimens are archived at the National Museum of Natural History (Smithsonian Institution) in Washington, D.C.

No metaphysical properties are currently assigned to probertite.

## *UNDERSTANDING BORON AND BORAX*

"Borax" is familiar to most folks as a general-purpose cleaner, laundry-detergent "booster," water conditioner, and household disinfectant. But in the contexts of mineralogy, chemistry, mining, and marketing, the word "borax" actually has four distinctly different meanings. Its name is derived from *būraq*, the Arabic word for "white," alluding to the color of borate salts. "Borax" entered the English language in the 14<sup>th</sup> century as a general term for all borate minerals. Borax is also the root of the word "boron," the base element of all borates. Boron (B) is a hard, brittle, light, semimetallic element with a low atomic weight of 10.81, higher than that of beryllium, but below that of carbon. Because of its strong chemical affinity for oxygen, boron never occurs free in nature. Ranking 38<sup>th</sup> among the elements in crustal abundance, boron is as common as lead. Although boron minerals are widely distributed, concentrated deposits suitable for commercial mining are rare. Borate minerals and compounds have been known since antiquity, but boron itself was not recognized as an element until 1808, when French chemist

Joseph Louis Gay-Lussac (1778-1850) and British chemist Sir Humphry Davy (1778-1829), working independently, isolated it as a gray, amorphous powder.

Many properties of boron are generally similar to those of silicon and carbon. Boron has an extremely high melting point of 3956° F. (2180° C.) With a specific gravity of only 2.35, boron is about 20 percent less dense than quartz [silicon dioxide, SiO<sub>2</sub>]. Although usually isolated as an amorphous powder, boron can also be prepared in a crystalline form that is similar to diamond in appearance and optical properties and is nearly as hard. An excellent neutron-absorbing material, elemental boron has several important applications in the field of atomic energy, mainly in instruments that detect and count neutrons, as control absorbers in nuclear reactors, and as a constituent of neutron shields. Boron also has unusual electrical properties. Elemental boron conducts electricity and acts as a metal, but in compounds it behaves as a nonmetal much like carbon and sulfur—the reason that borates are generally similar to carbonates and sulfates.

Now to return to the contextual meanings of the word “borax.” In its mineralogical usage, “borax” refers to a distinct mineral species—basic hydrous sodium borate [Na<sub>2</sub>B<sub>4</sub>O<sub>5</sub>(OH)<sub>4</sub>·8H<sub>2</sub>O]—that is one of the most abundant borate minerals. In 1753, borax was the first borate to be recognized as a distinct species.

But in the mining context, “borax” refers to any borate ore or mix of borate ores. The four abundant, borate ore minerals are borax, colemanite [basic hydrous calcium borate, CaB<sub>3</sub>O<sub>4</sub>(OH)<sub>3</sub>·H<sub>2</sub>O], ulexite [basic hydrous sodium calcium borate, NaCaB<sub>5</sub>O<sub>6</sub>(OH)<sub>6</sub>·H<sub>2</sub>O], and kernite [basic hydrous sodium borate, Na<sub>2</sub>B<sub>4</sub>O<sub>6</sub>(OH)<sub>2</sub>·3H<sub>2</sub>O]. Mines that extract any of these ore minerals individually or in combination are known as “borax” mines.

In its chemical and industrial uses, the word “borax” refers to the synthetic chemical compound anhydrous sodium borate (Na<sub>3</sub>BO<sub>3</sub>). This widely manufactured compound, known as “chemical borax,” is the basic feedstock for producing a host of boron-containing compounds with many uses (see “Technological Uses”). A substantial amount of chemical borax is used to manufacture the familiar drugstore item boric acid (H<sub>3</sub>BO<sub>3</sub>). A white crystalline powder, boric acid is prepared by treating borax with sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) according to the formula 2Na<sub>3</sub>BO<sub>3</sub> + 3H<sub>2</sub>SO<sub>4</sub> = 2H<sub>3</sub>BO<sub>3</sub> + 3Na<sub>2</sub>SO<sub>4</sub> (sodium sulfate). Boric acid is a nonirritating, slightly astringent antiseptic that in dilute aqueous solution was a traditional eyewash (a use no longer recommended). Boric acid is also used in pottery glazes, electroplating baths, and as a steel-hardening, alloying agent.

Finally, in its commercial context the term “borax” refers to consumer products that consist of disodium tetraborate (Na<sub>2</sub>B<sub>4</sub>O<sub>7</sub>) or several closely related, anhydrous and hydrous sodium borates. Of many commercial borax brands, the most familiar is Twenty-Mule Team Borax™, so named for the 20-mule-team freight wagons (see “About Our Specimens”) that once hauled borax ore in California. Commercial borax has been an effective and popular cleaning agent for well over a century. Heated solutions of commercial borates clean and bleach by converting some water molecules to hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>), a powerful oxidizing (bleaching) agent. Borate solutions have a pH, or hydrogen-ion concentration, of 9.5, thus providing an alkaline environment that enhances the effectiveness of liquid hypochlorite (sodium oxychloride, NaOCl) bleaches and other cleaners. Commercial-borate solutions also act as chemical buffers,

maintaining a high pH that accelerates cleaning reactions. Because boron and oxygen ions inhibit the metabolic processes of single- and multicelled organisms, commercial borates are also effective disinfectants. When mixed with laundry detergents, borates bond with detergent particles to keep ingredients dispersed evenly, thus maximizing the surface area of the active detergents and increasing cleaning effectiveness.

### *TECHNOLOGICAL USES*

As a minor borate ore, probertite is mined in small quantities along with the four major borate ores borax, colemanite, ulexite, and kernite. Borates are obtained from open-pit mines and by brine- and solution-extraction methods. In brine processing, borate-rich natural brines are pumped from underground wells into surface ponds for solar evaporation. In solution mining, superheated water is injected into underground beds to dissolve borates, then returned to the surface for evaporation. Recovered, crude borates are mixtures of borate minerals which are dissolved in water and purified. The individual borate minerals can be easily separated by fractional crystallization. After purification, borate-ore minerals are dehydrated and converted to chemical borax (see “Understanding Boron and Borax”).

About 60 percent of all borates are used in glassmaking, mainly in the manufacture of fiberglass, fiber-optic cable, and heat-resistant Pyrex™-type glassware. Another 10 percent is used in ceramics, ceramic glazes, and advanced fiber-composite materials. Smaller amounts go into agricultural fertilizers, detergents, soaps, paints, motor oils, enamels, welding-rod flux coatings, and coated papers. Borates are used in borax-bead tests for mineral identification. In these tests, chemical borax is first mixed with finely ground, metallic minerals. When heated to incandescence, metal oxides in the mineral sample are converted into metal borates which form molten beads with characteristic, identifiable colors.

Borates are among the few minerals in which the United States is self-sufficient. As the world's leading source of borates since the 1880s, the U.S. now accounts for about 25 percent of the 4.1 million metric tons of borates mined worldwide each year. Virtually all domestic borate production comes from the huge Boron Pit near Boron, California (see “About Our Specimens”). Turkey ranks second in borate production, followed by Argentina and Chile. Purified borate ores now sell for about \$400 per metric ton.

### *ABOUT OUR SPECIMENS*

Our probertite specimens were collected at the U.S. Borax Corporation's Boron Pit (also known as the Baker Mine and Kramer Mine) near the town of Boron in the Kramer district, Kern County, California. Boron, population 2,100, is located in south-central California on California Highway 58 about 90 highway miles east of Bakersfield, 40 miles west of Barstow, and near the northeast boundary of Edwards Air Force Base. Boron, elevation 2,460 feet, is 140 air miles northeast of downtown Los Angeles at the western edge of the Mojave Desert. The generally flat terrain is broken only by low ridges of dark, volcanic rock and is covered only by sparse, desert scrub growth.



As the site of the world's largest borate deposits, California's Mojave Desert has a colorful borate-mining history. Borates were first mined in the United States on a small scale in northern California's Tehama County in 1864. In 1872, prospector and entrepreneur Frances Marion Smith (1845-1931), later nicknamed "Borax" Smith, discovered and mined light, fibrous, ulexite nodules, called "cotton balls," near Death Valley. By 1881, several borax mines were operating on Death Valley playas. Miners soon discovered borates at other playas in California's Mohave Desert, and by the late 1880s the United States had become the world's largest borate producer. The most famous early borate mine was the Harmony Borax Works, which became forever associated with the twenty-mule-team wagons that hauled borax ore from Death Valley 166 miles south to a railhead. Twenty-Mule Team Borax™ was and still is marketed worldwide as a laundry and cleaning product.

California's—and the world's—greatest borate deposit was not discovered until 1913 when Dr. John. K. Suckow, a Los Angeles medical practitioner, planned to build a health spa on his desert homestead near the present site of Boron. While drilling for water, Suckow discovered borate minerals at a depth of 180 feet, an event that attracted large numbers of prospectors and land speculators who staked hundreds of nearby claims. Although the Pacific Coast Borax Company quickly acquired most of these claims, including Suckow's discovery well, sporadic drilling failed to locate a major borate deposit. In 1924, Suckow returned and began his own drilling-exploration program, finding a much larger, 70-foot-thick bed of borate minerals at a depth of 210 feet. In 1925, his Suckow Chemical Company sank a shaft and was soon mining five tons of borate ore per day. New drilling quickly revealed an even larger borate layer 120 feet thick on which mining began in 1927. At this time, the nearest town was the tiny road-junction settlement of Kramer, which lent its name to the new mining area—the Kramer Borate-Mining District. In 1928, a new and rapidly growing settlement variously known as Rich, Amargo, Borate, Baker, and Kern and immediately south of the new borate mines was incorporated as Boron.

Between 1927 and 1933, four underground mines near Boron produced 160,000 tons of borate ore to take over the market and force the closure of every other California borate-mining operation. After consolidation, ownership of the Kramer district borate deposit passed through the Western Borax Company; Borax Consolidated, Ltd.; California Borate Company, and finally the U.S. Borax Corporation. U.S. Borax closed the underground mines in 1957 and turned to open-pit mining. In 1967, Rio Tinto Minerals, a major international mining corporation, acquired U.S. Borax as a fully owned subsidiary.

Extensive mining and drilling has since fully revealed the geology of the Kramer Borate-Mining District, where a basaltic bedrock is covered by various sediments. Between 18 and 12 million years ago during the late Miocene Epoch, hot springs rose through the fractured basalt and altered the contained anhydrous borate minerals into hydrous borates. These dissolved and, after being transported by groundwater to the surface, became concentrated in a playa or intermittent, closed lake. Over a period of six million years, sedimentation created layers of clay, shale, and a thick layer of borates. The main deposit is a borate layer more than 1.5 miles long, one-half mile wide, and 200 feet thick that is covered by 400 feet of sandstone and shale overburden. The

borate ore, which is intermixed with particles of clay and shale, grades higher than 40 percent in purity.

Today, the U.S. Borax Corporation's Boron Pit, California's largest open-pit mine, is 1.5 miles long, 1 mile wide, and 700 feet deep. Mining begins with drilling and blasting to remove overburden and shatter the borate ore. Huge electric shovels then "scoop" 80-ton bucket loads of broken rock into 240-ton-capacity haulage trucks. Crushers reduce the ore to one-inch pieces, which are dissolved in a hot, dilute, aqueous borate solution. The resulting, concentrated borate solution is screened and allowed to settle to remove impurities, then cooled to crystallize the borates which are dried and converted to chemical borax and other borate compounds. The Boron Pit now yields three million tons of ore per year, which is processed into one million tons of borate compounds. A fleet of 800 railcars haul these borates to North American markets and to the company's export facility at the Port of Los Angeles. The Boron Pit supplies about one-quarter of the entire world demand for borates and its operating life at the current production rate is estimated at another 75 years.

More than 80 minerals have been identified in the Boron Pit. Along with probertite and the primary ore minerals borax, colemanite, ulexite, and kernite, these include calcite [calcium carbonate,  $\text{CaCO}_3$ ], orpiment [arsenic trisulfide,  $\text{As}_2\text{S}_3$ ], realgar [arsenic sulfide,  $\text{As}_4\text{S}_4$ ], rhodochrosite [manganese carbonate,  $\text{MnCO}_3$ ], pyrrhotite [iron sulfide,  $\text{Fe}_{0.1-0.2}\text{S}$ ], and several zeolite minerals (complex hydrous aluminum silicates). This deposit is the type locality for the minerals kernite, probertite, and mazzite-Na [hydrous sodium aluminosilicate,  $\text{Na}_8(\text{Al}_8\text{Si}_{28}\text{O}_{72}) \cdot 30\text{H}_2\text{O}$ ].

Our probertite specimens were collected in the mid-1980s. Until that time, probertite was considered extremely rare, even at its type locality at the Boron Pit. But in 1985, avid mineral collector and Boron Pit mine manager James W. Minette (1936-2002) discovered an unusual occurrence of well-formed probertite crystals. Realizing that this occurrence was one of the greatest sources of probertite ever found, Minette redirected mining operations to enable specimens to be collected. Minette eventually assembled one of the world's greatest collection of borate minerals. The Jim and Dawn Minette Mineral Collection was placed on the market in 2008 and is still being sold. Our probertite specimens are among those that Jim Minette collected in the mid-1980s and were originally part of his extensive and famed collection of borate minerals. We were very fortunate to have acquired specimens from this historic collection.

As you examine your probertite specimen, note first that its structure consists of radially oriented, acicular crystals, a form that is typical for probertite. Using a loupe, it may be possible to discern numerous longitudinal striations on the faces of the larger, needle-like crystals. The specimen is essentially colorless; its slight gray cast is due to the presence of small amounts of clay minerals. Although each acicular crystal is transparent, the overall specimen appears translucent because of the diffusion of light at the many face contacts of the individual crystals. This translucency is apparent when the specimen is backlighted with an intense light source. Probertite also has little "heft" in the hand because its specific gravity is only 2.14, meaning that your specimen weighs about 20 percent less than a similar volume of quartz. Tiny, gray-brown areas in your specimen are clay minerals; massive, white areas consist of the borate-ore minerals

colemanite and kernite. Your probertite specimen is a souvenir of both the world's greatest deposit of borate minerals and what was once a world-famous mineral collection.

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