Borate Mining History in Death Valley

Inyo and San Bernardino Counties

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Borates are a group of over 100 minerals in which the borate radical BO_3^{-3} is an important constituent. Elemental boron is unknown in the native state because of its strong affinity for oxygen. There are two categories of borates: (1) anhydrous borates (without water), which occur in metamorphic and igneous rock and are rare; and (2) hydrous borates, more common, which are non-marine evaporite minerals precipitated by the evaporation of water in saline lakes (playas) commonly found in arid regions.

Hydrous borates are white, colorless, or transparent and are brittle and relatively soft. Although there are numerous borate minerals, only a few hydrous borate minerals are commercially valuable as ores of the element boron. The principal borate ores found in California are:

Borax	$Na_2O.2B_2O_3.10H_2O$
Kernite	$Na_2O.2B_2O_3.4H_2O$
Colemanite	$2CaO.3B_2O_3.5H_2O$
Ulexite	$Na_2O.2CaO.5B_2O_3.16H_2O$

Borate minerals found in Death Valley are listed on Table 1.

TABLE 1. BORATE MINERALS IN DEATH VALLEY

Mineral Name	*Composition*
Sodium borates:	
Borax	$Na_2B_4O_7 . 10H_2O$
Sborgite	$Na_2B_5O_8 . 5H_2O$
Tincalconite	$Na_2B_4O_7 . 5H_2O$
Calcium borates:	
Colemanite	$Ca_2B_6O_{11} . 5H_2O$
Ginorite	$Ca_2B_{14}O_{23} . 8H_2O$
Gowerite	$Ca_2B_6O_{10} . 5H_2O$
Inyoite	$Ca_2B_6O_{11} . 13H_2O$
Meyerhofferite	$Ca_2B_6O_{11} . 7H_2O$
Nobleite	$CaB_6O_{11} . 4H_2O$
Priceite	$Ca_4B_{10}O_{19} . 7H_2O$
Magnesium borates:	
Hungchaoite	$MgB_4O_7 . 9H_2O$
Inderite	$Mg_2B_6O_{11} . 15H_2O$
Kurnakovite	$Mg_2B_6O_{11} . 15H_2O$
Macallisterite	$Mg_2B_{12}O_{20} . 15H_2O$
Strontium borate:	
Tunellite	$SrB_6O_{10} . 4H_2O$
Sodium-calcium borates:	
Probertite	$NaCaB_5O_9 . 5H_2O$
Ulexite	$NaCaB_5O_9 . 8H_2O$
Sodium-magnesium borate:	
Rivadavite	$Na_6MgB_{24}O_{40} . 22H_2O$
Sodium-silicon borate:	
Searlesite	$NaBSi_2O_6 . H_2O$
Calcium-magnesium borates:	
Carboborite	$Ca_2Mg(CO_3)(B_2O_5) . 10H_2O$
Hydroboracite	$CaMgB_6O_{11} . 6H_2O$
Wardsmithite	$Ca_5MgB_{24}O_{42} . 30H_2O$
Calcium-silicon borates:	
Bakerite	$Ca_8B_{10}Si_6O_{35} . 6H_2O$
Howlite	$Ca_2SiB_5O_9(OH)_5$
Calcium-strontium borate:	
Valkovite	$(Ca, Sr)_2B_{14}O_{23} . 8H_2O$
Natural boric acid:	
Sassolite	H_3BO_3

Borax is the most valuable boron compound, both as a raw borate mineral and as a refined chemical. It commonly occurs as glassy, clear to translucent monoclinic crystals. In dry air it turns white by dehydration into tincalconite, a dull white powdery mineral.

Kernite is found in large platy crystals or cleavable masses and cleaves easily into splintery fragments.

Colemanite commonly occurs as clear to white prismatic crystals or as granular to massive aggregates.

Ulexite occurs as rounded aggregates of soft white radiating needlelike fibers from which it gets its nickname "cotton ball" (Bates, 1969).

Boron compounds, commonly derived from borate ores, are used extensively in the production of glasses, such as pyrex and porcelain enamels for covering the steel of refrigerators, washing machines, sinks, bathtubs, stoves, and like products. Boron is also used in the manufacture of soaps, cleansers, herbicides, fluxes, gasoline antiknock compounds, pharmaceuticals, water softeners, food preservatives, and fire retardants (Ver Planck, 1957).

HISTORY OF BORATE MINING

Borate minerals have been used since ancient times as an antiseptic and washing agent. Babylonians (circa 2000 B.C.) used a borax flux to weld and braze precious metals for jewelry. Egyptians probably used it along with other chemicals in the secret art of preparing mummies. Borax glazes on pottery were used in China around 300 A.D. Specimens of these ancient glazes are still brilliant and beautiful today.

Borax obtained from lake beds in Kashmir and Tibet supplied Asia Minor and Far Eastern markets with borax for thousands of years. The word borax is probably derived from the Arabic word for borax, *buraq*.

Europeans first learned about borax in the 13th century when Marco Polo brought back borax crystals from Mongolia for Venetian goldsmiths to use as a flux. Since that time borax became a regular trade commodity in overland caravan routes. In the 1700s boracic acid was found in hot springs in the Mareninea district of Tuscany in northern Italy. In the 1800s small commercial deposits of borax were found in Chile and Turkey. However, it was not until the large discoveries of borax in California that the borate market dramatically developed.

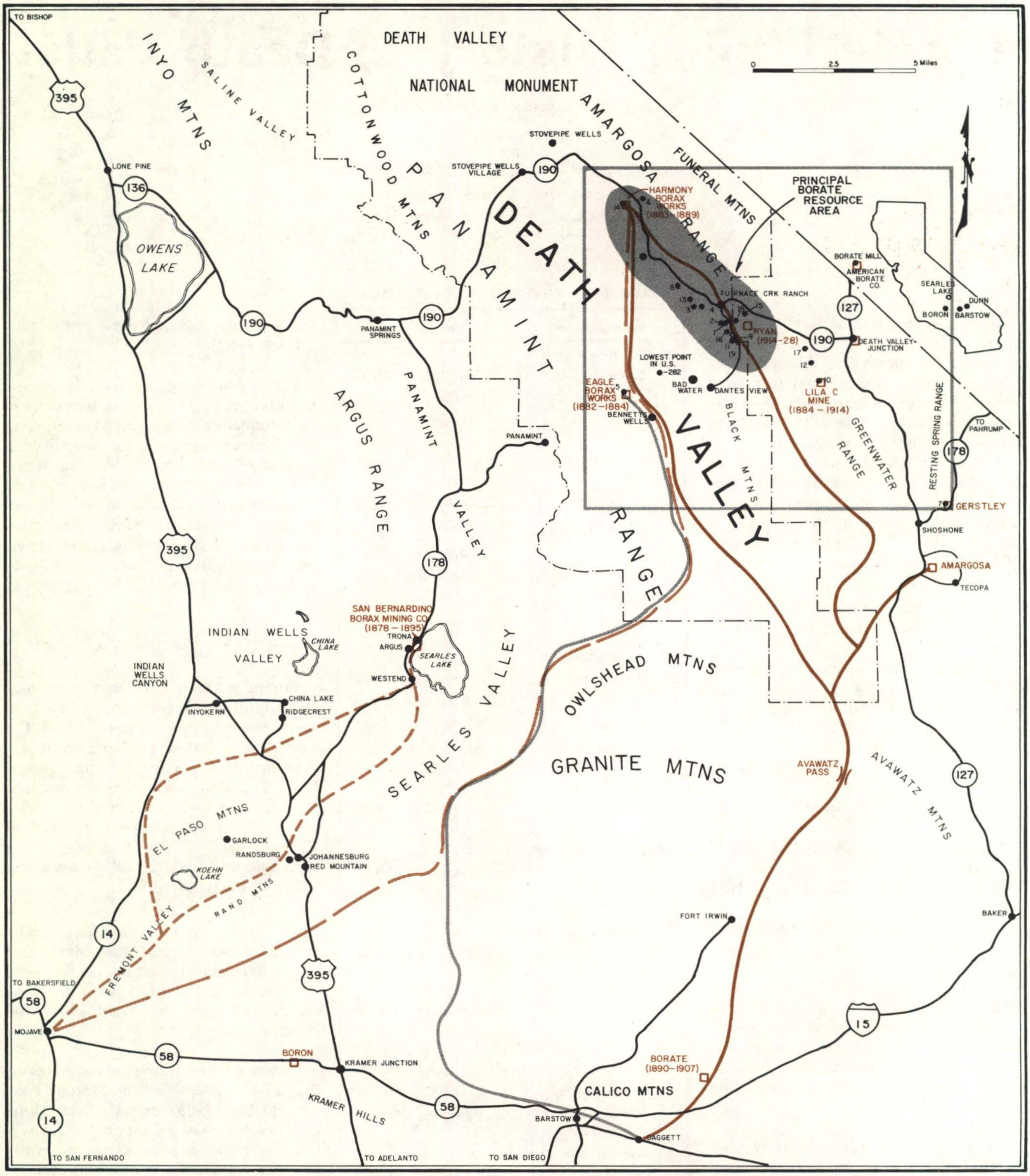
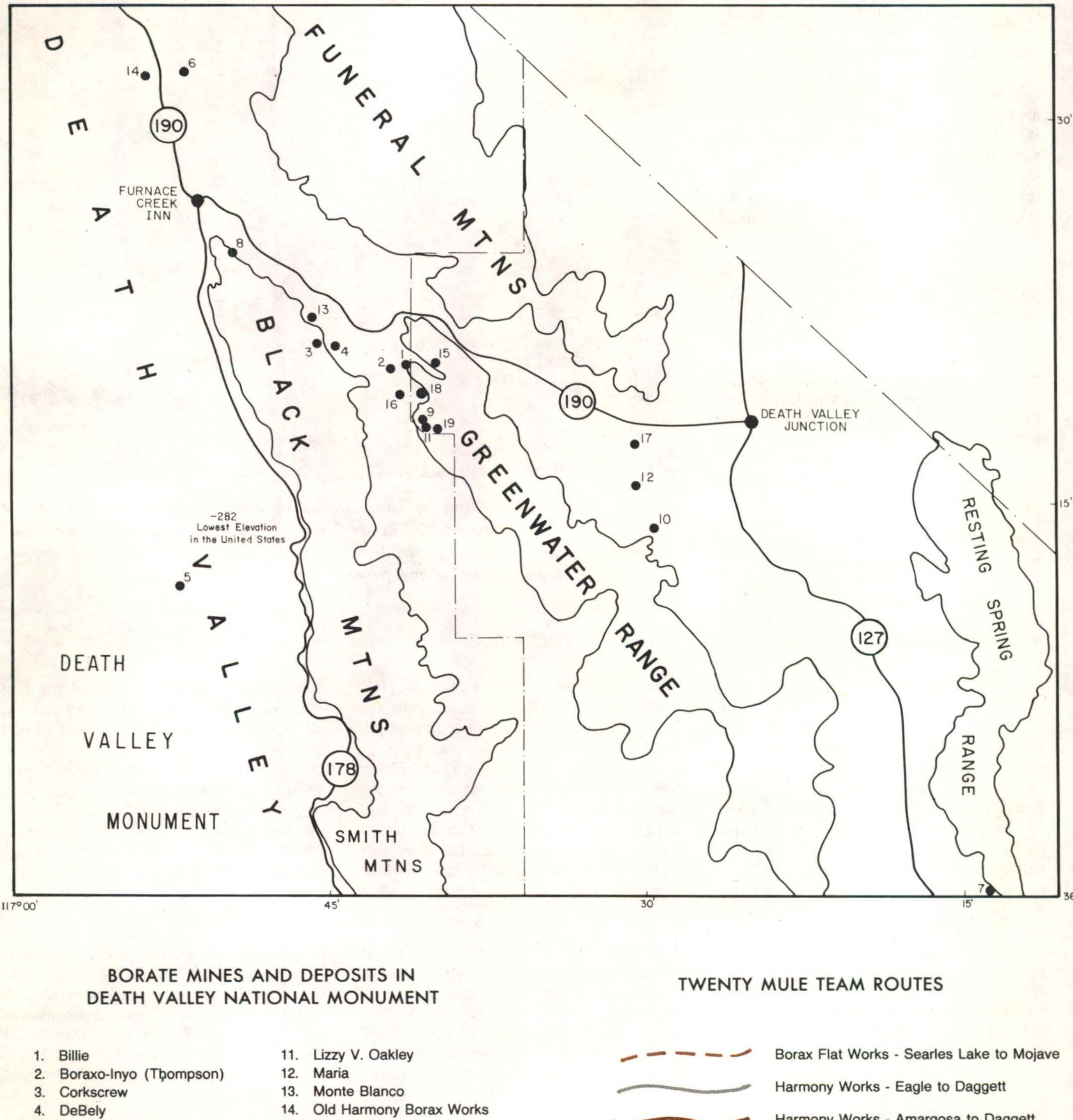


Figure 1. The Death Valley borate mining region. The general location map (above) is accompanied by the inset map of the principal borate mining areas in Death Valley National Monument (right). Prior to the 1925 discovery of the massive borate deposits in the Kramer District (located about three miles north of Boron), the chief source of boron was colemanite. Extensive colemanite deposits were found in folded and faulted Tertiary strata on the mountain slopes in the Furnace Creek area. These deposits occurred in a rather limited area which extended from the mouth of Furnace Creek southeast for about 25 miles to the Lila C mine area. Borate mining has been a significant part of the rich history of Death Valley.



BORATE MINES AND DEPOSITS IN DEATH VALLEY NATIONAL MONUMENT

1. Billie
2. Boraxo-Inyo (Thompson)
3. Corkscrew
4. DeBely
5. Eagle Borax Works
6. East Coleman
7. Gerstley
8. Gower Gulch
9. Grand View
10. Lila C
11. Lizzy V. Oakley
12. Maria
13. Monte Blanco
14. Old Harmony Borax Works
15. Played Out
16. Sigma
17. Terry
18. Upper and Lower Biddy McCarthy
19. Widows No. 3 and No. 7

TWENTY MULE TEAM ROUTES

- Borax Flat Works - Searles Lake to Mojave
- Harmony Works - Eagle to Daggett
- Harmony Works - Amargosa to Daggett
- Harmony Works - Mojave
- Borax Processing Areas

Dr. John Veatch first discovered borate in the United States in 1856 when he analyzed Tuscan Springs water in Tehama County, California and found it to contain borax. Later that same year he also discovered borax at a small saline lake, later named Borax Lake, near Clear Lake in Lake County, California. Twelve tons of borax were produced from these lakes in 1864; this was the first commercial production of borates in the United States (Absalom, 1980).

In 1870 ulexite or "cotton ball" was found in the desert lake beds near Columbus Marsh, Nevada. This find led to intensive exploration for borates throughout the 1870s and 1880s and resulted in several successful discoveries in the deserts of Nevada and southeastern California. Prospectors tested for borax by pouring sulfuric acid and alcohol over the white crystals, then striking a match to them. A bright green flame confirmed the presence of the mineral.

By 1883 there were 31 companies that produced borates from desert playas in Nevada and southeastern California. Most borate mining activities were as close as possible to the Central Pacific Railroad (now the Southern Pacific).

Photo 1. Ruins of the Harmony Borax works, founded by William T. Coleman & Company in 1882, acquired by "Borax Smith" in 1886. It was abandoned when colemanite ore proved more profitable than the ulexite or "cottonball" borax gathered from the surface of the playas. *Photo by Mary C. Woods.*

DEATH VALLEY BORATE MINING

Borates were discovered in Death Valley as early as 1873 but there was no interest in mining them until the 1880s. In 1875 Isadore Daunet discovered ulexite in Death Valley near Bennett's Well (Figure 1). In the summer of 1881 he and his partners built the Eagle Borax Works and began mining the borates. It was difficult to process ulexite into borax, the equipment was makeshift, the haul to the nearest railhead at Mojave was arduous, and the shipments were of poor quality compared to the borax coming out of nearby deposits in Nevada. The operation lasted for only two years. Daunet killed himself in San Francisco and his partners gave up the operation.

In 1881 Aaron and Rosie Winters discovered a ulexite deposit in the playa at the mouth of Furnace Creek Wash in Death Valley. Winters sent some samples to William T. Coleman, a prominent California industrialist who was the distributing agent for 'Borax Smith'. Smith was a borate magnate who owned the Pacific Coast Borax Company, the largest borate conglomerate in the United States at that time. Coleman realized the future importance of borate and bought out the Winters ulexite claim for $20,000.

In 1882 Coleman built the famous Harmony Borax Works (Photo 1) near the Winters discovery site and began processing 'cotton ball'. The process used by Coleman to produce borax from ulexite was simple. He dissolved the ore in boiling water, allowed the solution to cool and the borax to precipitate out. It was so hot during the summers at the Harmony Borax Works, however, that the solutions would not cool and the plant had to shut down temporarily.

Winters made another borate find at Amargosa between the present sites of Shoshone and Tecopa. Here summer temperatures reached a maximum of only about 110°F, and borax could be produced all summer long. In winter the richer deposits near the Harmony Borax Works were processed, and in summer, operations were moved to Amargosa (Evans, Taylor, and Rapp, 1976).

20-Mule Teams

A major problem Coleman faced was transporting the borax from his processing plants out of the rugged desert to the nearest railhead at Mojave—some 165 trail miles away. Since his production and the borate market would not support a railhead at the deposit, he decided the most efficient way to transport the borax to market would be by wagon. Coleman's superintendent, J.W.S. Perry, and a muleskinner, Ed Stiles, designed a 20-mule team wagon train with sturdy, giant wagons, at the cost of $900.00 each, to carry the borax over the rugged desert terrain (Photo 2). Ten wagons were made and each could haul a payload of 10 tons of borax. The rear wheels of the wagons were seven feet high and the front wheels were five feet high; each had steel tires eight inches wide and one inch thick. The wagon beds were 16 feet long, 4 feet wide, and 6 feet deep. Each empty wagon weighed 7,800 pounds and when loaded with borax, each weighed 31,800 pounds. Two loaded wagons and a water tank with 1,200 gallons of water weighed a total of 36 ½ tons. The length of this wagon train with mules was around 120 feet (Photo 3).

The mules and horses of the train were specially trained for their functions. Two horses were often in the lead position. Horses proved to be steadier, more reliable, and more intelligent in responding to the directions of the teamster. The following description of the team's functions has been taken from the U.S. Borax and Chemical Corporation's publication—*100 years of U.S. Borax, 1872-1972:*

Photo 2. The 20-mule team braved the harsh desert climate and hauled several million tons of borax destined for markets around the world. William T. Coleman originally developed the 20-mule team system to haul borax 165 miles across the desert from the Harmony Borax Works to the railroad at Mojave. The team averaged two miles an hour and required about 30 days to complete a round trip. *National Park Service photograph by Frashers.*

"The famous twenty-mule teams actually consisted of 18 mules and 2 horses, the latter used at the wheel positions because of their strength and obedience. The teams were controlled by a single jerk line fixed to the bit of the near (left) mule, the smartest animal in the team, and carried over 100 feet to the driver's hand through rings on the near mules' harness. The driver either sat on the perch on the lead wagon or rode the near wheelhorse.

To signal a left turn the driver gave the jerk line a steady pull; repeated light jerks signaled a right turn. The lead mule knew the signals and led the rest of the team in the indicated direction. When the train made a turn it was necessary for some of the mules to pull against the direction of the turn; otherwise the wagons would be pulled across the curve rather than around it. The fours, sixes and eights (numbering from the wheelhorse) were trained to jump over the chain that ran the length of the train and pull in a contrary direction to keep the wagons on the right track. Many mules knew their work so well that they would jump the chain and start pulling as soon as they saw the lead mule begin the turn, without a word from the driver. When the turn was completed the mules jumped back into position, one span after the other."

The original 20-mule teams hauled borax from the Harmony Borax Works across the desert to Greenland (later named Furnace Creek Ranch) then over the Panamint Mountains to the railroad junction at Mojave, a distance of 165 miles. From 1883 to 1889, the 20-mule teams hauled out borax from the Harmony Borax Works without the loss of an animal and without a single breakdown. The indomitable 20-mule team became a world famous symbol and trademark of the Pacific Coast Borax Company and later for many products made by their successor, the U.S. Borax and Chemical Corporation. Three sets of the original 20-mule team wagons are kept in running condition and are on exhibit at Boron, Furnace Creek Ranch, and Harmony.

The use of 20-mule teams spread to other borax mining operations. By 1889 the Meridian Borax Company and the San Bernardino Mining Company were also using 20-mule teams. Although the 20-mule teams did not run in the hottest part of the summers they would often run into July. During hot weather the stress on the men and animals was intense. At times temperatures hit 140°F and temperatures of 120°F were common. Even at midnight temperatures often hovered around 100°F. One wagon man died with a canteen of water in his hand.

Photo 3. The 20-mule team unloading borax at the railhead. After unloading, the team would haul provisions on the return trip to the borax processing area. From 1883 to 1889 the 20-mule teams hauled 20 million pounds of borax out of Death Valley—a tribute to the stamina of the swampers, teamsters, and animals. *Photo courtesy of the National Park Service.*

The action of intense heat and moisture forced up salt pinnacles along the route. These pinnacles sometimes reached three feet in height. Along one eight-mile stretch of road a six-foot-wide path across the salt pinnacles had to be graded by sledge hammers. These salt formations were cruel to the animals hoofs (Von Blon, 1921).

Discovery of Colemanite

Two events put an end to Coleman's Harmony-Amargosa borax operations: the discovery of colemanite at Borate and the collapse of Coleman's commercial and financial empire.

Ulexite and borax were the common boron minerals mined in the late 1800s. Late in 1882, R. Neuschwander discovered a new borate mineral, colemanite, near Furnace Creek then later in the Calico Mountains near the town of Borate (Photo 4). Coleman started buying up the colemanite claims but was unaware of the processing and mining problems colemanite presented. Colemanite required more complex processing methods than ulexite to render it into borax. Mining it also required expensive underground operations. Coleman's main colemanite mining and processing operations were at the town of Borate, about three miles east of Calico. Before Coleman could fully develop his colemanite properties, he went bankrupt in 1888. "Borax Smith" (Photo 5) acquired all of Coleman's borax properties and incorporated all of his holdings into one, the Pacific Coast Borax Company.

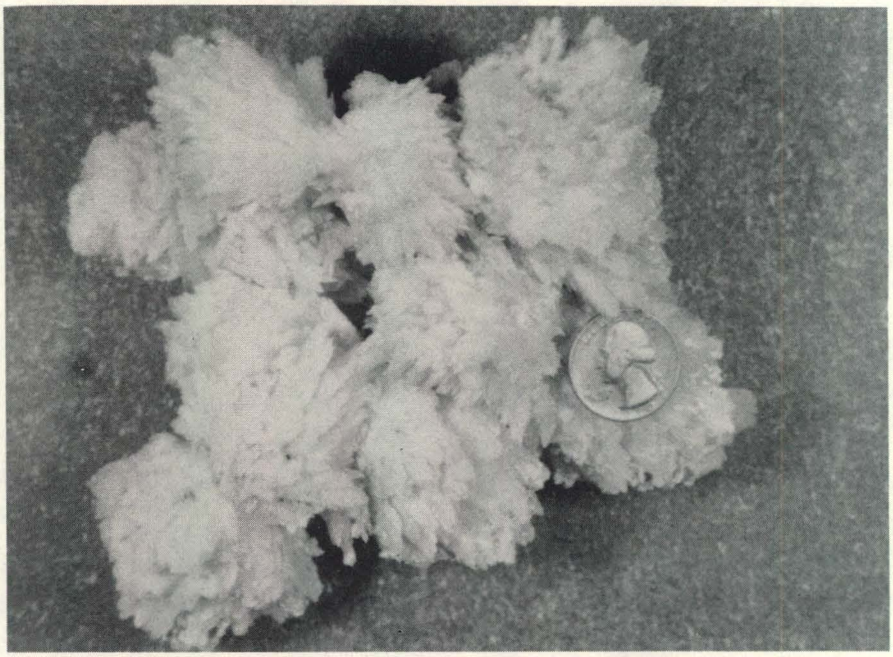


Photo 4. Colemanite is harder and heavier than borax and kernite. It occurs in clear to white sharp-pointed prismatic crystals, and as granular to massive aggregates. Colemanite decrepitates on being heated and is commonly associated with ulexite and probertite. *Photo by Charles E. Barker.*

Shortly after his consolidation, Smith closed the Harmony-Amargosa Works and mined colemanite ore at Borate. The ore was then transported by 20-mule team from Borate to the railhead at Daggett about 12 miles away. In 1898, another borax beneficiation plant was built at Marion, four miles from Daggett. Also in 1898 a narrow-gauge railroad was built from Daggett to Borate, and the 20-mule team haulage stopped.

Lila C Mine

After the colemanite ore was depleted at Borate, Smith moved his operation to the Lila C mine (named for a daughter of W.T. Coleman). The Lila C mine was discovered in 1884 by the Kinsey Brothers and was located in the Greenwater Range, about 35 miles southeast of the Harmony Borax Works. Smith began developing the mine in 1903 but production of borax could not begin until economical transport was provided. So in 1905 Smith's Pacific Coast Borax Company began building the Tonopah and Tidewater Railroad from Ludlow through Baker to Death Valley Junction to obtain colemanite from the Lila C mine. In 1907 the railroad reached Death Valley Junction, and a 7-mile spur put in from the Lila C mine to Death Valley Junction was used to haul the first rail shipment of colemanite. The spur was completed on August 16, 1907, and ore was shipped the same day. The Lila C mine had been producing and stockpiling borax since June.

From June to August the ore was hauled south about 30 miles to Zabriskie Station on the Tonopah and Tidewater Line by the 20-mule teams pressed back into service. The town of Borate was then abandoned, and all equipment was moved to the Lila C mine.

In 1912 a calcining plant was installed to upgrade the B_2O_3 content in the low-grade ore. High-grade ore was hand sorted and shipped by rail to Alameda, California or Bayonne, New Jersey.

As the Lila C mine became exhausted in 1914, the Pacific Coast Borax Company was already prepared to open new deposits near Ryan, using the just-completed narrow-gauge Death Valley Railroad from the new mine camp of Ryan to Death Valley Junction. A two rotary calcining plant for processing lower grade colemanite was built at Death Valley Junction. In January 1915 the Lila C mine was closed and a new group of mines was opened which included the Upper and Lower Biddy McCarty, the Played Out, the Grand Vide, the Lizzy V. Oakley, and the Widow mines within a few miles of Ryan and the Monte Blanco mine, about seven miles south of the Lila C mine. Open pit mining was initially employed at these mines; later, underground methods were used. By 1915, 150 men were working seven days a week to produce about 250 tons of colemanite a day. A 'baby gauge' railroad with rails two feet apart was built to connect these scattered mines with a central loading point at Ryan.

Around 1920 a colemanite deposit was found near Shoshone, Inyo County. The Pacific Coast Borax Company bought the claim, named the Gerstley mine, and began production in 1924 about the time the mines near Ryan were becoming depleted.

Sodium Borate

In 1925, a phenomenal discovery of sodium borate deposits was made in the Kramer borate district. These ore deposits were so rich and so extensive that Death Valley borate mining activities virtually stopped in 1928. The Kramer borate deposit is several hundred acres in extent, approximately 250 feet in maximum thickness, and has been estimated to contain 100 million tons of high grade borate ore. These enormous deposits are the single largest source of the world's borates and are estimated to last for at least a century at the current rate of production (Bates, 1969).

As a result of the Kramer borate discovery, in 1928 the Death Valley Junction concentrating plant was shut down, closing an era of significant borate production and processing in the Death Valley area. Borate mining all but ceased in the Death Valley area in the period from 1928 to 1956, but the borate mines were maintained on a stand-by basis. Small tonnages were shipped to fill special orders for colemanite or ulexite, such as for shielding around nuclear test sites and special pottery glazing mixtures. In 1956 ulexite production from the Gerstley mine near Shoshone was increased. Ulexite was used at this time for borate slurry for fire depressants released from airplanes (Evans, Taylor, and Rapp, 1976). In 1956 the Pacific Coast Borax Company organized into the United State Borax & Chemical Corporation which in 1968 became a member of the Rio Tinto Zinc Corporation (RTZ), a worldwide group of companies.

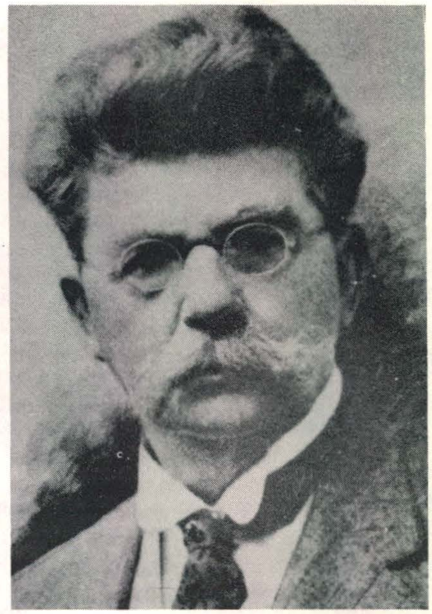


Photo 5. A 1907 photo of Francis Marion Smith alias "Borax Smith" and "Borax King". Smith was a determined entrepreneur who in the course of his 60-year career helped turn the borax market from a minor artisan trade into a major worldwide industry. *Photo courtesy of the James T. White Company.*

The final chapter of Death Valley borax mining began in 1971 when Tenneco Inc. began open pit mining in Furnace Creek Wash. It is currently an underground mining operation with a large processing plant just north of Death Valley Junction.

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CALIFORNIA GEOLOGY

TRIVIA

1. How many sides does a typical "column" have in a columnar basalt?
2. Where and when was the last volcanic eruption in California?
3. How old is the Division of Mines and Geology?

ANSWERS

1. 6; columns are typically hexagonal.
2. Lassen Peak, Shasta County; 1914 to 1917.
3. 105 years. It was established in 1880 as the California State Mining Bureau; the Division of Mines and Geology is the oldest continuously funded state geologic survey in the United States.

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Understanding California's Geology - Our Resources - Our Hazards

CALIFORNIA GEOLOGY

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In This Issue

Cover photo: The famous 20-mule team system of transporting borax out of Death Valley in the late 1800s was an exciting chapter in California's mining history. An article about the history of borate mining in Death Valley starts on page 171.

DEFINITIVE U.S.G.S. GEOLOGIC MAP OF YOSEMITE VALLEY

The U.S. Geologic Survey has recently published a definitive geologic map of Yosemite Valley. The map, titled, "Bedrock Geologic Map of Yosemite Valley, Yosemite National Park, California," was prepared by Frank C. Calkins, a U.S.G.S. geologist who worked on the map for many years. The map is accompanied by a brief text on the bedrock geology of the Yosemite Valley area prepared by N. King Huber, a U.S.G.S. geologist, and Julie Roller, a geologic field assistant.

Copies of the full-color 2-foot by 4-foot map may be ordered by mail for $3.10 from the following address:

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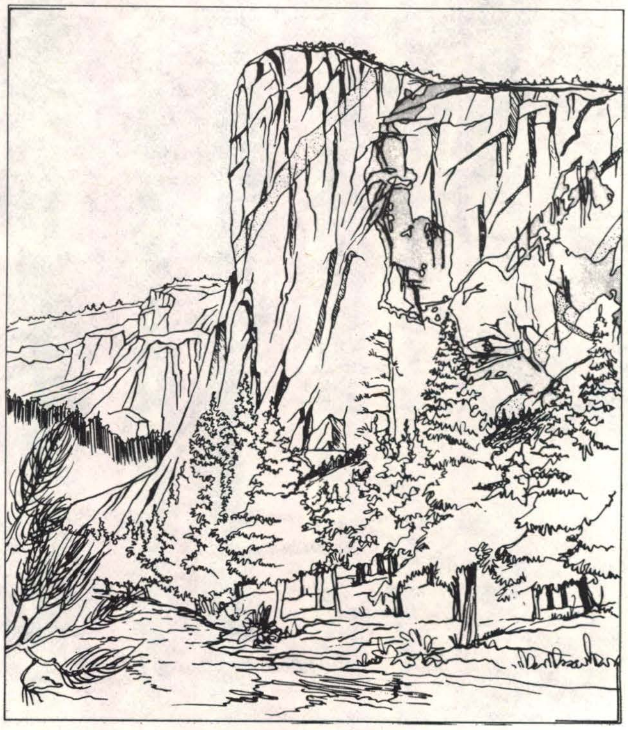
Orders must specify Map #I-1639 and include check or money order made payable to the Department of Interior—U.S.G.S.



Sketch of diorite dikes exposed on the east face of El Capitan, Yosemite Valley. *Sketch by Natalie Weiskal*