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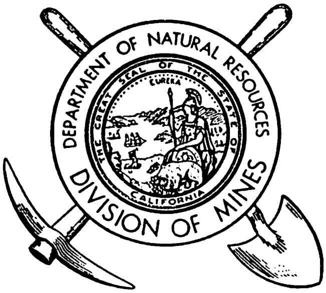

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HISTORY OF BORAX PRODUCTION IN THE UNITED STATES

By W. E. Ver Planck *

The American borax industry is very nearly synonymous with the California borax industry. In the latter part of the 19th century, however, borax production in Nevada equalled that of California and even exceeded it at times. Oregon also produced borax at about the same period.

Borax was one of the first of the nonmetallic mineral commodities to have been considered worthy of the attention of the prospector, the engineer, and the promoter. Like the precious metals, borax has held forth the enticing promise of fortunes to be made with little effort. To the popular mind, it is irrevocably associated with Death Valley and a host of semi-legendary episodes. While the borax industry can look back on a past that is not without its dramatic moments, today it is a mature industry in which profits are made only by hard work coupled with the best of engineering and business practices.

A century ago, borax was a high-priced commodity imported from England, mainly for pharmaceutical purposes. Consumption amounted to but a few hundred tons a year. The principal source of raw materials was the sassolite deposits of Italy, which were developed in the early 18th century. Prior to that time a very impure borax called tincal was obtained from the interior of Asia. Refineries were established first in Venice and later in other European cities and in England.

Lake County Period (1864-72). Borax was first detected in California in January, 1856, by Dr. J. A. Veatch while making an analysis of the water of Tuscan Springs in Tehama County. The search for a workable deposit culminated in September of the same year in the discovery of the small saline lake near Clear Lake in Lake County that has since been called Borax Lake. This lake, which occupies an isolated basin in an area of Quaternary volcanism, contains a strong brine, rich in sodium chloride, carbonate, and borate. In addition, the bottom mud was found to be crowded with borax crystals ranging up to several inches in length. Some time passed before the deposit could be studied and a company formed to work it, and it was not until 1864 that the California Borax Company with W. O. Ayers as Superintendent, actually produced borax.

The methods used by the California Borax Company were simple. Iron coffer dams, 4 feet square by 6 feet deep were floated out by means of a raft and dropped into the crystal-bearing mud. Then the mud within the coffer dam was shoveled out and the borax crystals were washed from it. In this way, and in spite of the loss of the small crystals, as much as 900 pounds of borax were obtained from the mud within a single coffer dam. The crystals recovered were refined by dissolving in hot water and recrystallization. From 1864 to 1868 an average of 300 tons a year of refined borax was produced, which sold for 28 to 35 cents per pound. This material according to an analysis made in 1865 was 99.95 percent pure.

Before long the company felt that the supply of crystals that could be recovered in this way was limited, and means of increasing the

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* Geologist, California State Division of Mines.

efficiency of the operation were considered. Plans were made to treat the lake brine itself, and bore holes were put down in order to search for an artesian source of borate brine. Work was begun on the recovery of borax from the mud, which was estimated to contain some 20 percent of borax. When leaching with hot water proved to be ineffective, a plant was made to ''roast'' the mud before leaching. Before the problem was solved, however, the lake was flooded, possibly from a flow of artesian water from a well the company sank, perhaps because the winters at that time were unusually rainy. In any case, no more borax was produced from Borax Lake. In 1934, M. Vonsen and G. D. Hanna visited the area, and found what was apparently one of the California Borax Company's cofferdams sunk in the mud near the center of the lake. Curiously enough they found that the mud contained several pounds per cubic foot of borax crystals, although reports contemporaneous with the mining activity agree that the supply of crystals had become seriously depleted by 1868.

After the flooding of Borax Lake, the California Borax Company transferred its operations to a similar alkali lake called Little Borax Lake or Lake Hachinhama on the west side of Clear Lake near Mount Konocti. Some time in the 1930s the salines of Lake Hachinhama were flushed out with fresh water pumped from Clear Lake. Unlike Borax Lake, the mud of Lake Hachinhama contained no borax crystals, and it was necessary to devise a way of recovering borax from the mixed alkali brine. Fractional crystallization was tried, but while borax could be separated from sodium carbonate and salt in the laboratory by evaporation, the yield was disappointingly small when tried on a large scale. Finally the attempt to crystallize pure borax was given up, and it was found to be possible to crystallize a mixture of salts from which pure borax could be obtained by washing away the more soluble sodium carbonate and sodium chloride with cold water. The lake water was first partially concentrated by solar evaporation in shallow ponds floored with brick and asphalt and then concentrated to saturation by boiling. The hot concentrated liquor was then cooled in milk pans of 2 or 3 gallons capacity, because it had been found that the yield of borax was greater from a small volume of solution. At one time as many as 4,000 of these small crystallizing pans were in use. After the solution had cooled, the mixed crystals from the pans were washed with cold water, and the borax that remained was purified by recrystallization as had been practiced at Borax Lake. Borax was also recovered from the salt crust that formed when the lake dried up in summer. When the crust was removed it was renewed by efflorescence, and two or three crops could be gathered in one summer. This crust material was added to the evaporating ponds to increase the strength of the brine.

In 1872 ulexite, a sodium-calcium borate, was available in quantity in San Francisco; and the California Borax Company experimented with obtaining borax from it. Theoretically, if a calcium borate is treated with sodium carbonate, double decomposition takes place, producing insoluble calcium carbonate and borax that remains in solution. The Company planned to use the Hachinhama brine as a sodium carbonate solution, the comparatively small proportion of borax it contained being added to that obtained from the decomposition of ulexite. They found that this process was difficult to handle on a commercial scale. By prolonged boiling of a mixture of lake brine and ulexite and by using a substantial excess of ulexite, borax-rich liquor could be obtained, which, when cooled, yielded borax crystals. How successfully this was carried out is not clear. The California Borax Company remained active until 1874, and ulexite is reported to have been shipped to Lake County in bulk. Borax production from Lake Hachinhama, however, was reported only in 1872; but of course any borax produced by the treatment of ulexite should not properly be attributed to Lake Hachinhama.

Playa Period (1872-90). Small though the Lake County borax production was, it nearly eliminated imported borax from the American market. Moreover, borax was becoming a more familiar commodity, and the prospector was beginning to keep his eye open for it. Indeed, borax had been noted in the playas and saline lakes of California and Nevada before 1870, but this fact passed almost unnoticed. Columbus Marsh, Esmeralda County, in Nevada, later an important source of borax, was located in 1864 as a salt deposit. The salt was used in the Washoe process for treating gold and silver ore; and Dr. Partz, a metallurgist, identified borates in the Columbus Marsh salt. He obtained samples and sent them to the east as a matter of scientific interest.

About 1870, however, borax began to attract more attention. A ulexite cotton ball, said to have been picked up in Nevada by a teamster, reached the California Borax Company men who dispatched a prospecting party to search for the plane where it had been found. A San Francisco company attempted to obtain borax by evaporating the alkali water of Ragtown or Big Soda Lake in Churchill County, Nevada. In 1870 or 1871 William Troup found ulexite, first near Sand Springs in Churchill County, and later in Columbus Marsh. Apparently Troup had been looking for deposits of borates since 1860 when Dr. Veatch had told him that borates occurred in Mono Lake and probably were to be found in Nevada also. Troup prepared some borax by boiling a sample of the Sand Springs ulexite with sodium carbonate from Ragtown (Soda) Lake. Encouraged by this, he shipped 1700 pounds of ulexite from Columbus Marsh to San Francisco where it was converted to borax and sold.

By 1873, ulexite was being recovered on a small scale from a number of the Nevada borate playas, but this development attracted little attention outside the borax industry. Perhaps one reason that these early playa operations were unspectacular was the difficulty of obtaining borax from ulexite. A considerable quantity of ulexite was shipped to England for treatment as well as to San Francisco, and apparently to Lake County. In addition, refining on a small scale was carried out at the town of Columbus near Columbus Marsh, Nevada.

In October of 1872, F. M. Smith, later president of the Pacific Coast Borax Company, made a spectacular discovery that attracted wide attention. Smith was a prospector for gold and silver and at that time was operating a timber claim that overlooked Teels Marsh in Mineral County, Nevada. Out of curiosity, he took a sample of the powdery surface crust of the playa and left it to be assayed at Columbus, 16 miles away. So rich in borax was the sample that the news quickly spread and Smith only partially succeeded in locating the most favorable parts of the playa for himself. The task of location was made difficult and troublesome by a change in the regulations made just at this time. Previously, borax locations had been made under the saline laws of Nevada, which allowed a locator to take 160 acres. Now it was decided that borax land should be located as placer claims of 20 acres each. Smith had to relocate his property and temporarily lost control of some of it. Eventually, however, he and his brother obtained much of the best borax land and Smith Brothers became the largest of the borax producers in the 1870's and 1880's.

A close second among the early borax producers was the operations of John W. and Dennis Searles on what is now Searles Lake in San Bernardino County. About 1862 they were prospecting and mining in the Slate Range and may well have suspected the presence of borax in Searles Lake. Some ten years later, after the Teels Marsh discovery, Searles saw specimens of Nevada borax and realized that the same material occurred at Searles Lake. Accordingly, in April 1874, the Searles brothers, E. W. Shillings, and J. D. Creigh hurried to Searles Lake to locate borax land. As at Teels Marsh a host of other locators swarmed in, and here also the change from the 160-acre to the 20-acre law resulted in confusion. The Searles organization got into production in 1874, and on January 1, 1878 was incorporated as the San Bernardino Borax Mining Company with J. W. Searles as superintendent.

In the early 1870's borax producers sprang up like weeds on the playas of southeastern California and Nevada. Hanks (1883) lists 31 organizations that contributed all but between 2 and 3 percent of the total United States production of borates up to June 1, 1883. Because some of the organizations that Hanks lists produced as little as 1,000 pounds, is seems likely that the production of nearly a million pounds that he does not account for may have been contributed by literally hundreds of additional small, ephemeral enterprises. In California, the known activity was confined largely to Searles Lake, where, in addition to the Searles Brothers' San Bernardino Borax Mining Company, T. Dodge and Company reported production in 1876. Borax locations were made at Koehn Lake, Kern County in 1873, in Salt Wells Valley, Inyo County, in 1874, and in Death Valley at about the same time. The borax playas of Death Valley, however, were not to be productive until some 10 years later. With the exception of the San Bernardino Borax Mining Company, all the important early playa operations were in Nevada. At Hot Springs Marsh, Churchill County, borax was produced in 1871. At Sand Springs (Salt Wells) Marsh in the same county, the American Borax Company was active in 1870 and for a year or two after. Later the American Borax Company operated a short time 50 miles northwest at a playa close to the Central Pacific, now Southern Pacific, Railroad. In 1871 a second company also was active at Sand Springs Marsh. In Esmeralda County at least four borax companies were active at Columbus Marsh, including the Pacific Borax Company of F. M. Smith. In 1875 the Pacific Borax Company moved to Fish Lake Marsh, also in Esmeralda County, and was active there until at least 1884. At least one other company, Mott and Piper, was operating at Fish Lake Marsh in 1873. At Teels Marsh in Mineral County, was the large Smith Brothers operation, later called the Teels Marsh Borax Company, and probably others. At nearby Rhodes Marsh, Rhodes and Wasson were producing one ton a day of refined borax in 1874, and at a somewhat later date the Nevada Salt and Borax Company was producing both salt and borax.

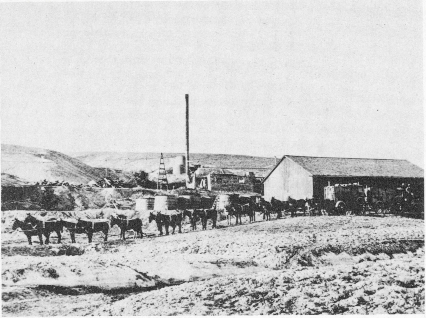

FIGURE 1. Harmony borax works, 1882-90. *Photo courtesy Pacific Coast Borax Company, reprinted from Division of Mines Bull. 170, Chapt. 8.*

FIGURE 2. Wood-burning steam tractor at Furnace Creek Ranch. Unsuccessfully employed in an attempt to replace 20-mule team in transportation of borax. *Reprinted from Division of Mines Bulletin 170, Geologic Guide 1.*

Probably few of these ventures were financially successful. Their promoters were unbelieveably optimistic, for they overestimated the richness of the deposits and failed to realize that exacting specifications must be met in order to dispose of their products. Consumers, not failing to note the potential over-supply and anticipating a price fall, cut their orders to a minimum. Then some producers, frantic to dispose of their output under any conditions, began cutting prices; and the borax market collapsed. The price of refined borax at San Francisco dropped from an average of 25 cents per pound to as little as 6½ cents in 1874. Although the price later rose to between 11 and 13 cents and the demand for borax gradually expanded under the influence of the lower prices, all but a handful of the playa operations had been permanently closed by the late 1870's. When Hanks made his study of the borax industry in 1882, of a total United States production of nearly 42 million pounds of refined borax, nearly 24 million had come from Nevada, and five companies were productive. These were Smith Brothers at Teels Marsh, the Nevada Salt and Borax Company at Rhodes Marsh, the Pacific Borax Company and the Saline Valley Borax Company at Fish Lake Marsh, Nevada, and the San Bernardino Borax Mining Company, at Searles Lake, California. In Death Valley and the Amargosa Valley, several companies were active in 1882, but most of them had not started production.

Borates were noted in Death Valley at least as early as 1873, but not until 1880 was there any interest shown in them. In that year Aaron Winters, a resident of Ash Meadows, heard about the borax activities of Nevada from a traveler, and discovered the borate-bearing playas at the mouth of Furnace Creek. In 1882 he and several others discovered the Amargosa deposits. These claims he sold for a substantial sum to W. T. Coleman & Company, wholesale merchants. In 1883 the Greenland Salt and Borax Company and the Amargosa Mining Company were preparing to produce borax near the mouth of Furnace Creek. The Amargosa Mining Company also was developing deposits near Resting Springs in the Amargosa Valley. In 1884 Coleman organized two new companies, the Harmony Borax Mining Company to work the deposits near Furnace Creek, and the Meridian Borax Company with deposits in the Amargosa Valley.

Although Coleman began producing in 1883, the Eagle Borax Company produced some borax a little earlier. Isadore Daunet and several partners formed this company to work ulexite deposits near Bennett's Well in the southern part of Death Valley. They succeeded in producing some borax in 1882, but because of the difficulty in treating the ulexite ore, the physical discomforts of that area, and the long and difficult haul to the railroad, the enterprise failed.

Impure borax, not ulexite, was the rich ore of the playa borax operators. Calcium borates have never been found at Searles Lake; as for the Nevada playas, Le Conte's sketch map (Hanks, 1883, p. 52) of Rhodes Marsh shows areas of borax crust clearly differentiated from ulexite areas. To judge from the method of treatment, at Teels Marsh also borax must have been used. In the early 1880's ulexite was considered as the reserves of the future to be drawn upon after the borax was exhausted. At Rhodes Marsh samples, or more properly, specimens, of the crust contained as much as 50 percent borax. At Searles Lake the material treated averaged over a considerable period nearly 8 percent borax or a little less than three percent B_2O_3.

The recovery of borax from ulexite and other calcium borates is a comparatively difficult chemical operation that has perhaps been efficiently carried out only in the large refineries such as the one operated for many years at Bayonne, New Jersey. As the Lake County men discovered, the reaction with sodium carbonate is inefficient. That salt being abundant in Nevada, however, ulexite was nevertheless treated with sodium carbonate at the deposits, especially in the 1890s. An alternative procedure was the manufacture of boric acid, which could be converted to borax if desired. According to Hanks (1883), ulexite shipped to England was made into boric acid by treatment with hydrochloric acid. The refineries in San Francisco and at Columbus Marsh that operated during the 1870s used the Formhals process. Sulfur dioxide gas obtained by burning sulfur was injected into a mixture of ulexite and water. There resulted a boric acid solution that could be separated from an insoluble residue. Today boric acid is made with sulfuric acid, but this seems not to have been practiced in the 19th century.

Treatment of borax crusts, however, was relatively simple. Crude borax material was boiled in hot water until the borax dissolved, and then the hot solution was decanted from the insoluble residue into crystallizers for cooling. Borax crystals formed that were purified by recrystallization. Borax produced in 1883 by the San Bernardino Borax Mining Company, it is reported, contained 99.85 percent borax, while some from Esmeralda County, Nevada was 98.93 percent pure.

The Smith Brothers' plant at Teels Marsh used nine iron boiling tanks, 8 feet in diameter and 7 feet deep. They were heated by wet steam coils, that is, steam escaped from the submerged coils through small holes into the solution. The crystallizers were of galvanized iron. Two 24-inch boilers supplied steam to the boiling tanks. The Smith brothers' Pacific Borax works at Fish Lake Marsh contained six boiling tanks, 9 feet in diameter by 7 feet deep. Mud tanks were provided to receive the solids from the boiling tanks after the concentrated solution was drawn off. Here the mud was sampled. It could be sent back to the boiling tanks for retreatment or to a shallow tailings pond, where in time a borax-rich efflorescence would form similar to the natural borax crust of the playa. At the Searles Lake operation borax crust and borax crystals were dissolved in five boiling tanks, each of 7,000 gallons capacity. Thirty cylindrical galvanized iron crystallizing vats were used, while the recrystallizers were square and lined with galvanized iron. Fresh water came from fourteen 55-foot wells, and steam was generated by a boiler 42 inches in diameter. Fifty men and 35 animals were employed in 1882.

Fuel burned under the boilers of the borax plants was sagebrush, greasewood, and whatever other desert shrubs could be found. At Searles Lake, crude oil was substituted about 1887, but brush was still being burned by the Nevada plants in 1892.

The playa borax producers, being for the most part in isolated regions, had formidable transportation problems. Probably every user of borax is familiar with the 20-mule team borax wagons that the Pacific Coast Borax Company has adopted as its trademark and knows that they were used on the difficult run out of Death Valley. Used in pairs, these giant wagons could haul about 48,000 pounds of borax the 165 miles from Greenland to Mojave. It was John R. Spears, a New York journalist who visited the borax country in 1892, who did much to immortalize the Death Valley 20-mule teams. So completely did they capture his imagination, that he devoted an entire chapter of his book (Spears, 1892) to the borax wagons and the men who operated them. Actually, the Death Valley wagons were unusual mainly in their size. Freight wagons of less heroic proportions were widely used beyond the reach of the railroad. The San Bernardino Borax Mining Company, for example, also had its 20-mule teams, which operated from Searles Lake to Mojave, a trip that took 8 days.

The Nevada borax companies were more fortunate because the Carson and Colorado Railroad, which started building south from Mount House in 1881 and reached Keeler on Owens Lake in 1883, ran close to the borate playas of Esmeralda and Mineral Counties. The freight rate for borax from Columbus to San Francisco was reported to be $80 per ton in 1873, but only $12.50 in 1882, after the railroad was open.

Colemanite Period (1890-1907). Colemanite was discovered near Furnace Creek, Inyo County, late in 1882. The discovery was made by R. Neuschwander, and the new mineral was described by J. T. Evans of the California Academy of Sciences and by others. It was named for William T. Coleman, the Death Valley borax producer. In 1883, silver prospectors discovered colemanite and other borates in the Calico Mountains, 10 or 15 miles north of Daggett. Soon after the discovery the Coleman Company began buying up the more promising of the borate claims; but perhaps because colemanite was an unfamiliar borax ore that had to be mined by underground methods, development was slow. The principal colemanite operations were at Borate, about 3 miles east of the old silver mining town of Calico.

In 1888, while the deposits at Borate were being prepared for full production, W. T. Coleman and Company went into bankruptcy. The company was liquidated, and in March, 1890, F. M. Smith acquired Coleman's borax properties. Smith then consolidated all his holdings into one company, the Pacific Coast Borax Company, which was incorporated on September 5, 1890.

Properties included Smith's operations at Teels Marsh, Columbus Marsh, Rhodes Marsh, and Fish Lake Marsh in Nevada, and Coleman's properties in Death Valley, the Amargosa Valley, the new colemanite mines at Borate and a borax refinery at Alameda. The playa operations in Death Valley and the Amargosa Valley were closed, and between 1890 and 1907 the young Pacific Coast Borax Company obtained a large share of its borax ore from the mines at Borate.. Few details of this operation have been published. The colemanite deposits occur in two zones separated by a stratigraphic thickness of about 50 feet. For a distance of about 1½ miles along the northeast slope of Red Mountain, the colemanite-bearing strata are honey-combed with numerous shafts, drifts, and cross cuts. When mining commenced the borate beds were thought to be comparatively uniform in width and grade, but development revealed that the borates occurred as disconnected pockets that were difficult to find. In the stopes hand-drilling was practiced, and the ore was sorted underground. In 1906 the ore was hoisted through two inclined shafts that were equipped with cages and 50-horsepower gasoline hoists. The deepest level was at about 600 feet.

At first, hand-sorting was the only beneficiation. The ore was hauled 12 miles to Daggett, the nearest railroad station, with two of the 20-mule team wagons that had been used in Death Valley. It was at this time that Spears saw the 20-mule teams and wrote the book that made them famous. The material shipped averaged about 35 percent B_2O_3.

The ore from Borate was treated in the refinery in Alameda, which, had originally been built by Coleman expressly for that purpose. There the lump ore was reduced by crushers, grinders of the coffee-grinder type, and buhr mills to a fine powder, and sized with silk screens. The ground ore was treated with a hot sodium carbonate solution in reaction tanks provided with mechanical agitators. The calcium carbonate precipitate, after several washings, was discarded and the borax-rich solution went to crystallizers where borax crystals formed on suspended wires. This borax was purified by recrystallization.

The first beneficiation plant was built in 1898 at Marion, 4 miles from Daggett. Rail connection with the mines at Borate was provided at the same time to replace the 20-mule teams. The plant as first designed was not satisfactory, and it was not put into regular operation until about 1900. This concentrator, as well as others built later, took advantage of the fact that colemanite decrepitates or flies to pieces when heated. By screening, the coarse material, mostly waste, can then be separated from the fines, mostly decrepitated colemanite. Borates other than colemanite do not decrepitate and cannot be recovered by the roasting process. The plant at Marion contained a Holthoff-Wethey roaster, a furnace of the reverberatory type with two hearths and mechanical rabble arms to move the ore forward. The temperature was 1200° F. The capacity was between 75 and 100 tons a day of crude ore.

The Pacific Coast Borax Company's holdings included the Chetco borate deposit on the Oregon coast a few miles from the California boundary. The chalk-like borate that occurs there in clay associated with serpentine was known at an early date and at one time was used locally as carpenter's chalk. A specimen reach San Francisco in 1871 and was identified as the calcium borate priceite. In 1872 some of the Oregon borate was used in San Francisco as a silver polishing compound. During 1891 and 1892 the deposit was worked under lease from the Pacific Coast Borax Company, and the output was sent by ship to the Alameda refinery.

In 1896 Smith went to England to explore the possibilities of developing an overseas market for borax. He decided to combine forces with a British chemical company; and the same year a new company, The Pacific Borax and Redwoods Chemical Works, Limited, was formed. Smith and other directors of this company organized Borax Consolidated, Limited, in January, 1899, with deposits and refineries in France, Chile, Peru, and Turkey as well as the United States and England.

It was decided to shift the refining operations in the United States to a more central location on the East coast; and a new plant was completed at Bayonne, New Jersey, late in 1898. Thereafter the Alameda refinery was operated on a reduced scale to supply the western market. These arrangements lasted until 1924 when the existing refinery at Wilmington was completed.

Although by 1890 colemanite was being mined at Borate, the playa operations continued for a number of years. In the year ending June 30, 1892, the production of refined borax was 6,690 tons. The Pacific Coast Borax Company produced 5,000 tons of this from the colemanite mines at Borate, the playa deposits at Teels Marsh and Columbus Marsh and the Chetco deposit. The San Bernardino Borax Company produced 540 tons at Searles Lake, Conn and Trudo, 360 tons at Saline Valley, Inyo County, in a playa operation that had begun in 1888, the Columbus Borax Company, 240 tons from Columbus Marsh, and the Nevada Salt and Borax Company, 550 tons from Rhodes Marsh. A company recovered borates from the playa in Salt Wells Valley, Inyo County, in 1894. In 1900, the Rose Valley Borax Company commenced playa operations south of Lake Alvord in southeastern Oregon, and in 1901 produced 400 tons of refined boric acid. The San Bernardino Borax Mining Company, however, last reported production in 1893. Plans were made to modernize the works in 1898, but the following year Borax Consolidated Ltd., parent company of the Pacific Coast Borax Company, obtained a controlling interest in the property and the project was abandoned. The last of the California playa operations appears to have been the one in Saline Valley which produced borax through 1907. In Nevada leasers operated on a very small scale until about 1908.

Several other interesting developments took place during this period when the older playa operations were gradually supplanted by colemanite mining. It was then that the low-grade borate-bearing shales of the Calico district, called borax muds at the time, were developed. Moderately to steeply dipping ore bodies containing as little as 10 percent B_2O_3 were mined by means of shafts and drifts. The low-grade ore was leached with sulfuric acid or, in a modification of the old Formhals process, with a sulfur dioxide solution; and a boric acid concentrate was obtained from the resulting weak solution by solar evaporation.

One of the pioneers of these "mud" operations was W. P. Bartlett, superintendent of the Western Minerals Company, whose mine and plant were near Calico. As early as 1897 Bartlett began the development of a sulfuric acid leaching process, and from 1901 to 1907, a 95 percent boric acid concentrate was produced experimentally. Despite an expenditure of about $140,000 the Western Minerals Company plant never got into full scale production.

Development of Judge A. J. Owens' Columbian mine, between Barstow and Yermo, was begun prior to 1894. In 1899 this property was sold to the Columbian Mining and Chemical Company and resold two years later to the Standard Sanitary Company of Philadelphia. A sulfur dioxide leaching plant was built, and the mine and plant were operated by the American Borax Company, an affiliate of the Standard Sanitary Company. Boric acid was produced from 1901 through 1907.

Judge Owens was also associated with the Columbus Borax Company, which had operated in Nevada. In 1897 or 1898 the Columbus Borax Company opened the Gem mine 4½ miles south of Daggett. Most of the output was obtained by W. P. Bartlett of the Western Minerals Company for the Stauffer Chemical Company under a working agreement with the Columbus Borax Company.

Still another enterprise was that of the Palm Borate Company, called the American Board of Promoters Boracic Acid Company before 1903.

A borate orebody of 5 to 8 percent B_2O_3 content was developed half to 1½ miles south of the main colemanite-bearing zone. Reorganized in 1907 as Borax Properties Incorporated, the company built a boric acid plant, which is said to have been operated for only 10 days.

At about this time also, the Frazier Mountain district in the northeast corner of Ventura County achieved its greatest prominence. Colemanite was discovered there in 1898 by McLaren, a prospector, who identified the white mineral that had previously been dismissed as "lime." The Frazier Borate Mining Company developed the Frazier mine close to the site of the original discovery. Production began in 1901, and in the same year the Stauffer Chemical Company bought the property. The nearby Columbus mine of the Columbus Borax Company was located in 1899 by B. F. Stevens. Production began in 1902, and the ore was sent for refining to M. Calm & Brothers in Jersey City, and Thomas Thorkildsen & Company bought the property. Both mines were handicapped by a difficult transportation problem. H. S. Gale (1914b) reports that from 1899 to 1907 inclusive, when the mines closed, the Frazier Mountain district produced 35,000 tons of crude ore, valued at $1,000,000. The value of the California production during those years ranged from over $2,000,000 in 1902 to a little more than $600,000 in 1903.

Death Valley Period (1907-1927). By 1900 it became apparent that the Pacific Coast Borax Company's mine at Borate would not last forever. By now the mine was 500 to 600 feet deep, and mining costs were rising. The Pacific Coast Borax Company began exploring Death Valley and the Amargosa Valley for a new orebody. Development of a new mine began in 1903. It was at the southeast end of the series of colemanite-bearing lake beds that angles across the Black Mountains of Inyo County, and it was called the Lila C. Three parallel colemanite beds 6 to 18 feet wide were traceable on the surface for 2500 feet, and the B_2O_3 content was reported to be 40 percent. This orebody was developed by inclined shafts and drifts.

Production could not begin, however, until transportation was provided. During the development stage access was by means of a special road that ran from the Lila C. southeastward close to the California-Nevada boundary through Mesquite Valley and State Line Pass to Manvel, a station on the now abandoned Ivanpah Branch of the Santa Fe Railway, 100 miles away. Over it wagons were drawn by steam traction engines. To the engineer of the mid-20th century it may be a surprise that mines and lumber companies quite commonly used steam traction engines at the turn of the century. The Frazier Borate Mining Company used them to haul borax ore from the Frazier Mountain district. Somewhat earlier they were used to haul salt on Danby Lake, San Bernardino County. Many of these machines were built by the Daniel Best Manufacturing Company of San Leandro, which constructed more than a hundred between 1889 and 1901. The 50-horsepower model of 1901 weighed 15½ tons and could run at 3 or 4 miles per hour. A vertical boiler 4 feet in diameter and 5 feet 10 inches high provided steam for two 9-by 9-inch cylinders geared to the inner periphery of the driving wheels. The two rear wheels were 8 feet in diameter with tires ¾-inches thick and from 24 to 60 inches wide. The single front wheel was 5 feet in diameter. The Best Company also made

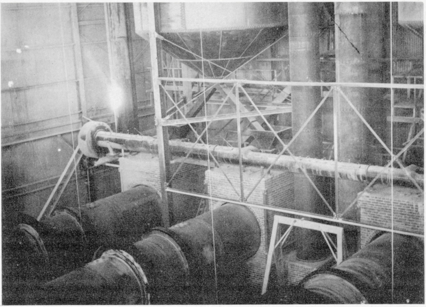

FIGURE 3. Rotary roasters at mill of Pacific Coast Borax Company.
Photo by E. Huguenin, 1916.

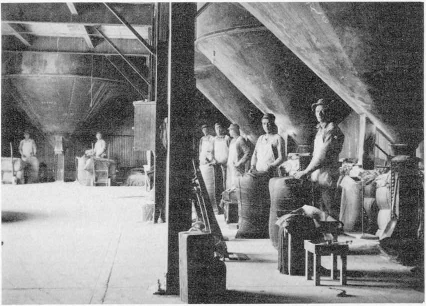

FIGURE 4. Sacking concentrates at Death Valley Junction.
Photo by E. Huguenin, 1916.

an ore wagon of 16 tons capacity, two of which were commonly pulled by one engine.

Traction engines, however, proved inadequate; and in 1905 the Pacific Coast Borax Company commenced building the Tonopah and Tidewater Railroad northward from Ludlow on the Santa Fe. The route was east of Death Valley through the Amargosa Valley not far from the Lila C. Mine, and the destination was the new mining camp of Bullfrog over the state boundary in Nevada. Early in 1907 construction reached the borax area. The Lila C. was connected to the railroad by a spur, and that summer the first shipment of colemanite went out over the T. and T. Immediately the mines at Borate and the mill, shops, and other facilities at Marion were abandoned; and all activities were transferred to the new mine. For a time the Lila C. ore was shipped without beneficiation, but in 1912 a calcining plant was in operation. This one contained rotary calciners constructed in such a way that the colemanite did not come in direct contact with the flame.

It was more than coincidence that the year the Lila C. mine opened, the price of borax dropped from 6½ to 7 cents a pound to 4½ to 5½ cents. No doubt it was hoped that the lower price made possible by cheaper mining would expand the borax market; the drop in price also caused the near-permanent shutdown of all the older borax operations, including the Saline Valley playa operation, the low-grade "mud" deposits of Daggett, and the colemanite mines at Frazier Mountain.

The Pacific Coast Borax Company was not to be alone in the field for long, however, for in November 1907 colemanite was discovered in Tick Canyon, Los Angeles County, 5 miles north of Lang on the Southern Pacific Railroad and only about 30 miles from Los Angeles. The deposit was acquired by the Sterling Borax Company, a consolidation of borax interests formed late in 1907. These included the Stauffer Chemical Company's Frazier Borate Mining Company with holdings in the Frazier Mountain district, the American Borax Company, which owned a deposit in Inyo County in addition to the boric acid works at Daggett, the Brighton Chemical Company which operated a refinery in Pennsylvania, and Thomas Thorkildsen and Company with a refinery in Chicago. The steeply dipping Tick Canyon orebody was traceable for 1,000 feet on the surface and averaged 16 feet wide. Because it was much richer than the Daggett ores and far more accessible than the mine at Frazier Mountain, development was pushed, and production began in 1908. Ore obtained by underground mining was calcined at the mine and shipped to Lang over a railroad built in Tick Canyon. From Lang the ore went to the Company's numerous refineries. The Sterling Borax Company produced a substantial share of the colemanite mined from 1908 to 1920. Faced with an ever-declining price for borax and, as the mine grew deeper, with rising mining costs, the company finally sold the property to the Pacific Coast Borax Company in 1921, which operated it through 1923. The plant was dismantled in 1926.

Meanwhile there was renewed activity in the Frazier Mountain district. The Russell Borate Company was formed in 1907, and during 1909, 1910, and 1911, developed the Russell mine between the Frazier mine and the Columbus mine. Production began in November 1911 and continued until 1913. The property was sold to the Stauffer Chemical Company. Some prospecting was done north of Frazier Mountain in 1917, but no ore was produced. The Columbus mine was reopened in

1912 by the National Borax Company, and production was reported in 1912 and 1913. Afterwards the property came into the control of Pacific Coast Borax Company interests and was not operated again.

In the Calico Mountains development of the Neel Borate mine, on Pacific Coast Borax Company property, began in 1915, and a modest tonnage of colemanite was produced from 1920 to 1924 inclusive. This work was done by D. D. Connell under contract. Others also conducted small scale scavenging operations among the old workings at Borate until the mid-1920s. Other work was done by the Union Borax Company, which was a subsidiary of the Standard Sanitary Company and affiliated with the American Borax Company. From 1919 to about 1924 claims adjoining the old mines at Borate were explored in the hope of finding rich pockets of colemanite. Workings include a shaft 640 or more feet deep and a long cross cut. There is no record of production.

Back in Death Valley the Lila C. mine began to show signs of exhaustion, and in 1914 the Pacific Coast Borax Company prepared to mine a new group of orebodies to the northwest in the Furnace Creek area. A new beneficiation plant was constructed at Death Valley Junction, and the narrow gage Death Valley Railroad was built approximately parallel to the route of the present State Highway 190. The camp at the western terminal of the Death Valley Railroad was called Ryan, the same name that had been used for the camp at the Lila C. mine. The Lila C. was closed and operations transferred to the new mines in January 1915. At the new Ryan was the Biddy McCarty mine. Others in the vicinity were the Lower Biddy, the Grand View, the Oakley, the Played Out, and the Widow. Mining was carried out largely by means of glory holes. Ore from the various workings was taken by 24-inch gage cars pulled by gasoline locomotives to the main ore bins at Ryan.

The beneficiation plant at Death Valley Junction contained four rotary calciners which, like those at the Lila C. mine, contained an inner chamber to keep the colemanite from direct contact with the flame. The kiln temperature was 1300° F, and the minus 24-mesh concentrate, which amounted to 44 percent of the plant feed, contained 42 percent B_2O_3. The tailings contained 4 percent B_2O_3.

About 1917 two more rotary calciners were installed, and gravity concentrating equipment was added to supplement the calciners, which were ineffective in recovering borates other than colemanite. The plus 24 mesh material that had not decrepitated was recrushed to minus ¼-inch and sized with 24 mesh screens. Oversize was treated in Hartz jigs and minus 24 mesh by Wilfley tables. Capacity of the plant was 300 tons per day.

In 1914 F. M. Smith was forced to sell his interest in Borax Consolidated, Ltd., because of a series of unfortunate private investments. He seems, however, to have been determined to get back into the borax business; but an opportunity did not immediately occur. In 1919 or 1920 he organized the West End Chemical Company for the purpose of recovering borax and potash from Searles Lake, but this enterprise did not immediately bear fruit. Late in 1920 John Perkins, a prospector, discovered colemanite in White Basin in the Muddy Mountains, Clark County, Nevada. F. M. Lovell and George Hartmen then began a systematic search for an extension of the White Basin deposits and the following January discovered the much larger deposits in nearby Callville, Wash. F. M. Smith purchased the Callville, Wash. property for

$250,000, and the West End Chemical Company's Anniversary mine made its first shipment in July 1922. The mine closed in 1927 after producing an estimated 100,000 tons of ore with a B_2O_3 content of 25,000 tons.

In White Basin a lively controversy arose over the ownership of the colemanite deposits. The United States Borax Company, an affiliate of the Pacific Coast Borax Company, purchased the deposits from the discoverer and covered them with lode claims. About 1924 the American Borax Company, having abandoned its efforts to develop a deposit in the Calico district, blanketed these lode claims with placer claims and commenced mining operations. At length the United States District Court at Carson City, Nevada, decided in favor of the United States Borax Company, leaving that company free to sue the American Borax Company for trespassing.

One of the last discoveries of colemanite was the deposit now known as the Gerstley mine near Shoshone, Inyo County. It was found by a prospector some time after 1920. The deposit is on State land and since its discovery has been leased to Pacific Coast Borax Company interests. Until May 7, 1936, it was held in the name of C. M. Rasor and since that date by the United States Borax Company. Production began late in 1924. One cannot but wonder if the Pacific Coast Borax Company, which had replaced the mine at Borate with the Lila C., and the Lila C., with the Ryan group was about to transfer its operations once more. The question is academic, however, for in 1925 came the discovery of the rich sodium borate orebodies of the Kramer district that rendered all the colemanite mines submarginal.

Kramer Period (1927-Present). Borates were first noted in the Kramer district more than 10 years before the important discoveries. Dr. J. K. Suckow found colemanite quite by accident in a well being drilled for water. The announcement was made in the fall of 1913. Most of the agricultural entries in the vicinity were released and mining claims, mostly placer claims, located. The Pacific Coast Borax Company and affiliated organizations acquired as many as possible of these privately held claims, including Suckow's discovery claim.

The early exploratory work was dilatory and discouraging. Most of it was done near Suckow's discovery well, from a mile to 3 miles west of the sodium borate orebody. Much of it was done by the Pacific Coast Borax Company. Ulexite and colemanite that occurred as nodules in lake beds were encountered in prospect shafts and drill holes, and the limits of the western part of calcium borate body were defined.

An interesting phase of the early exploratory work was the production of a modest tonnage of calcium borate ore in 1925. The Suckow Chemical Company, J. K. Suckow, President, continued work somewhat east of the discovery well and after several failures, including the Suckow Number One shaft, located a promising body of calcium borates. The mining shaft sunk to reach it, known as the Suckow Number Two shaft or the Suckow Colemanite mine, encountered the borates at a depth of 210 to 280 feet. They were in the form of nodules of colemanite with ulexite up to a maximum of one foot in diameter that ranged from masses of compact colemanite to borate and clay mixtures. Contemporary reports describe the deposit as being of rather lower grade than the colemanite deposits being worked at the time. This mine was not operated in 1926.

Meanwhile, William M. Dowsing and J. L. Hannam discovered the more important sodium borate body in the spring of 1925, but their discovery was kept as a closely guarded secret. After proving the deposit with a series of holes in the central part of the orebody, they sold their claims to the Pacific Coast Borax Company early in 1926. That August a shaft reached the ore, and production from the Baker mine, as the new mine was called, began in 1927. The colemanite mines of the Pacific Coast Borax Company, except for the Gerstley mine, were closed in June, 1927.

Soon after the Pacific Coast Borax Company began developing the new property a new sodium borate was recognized; and its analysis was reported by the Company laboratory at Wilmington, California, on August 18, 1926. The new mineral was named rasorite after Clarence R. Rasor, field engineer of the United States Borax Company. In the meantime, W. T. Schaller obtained some samples of the Kramer ore and determined the properties of the new mineral. Not knowing that the Pacific Coast Borax Company was already using the name rasorite, Dr. Schaller called the new mineral kernite. Largely because Dr. Schaller had followed the unwritten rules that govern the naming of new minerals, the name kernite has gradually supplanted the earlier name.

One reason that the Pacific Coast Borax Company pushed the development of the new orebody at Kramer was the rising output of borax from Searles Lake. After the San Bernardino Borax Mining Company ceased its crustal operations in 1893, Searles Lake became dormant. About 1908 the California Trona Company was incorporated for the purpose of producing soda ash both from the brine and from reefs of trona on the east side of the lake. This operation failed in 1909 but was reorganized as the American Trona Corporation. Meanwhile the shortage of potash that became acute during World War I began to develop, and Searles Lake was realized to be an important potential source of that commodity. Development work on the treatment of the complex lake brine was carried out by at least three organizations; the American Trona Corporation, Borosolvay, and the West End Chemical Company. Soon it became apparent that borax would be an unavoidable byproduct.

In 1913 the American Trona Corporation began work on a plant to produce potassium chloride, borax, and other salts by treating 2 million gallons of lake brine a day. The Mining and Scientific Press (1914) speculated that the sale of potash would support the entire operation and that the byproduct borax, the estimated production of which approximated the entire world's consumption, could be sold for whatever the market would bring.

As it turned out, the treatment of the brine was far more difficult than had been supposed. The American Trona Corporation's first plant was a failure and had to be redesigned. Finally in 1916, both the American Trona Corporation and the Borosolvay plant, which was owned by the Pacific Coast Borax Company and operated by the Solvay Process Company, succeeded in producing comparatively impure potash in highly inefficient plants that were profitably operated only during the war-stimulated shortage of potash. The Borosolvay plant was closed in 1920, and there is no record of borax production. The American Trona Corporation first produced borax in 1919. Following the war the American Trona Corporation initiated an intensive research program that enabled it to reduce costs and improve the quality of its products. Reorganized as the American Potash & Chemical Corporation, the company is now an important manufacturer of chemicals and produces a significant share of the world's supply of borax.

It has already been mentioned that F. M. Smith's West End Chemical Company built an experimental plant on Searles Lake about 1920 and attempted to produce borax and potash. The process was not a success, and the plant was redesigned to recover soda ash and borax. Production of soda ash began in 1927 and of borax in 1930. A comparatively small production of borax from Owens Lake began in 1929. It is recovered by the Pittsburgh Plate Glass Company's soda ash plant at Bartlett.

In the Kramer district, the Suckow Chemical Company and the Western Borax Company, in addition to the Pacific Coast Borax Company, have mined borax and kernite. The Suckow mine was 1½ miles west of the Pacific Coast Borax Company's Baker mine. Development began in the latter part of 1926, and production started in December, 1929. A comparatively small tonnage of borax had been mined when the Suckow Chemical Company became involved in litigation with the Pacific Coast Borax Company, and the mine was closed in April, 1932. The larger company obtained control of the Suckow mine; and since 1935, as the West Baker mine, it has been an important unit of the Pacific Coast Borax Company's operations.

The Western mine lies west and south of the Pacific Coast Borax Company's Baker mine. This property was developed by W. M. Balling and associates, who previously had explored some miles to the west and beyond the limits of the calcium borates. Kernite was discovered on what was to be the Western Borax mine in July, 1927. Balling transferred his interests to the Western Borax Company and remained as Superintendent of the Western Borax mine. Production began in November, 1928, and continued until mid-1933, when the property was sold to Borax Consolidated Ltd., parent company of the Pacific Coast Borax Company. The total production of the mine is estimated to have been 160,000 tons of crude ore at the time of its closing. As the result of action by the Federal Government, however, the Pacific Coast Borax Company was not permitted to acquire title to a 10-acre portion of the Western Borax Company property known as the Little Placer. Late in 1954 a group including Harvey S., Henry T., and Seeley G. Mudd obtained a Federal lease on the Little Placer and are preparing to produce borax.

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