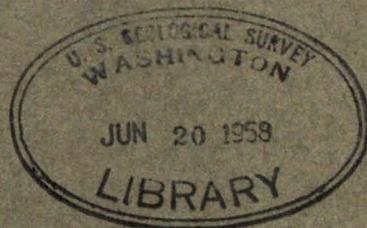


U. S. Geological Survey.

Reports, open-file, no. 440.
1958.



(200)
R290

U. S. Geological Survey.

Reports, Open-file,
no. 440, 1958.

Borate Deposits of the Mojave Region, California/

By

Ward C. Smith

U. S. Geological Survey

Claremont, California

U. S. Geological Survey

OPEN FILE REPORT

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

/ This article is essentially the same as a talk presented at the Annual Meeting of the Colorado Mining Association at Denver, Colorado, February 8, 1958.

CONTENTS

	Page
Abstract	3
Introduction	4
Uses of boron and borates	5
Products of boron users	6
Commercial compounds of boron	7
Boron minerals.	8
Production in the United States.	10
World occurrences.	11
Tibet	11
Italy; Germany; Russia; Australia; Asia	12
South America	13
U. S. Borate Deposits.	14
General features.	15
Searles Lake example	17
Results of basin drilling	22
Kramer District example.	23
Results of drilling near Kramer	25
Outlook for new discoveries.	26
References	27

Borate Deposits of the Mojave Region, California

By

Ward C. Smith

Abstract

Output of the United States borate producers reached approximately 1,000,000 tons in 1957, nearly four times the average annual production of 1941-45. Increasing consumption for long-established uses and several new ones accounts for the rise; further rise, for new uses such as high energy fuels, lies ahead. Among known borate deposits, the largest are at Searles Lake and Kramer, which supply 90 percent of the world's recorded production. The Kramer ore body, which is very large, consists of remarkably pure sodium borates in Tertiary lake beds. At Searles Lake, also large, the borax is produced from brines pumped out of salt layers which are the residue of a dessicated Pleistocene lake. Prospecting for borates is now more active than it has been for years. The best prospecting ground is in the alluvial-covered basins of western Nevada and particularly southeastern California, in concealed sections of Tertiary continental sediments. Several playas or salt flats that resemble Searles Lake were test-drilled for the U. S. Geological Survey by a contractor but the holes encountered no borates. Drill holes near Kramer, however, encountered a deposit of colemanite in lake beds.

Introduction

During recent years, a number of newspaper and magazine articles have discussed possible new uses of boron. In July 1957 defense agencies announced that certain manufacturing plants producing "high energy" fuels for military aircraft were being enlarged, and that in these fuels the main components are hydrogen and boron. Five years earlier, in 1952, the U. S. Geological Survey began an investigation of the domestic deposits of borate minerals. This was at the request of the U. S. Navy, Bureau of Aeronautics. Since 1952, therefore, the geology of borate deposits, and many of their special aspects, have been studied by a sizable group of geologists, mineralogists, and other specialists of the Geological Survey. This report contains material gathered by our group efforts. Naturally, I would like to acknowledge here the contributions of all who have been active in the group, and I regret that it is impractical to cite each of them by name.

Uses of boron and borates

The producers of boron supply a broad market, because the consumers of boron compounds are spread widely in our economy. Individuals use boron in borax soap powders, in common household borax, and in the boron-bearing gasoline recently marketed in several parts of the country. Industrial users take large quantities; the glass manufacturers, for example, consume about a fourth of the production. Most individuals do not realize that a great number of things familiar to them require boron compounds for their manufacture or processing. A few typical products listed below bring out the importance of boron in daily life.

Products of boron users

Industry	Typical products
Consumer Products	Soaps Pharmaceuticals "Boron gasoline"
Ceramics	Glazed ware of all kinds Enamels on metals
Glass making	Automobile headlight units Fiber glass Optic glasses Heat-resisting glass ("Pyrex")
Metal products	Fluxing compounds De-oxidizing compounds
Agriculture, Forestry	Mold retardant in food processing Trace element in fertilizers Weed killers Insecticides Fire retardant
Industrial Products	Leather preservative Paper glaze component Abrasives

Commercial compounds of boron

Boron enters commerce mostly as sodium borate--borax and anhydrous borax--and as boric acid. Chemical composition and B₂O₃ content of these compounds are as follows:

Principal commercial boron compounds

Commercial name	Chemical name	Chemical composition	Boron content	
			percent B	percent B ₂ O ₃
Borax	Sodium borate (decahydrate)	Na ₂ B ₄ O ₇ ·10H ₂ O	11.3	36.5
Anhydrous borax	(Sodium borate (anhydrous))	Na ₂ B ₄ O ₇	21.5	69.1
Boric acid	Boric acid	B(OH) ₃	17.5	56.3

Users also may obtain boron in a wide variety of other forms, ranging from elemental boron to organic compounds. The producing companies have large chemical plants and research staffs and the list of their products is always increasing.

Boron minerals

The boron minerals of greatest economic importance in the United States are borax, ulexite, and colemanite. Their chemical relationships are indicated by listing them, with some minor minerals, grouped by composition. (See also Palache and others, 1951, p. 320-21). The list does not include hydrated borates of calcium-magnesium and magnesium, which are major minerals in deposits elsewhere in the world but found only in small amounts in domestic deposits, nor does it include other borates of less importance.

Principal hydrated borate minerals

Chemical group	Mineral name	Chemical composition	Boron content	
			percent B	percent B ₂ O ₃
Sodium borates	Kernite ("Rasorite")	Na ₂ B ₄ O ₇ ·4H ₂ O	15.8	50.9
	Borax ("Tincal")	Na ₂ B ₄ O ₇ ·10H ₂ O	11.3	36.5
Sodium-calcium borates	Probertite	NaCaB ₅ O ₉ ·5H ₂ O	15.4	49.5
	Ulexite	NaCaB ₅ O ₉ ·8H ₂ O	13.3	42.9
Calcium borates	Colemanite	Ca ₂ B ₆ O ₁₁ ·5H ₂ O	15.7	50.8
	Meyerhofferite	Ca ₂ B ₆ O ₁₁ ·7H ₂ O	14.4	46.7
	Inyoite	Ca ₂ B ₆ O ₁₁ ·13H ₂ O	11.7	37.6

Among the minerals, borax is especially important. Borax was the first borate mineral mined in the United States--in 1864 at Borax Lake, California, north of San Francisco. (For details of the history of borax production in the United States, see Hanks, 1883, and Ver Planck, 1956). From 1872 to 1890, both borax and ulexite were mined from the efflorescences in the salt flats, or "borate marshes", of western Nevada and southeastern California. Next, colemanite became the leading borate mineral as mining moved from the marsh deposits to the Tertiary bedded deposits in the hills. Since 1927, borax has been dominant. It is the ore mineral at Kramer, the leading domestic producer, and it is also common to speak of borax at Searles Lake, though mining there consists of pumping brines that contain the sodium borate in solution, along with potash and other valuable components.

Production in the United States

Domestic production of borate minerals has been rising steeply for several years because of steady increases in established uses and the development of new uses other than military. The use of boron in high energy fuels has not yet had a significant effect on domestic production. Rounded figures for domestic production, which has come entirely from southeastern California, are as follows (Arundale, 1956, p. 139; Calif. Div. Mines, 1958, p. 8-9):

Period	Production per year (tons of borates)
1941-45 (average)	273,000
1946-50 (average)	500,000
1951-55 (average)	730,000
1956	944,950
1957 (estimated)	1,000,000?

According to the latest authoritative figures, which are for 1956, when 944,950 tons were produced, our domestic borate production was valued at \$39,591,953. The indicated average value--about \$40 per ton--is the price at the producing plants in California.

World Occurrences

A few notes on world production of borates will give additional background to our picture of our domestic industry. We do not have reliable figures for world production, because certain countries do not release figures. We believe that the United States, which exports from a fifth to a fourth of its production, has been supplying the world with about 90 percent of its requirement for some thirty years.

Borates produced outside the United States (Stipp and Marks, 1957, p. 9-10)

Country	Production (Metric tons)	Product
Argentina	13,000	Ulexite
Germany, West	40,470	Boron compounds
Italy	3,707	Boric Acid
Turkey	42,186	Boron minerals

A few highlights of the occurrence and production of borates outside of the United States follow. (See also Anonymous, 1933, p. 20-44).

Tibet and nearby parts of the high region north of India contain borate deposits that are noted as the world's first important source of borax for commerce. Carried to Europe at first by caravan, beginning about 1250 (the time of Marco Polo), the borax from Tibet was the chief supply until about the middle of the 19th century. The deposits are little known, and they must be small. Their geologic types seem to include hot-spring aprons and desert basin salines.

Italy developed a small but steady production in the middle of the 19th century, and displaced the supply from Tibetan sources. The striking feature of the Italian production, which still continues, is its source: The boron is recovered from steam and hot water poured out of fumarolic vents in Tuscany. The waters yield boric acid $B(OH)_3$. (The mineral of this composition is sassolite).

In Germany, at the famous Stassfurt locality, the marine sediments of Permian age that are mined mainly for potash, also yield some borate (hydroboracite, $CaMgB_6O_{11} \cdot H_2O$).

The Russians produce borax in the region of the Inder Lake, in western Kazakhstan. The quantity produced is not reported, but it appears to be large enough to meet the needs of the country. Mineralogic reports (Godlevsky, 1937, p. 315-368) indicate that there are deposits of several kinds. The primary deposits are in Permian marine sediments. These contributed boron to more valuable secondary accumulations in (Tertiary?) continental deposits, and also to the brine of a salt lake.

Turkey has produced minor quantities of borate for years. After a decrease in production of priceite ($Ca_4B_{10}O_{19} \cdot 7H_2O$) (see Palache and others, 1951, p. 341-343) from the well-known locality near Panderma, with exhaustion of the deposit there, new production came from a nearby deposit discovered in 1951. In the new deposits, the chief borate is colemanite, but they include other borates (Meixner, 1953, p. 86-92).

Australia and Asia (other than Tibet, mentioned above) seem to lack borates. Africa also is lacking, so far as production records go, though possibly borates occur in potash prospects in Eritrea, tested by Italians in the early 1930's.

When we consider South America's borates along with those of the United States, we realize that the western hemisphere is well endowed with known, usable deposits. Borates are found in a number of extensive salt flats ("salares") in the dry basins of the Andes of Argentina, Chile, Bolivia and Peru (Miller and Singewald, 1919; Singewald, 1943). It is interesting to know that South America also has, in addition to the "salare" type of borates, a few bedded deposits in Tertiary continental sediments. One contains kernite, the sodium borate long known only at Kramer (Ahlfeld and Angelelli, 1948; Muessig and Allen, 1957, p. 426-437).

The borates produced from some of the South American salares were most important in world trade in the latter part of the 19th century, but exports shrank as California production became dominant. Today a few localities produce small quantities, used for national consumption. Most of the South American deposits are unworked because their grade is low, or because their location, remote from world markets, makes the cost of transportation high.

U. S. borate deposits

A noteworthy feature of the borate industry in the United States, is that the steadily rising demands for borate raw materials are met mainly by two sources of supply in southeastern California: the Kramer district, which supplies two-thirds or more of the production, and Searles Lake. Other districts contribute only minor quantities. Most smaller deposits have been idle ever since the two big sources came into full production, about 1927, and prospectors have had little reason for persisting in a search for new borate deposits. In the last two years or so, however, interest in prospecting has risen perceptibly, and in January 1957, five holes were drilled in the Kramer district to test for borates.

General Features

The known borate deposits of the United States geographically are limited to California, western Nevada, and southern Oregon. Practically all the springs and wells known to contain more boron than average surface waters are limited to the same area. We assume these surface occurrences reflect the presence of subsurface rocks that contain, and yield to the surface more boron than generally found in the earth's crust. It seems likely that the boron content of the subsurface rocks of the boron-bearing province need be only slightly higher than the figure computed as the average in the earth's crust, 3 parts per million (Mason, 1952, p. 41).

In geologic mode of occurrence, our domestic borate deposits of commercial value (past or present) are essentially saline materials, accumulated with other continental sediments within basins of interior drainage. A major essential process in the concentration of soluble constituents in such basins is desiccation. The process builds accumulations within periods of time that are geologically rather short.

In geologic age, the borate accumulations range from Recent back through the Tertiary at least as far as middle Miocene, perhaps farther. The oldest deposits may be as old as Cretaceous; they consist of bedded colemanite in non-fossiliferous beds in Clark County, near Las Vegas, Nevada (Longwell, 1949, p. 935). The Calico Mountains colemanite deposits are well-dated as mid-Miocene (Lewis, G. E., written communication, 1954). The colemanite-ulexite deposits of the Furnace Creek district, Death Valley, are probably Pliocene (Noble, 1941, p. 954-956), and the Kramer deposit is probably Pliocene (Gale, 1946, p. 335) also. The Searles Lake brine and salt layers are of Quaternary age; the upper part rests on mud layers which are 25,000 to 10,000 years old, according to C^{14} determinations (Libby, 1954, p. 739).

Searles Lake example

Searles Lake is interesting both as a very large mineral deposit and as an example of what surface processes can do to concentrate minor components and put them in reach of profitable extraction. The Searles Lake borax is produced, along with several coproducts, from brines pumped out of two porous bodies of crystalline salt that underlie a salt flat. In brief, these crystalline salt bodies and their enclosed brines are the residues of water which, during late Pleistocene time, entered the basin from a long drainage, essentially that of the Owens River (Gale, H. S., 1914, p. 251-323).

Some figures make the size of the Searles Lake deposit tangible. About 12 square miles of salt are exposed in the middle of the basin, and about 27 more square miles at the margin are covered by several feet of slope wash. The exposed salt is the top of an "Upper Salt Body", which has a maximum thickness of 95 feet; it rests on a "Parting Mud" layer, (about 15 feet thick) which in turn is underlain by a "Lower Salt Body" with a maximum thickness of 54 feet. The salt bodies are crystalline and they are layered. The dominant saline mineral changes with depth, the sequence in the upper layering being halite, hanksite, and trona. With these minerals are other chloride, sulfate, and carbonate compounds of sodium. Borax crystals and layers of borax form a minor part of the salt bodies; in aggregate, the solid borax contains more boron than is in the brine, but only brine is worked. The brine makes up 35 to 50 percent of the volume of the crystal bodies. On average it contains about 1.0 percent B_2O_3 ; the total dissolved solids being 35 percent of the brine (Haines, D. V., and Smith, G. I., written communication, 1957).

From data such as those just given, the total boron content of Searles Lake has been calculated from time to time. A representative published figure is that of Turrentine (1926), who estimated 17,350,000 tons of B_2O_3 in the brine and solid crystals of the "Upper Salt Body" alone. This, and all the associated saline material, is the concentrate from a lake that began to receive inflow (or a revived inflow), about 25,000 years ago. The date is based on the determinations of C^{14} in the "Parting Mud" (Libby, 1954). The boron content of the inflow is suggested by measurements of the dissolved solids carried by the Owens River in recent years. Reliable figures (Wilcox, written communication 1946) indicate that the lower river carries about 700 tons of B_2O_3 per year. If this were the average for 25,000 years, the total would be 17,500,000 tons. This near coincidence with figures above is accidental, because other factors must enter into a complete appraisal of inflow, but obviously the figures involved are of the right order of size.

Of special interest and significance is another result of the thorough search for boron in the Owens River and its tributaries that was made 10 to 20 years ago (Wilcox, written communication, 1946). It was shown that nearly four-fifths of the boron that is now carried in the lower Owens River comes from one group of hot springs along Hot Creek, which is in the headwaters, near Mammoth Lake and the Mono Craters. Analyses and stream measurements of these springs, made over a ten-year span (1936-1947), indicate that they supply water containing 8 to 11 parts per million of boron. This is three or four times the average of the earth's crust. Presumably the springs pour out a mixture of surface water (no boron) and boron-bearing hot water. The ratio in the mixture is unknown. If we knew where the springs get their boron, we would have this geologic story complete: Primary source, ore-forming fluid, processes of transport and deposition, and commercial ore body.

The foregoing account of Searles Lake omits some important parts of the story. It omits details of Pleistocene climatic changes, consequent changes of the rate of inflow to Searles Lake, and balancing periods of desiccation. Other interesting details relate to the fact that Searles Lake basin is the middle basin of a chain of five basins. The basins upstream were catchments for detritus and preliminary "treatment tanks", while those downstream took overflow when the Pleistocene lake stood at the maximum high-water strand (about 600 feet above the present salt flat). The general trend of longer complicated treatment is to separate soluble salt from detritus and one salt from another. The treatment may isolate materials in separate basins. Or, within a basin, the salts may become segregated (imperfectly) into successive layers, or into zones distributed laterally from margin to center.

Results of basin drilling

With the Searles Lake deposit as an example of what might accumulate in a geologically short period of time, the U. S. Geological Survey tested the playas and salt flats in several basins in the Mojave region by drilling. The guides for prospecting seemed clear: (1) Select a salt flat or a dry lake with large drainage area tributary to it, or with high shore lines; (2) give preference to a member of a chain of basins; (3) expect a lake salt to be flat-lying and widespread (hence drill only one or two holes in a basin); (4) moderate depth is enough. (The Survey holes were less than 1,000 feet deep, except one that was 1,070 feet).

Test holes were drilled in eight basins that had never been tested adequately before. No new saline discoveries came from this group of holes, but they served to eliminate several basins from the class of "possible Searles Lake" deposits. (For details, see Smith, G. I., and Pratt, W. P., 1957, and subsequent chapters of U. S. Geological Survey Bulletin 1045).

Kramer District example

The Kramer ore body has been a challenge to geologists and prospectors ever since it was discovered. The first discovery at Kramer was accidental; the calcium borate colemanite was struck in a well drilled for water in 1912. Further drilling, over a period of 15 years, revealed the main ore body, which consists of the sodium borates, borax and kernite. The borates are in lake beds that do not outcrop; they lie beneath younger sands and gravels, at depths of 150 to 1,100 feet. The lake beds are moderately tilted and faulted. Some layers that are of mining thickness are nearly pure borax. The average grade of ore is not given clearly by Gale, but it seems to be high. The size of the ore body is very large. According to H. S. Gale (1946), the main ore underlies about 500 acres of ground, it is as much as 150 feet thick, and it contains nearly 100,000,000 tons of ore.

The prospector who is attracted to the western Mojave Desert by the example of Kramer finds that the deposit lies in the middle of about 3,000 square miles of subdued topography of Basin and Range type. The U. S. Geological Survey studied the western Mojave in several ways: A geologic map was prepared in moderate detail, with special attention to the stratigraphy and structure of the Tertiary rocks. Geophysics crews of the Survey made ground surveys with magnetic, seismic, and (most effectively) gravimetric methods, to determine bedrock configuration below the basin fills. A large part of the area was surveyed with the airborne magnetometer, in search of structures hidden below alluvium. The springs and wells were canvassed and sampled in search of traces of boron, as indicator of concealed borates. With the geological surveys for background, three sites were selected for test drilling.

A map of the vicinity of Kramer currently being prepared by T. W. Dibblee and D. R. Mabey shows features of the geology and gravimetric data that are typical of the Mojave. Alluvium covers three-fourths of the ground, outcrops of the Tertiary rocks (which are expected to contain any borates that may exist) cover only a tenth, and the remainder is pre-Tertiary crystalline rocks. Each site drilled under the direction of the Geological Survey is on a block of ground selected because it is (1) near Kramer; (2) alluvial covered; (3) marked by Tertiary outcrops around the margins; (4) underlain, according to gravimetric and seismic surveys, by a block of sediments and not by thin gravel on a pediment on crystalline rocks; (5) not adequately tested by previous drilling.

Results of drilling near Kramer

The results of the drilling are to be given in a report now being prepared for publication. The main results are as follows. Hole 1, south of Four Corners, and Hole 2, west of the Kramer deposit, proved to be barren of traces of borates. The results illustrate that a thick section of sediments is no guarantee that borates will be found.

Holes 3, 4, and 5, which lie a mile apart along a north-south line about 8 miles east of the Kramer deposit, encountered the calcium borate colemanite in lake beds at depths of 1,020 to 1,460. The B_2O_3 content, in layers 2 feet or more thick, ranges from 7 to 20 percent. Colemanite was particularly abundant in Hole 5: determinations of the acid-soluble borate in samples from this hole showed that 76 feet of core recovered from the depth interval 1,051 to 1,131 feet averaged above 14 percent of B_2O_3 . The enclosing lake beds are mineralogically like those containing calcium borates at the Kramer mining area, containing not only colemanite but the peculiar combination of realgar, a magnetic iron sulfide, and analcime. It seems clear that these beds formed in a lake very similar to that in which Kramer formed, if not in the same or a connected lake.

Outlook for new discoveries

The geologic studies indicate that borate deposits are to be sought in Tertiary continental sediments in the Basin and Range province. The outcrops in the ranges have been prospected adequately, but extensive blocks of Tertiary rocks concealed below younger alluvial fan and volcanic deposits have not. The outlines of the blocks are indicated by geologic and gravimetric surveys, but to test them requires drilling. At the present time, substantial private programs of exploratory drilling are underway, and it seems likely that these will make one or more significant additions to our national reserves of borate ore.

References

Reports that describe the cores from test holes, and other results of the U. S. Geological Survey borate investigations, are being prepared for publication. The reports published so far, and those made available for public inspection by placing them in open file, are listed below, preceding an alphabetic list of other literature cited in this report.

U. S. Geological Survey Bulletin 1045

Geologic investigations in Mojave Desert and adjacent region,
California.

- (a) Core logs from Owens, China, Searles, and Panamint basins, California, by G. I. Smith and W. P. Pratt. 1957. p. 1-62, pl. 1, fig. 1-2.
- (b) Core logs from two test holes near Kramer, San Bernardino County, California, by D. D. Dickey. 1957. p. 63-79, pl. 2, fig. 3.
- (c) Core logs from Soda Lake, San Bernardino County, California, by S. Muessig, G. N. White, and F. M. Byers, Jr. 1957. p. 80-96, pl. 3, fig. 4.

Reports in open file

(Available for inspection at the U. S. Geological Survey library,
Washington, D. C.

Geologic reconnaissance and test-well drilling at Camp
Irwin, California, by Fred Kunkel and F. S. Riley,
1956, 56 p., 1 pl.

Geologic map of the Alvord Mountain quadrangle, California,
by F. M. Eyers, Jr., 1956, 1 map, 2 geologic structure
sections.

Geology and petrology of the Lava Mountains, by G. I. Smith,
1956, 230 p., 59 illus., 15 tables.

Preliminary geologic map of part of the southeastern Mojave
Desert, San Bernardino County, California, by D. H. Kupfer
and A. M. Bassett, 1956.

Core logs from Searles Lake, San Bernardino County, by
D. V. Haines, 1957.

Ground-water reconnaissance in the western part of the Mojave
Desert, California, with particular respect to the boron
content of well water, by R. S. Stone, 1957, 102 p., 13 pls.

Simplified geologic map of the western Mojave Desert,
California, by T. W. Dibblee, Jr., 1957.

- Anonymous, 1933, Borates, in The mineral industry of the British Empire and foreign countries, 2nd ed., 1920-1932: London, Imperial Institute, p. 20-44.
- Ahlfeld, F., and Angelelli, V., 1948, Las Especies Minerales de la Republica Argentina: Univ. Nac. Tucuman, Inst. Geol. y Min., Jujuy, Pub. 458, p. 162-168.
- Arundale, J. C., 1956, Boron, in Mineral facts and problems: U. S. Bur. Mines Bull. 556, p. 137-141.
- Arundale, J. C., and Mentch, F. B., 1956, Boron, in Minerals Yearbook 1953: U. S. Bur. Mines, v. 1, p. 251-260.
- California Division of Mines, 1957, Boron: Calif. Div. Mines, Mineral Information Service, v. 10, no. 10, p. 1-5.
- _____, 1958, Mineral production review, California, 1957: Calif. Div. Mines, Mineral Information Service, v. 11, no. 1, p. 8, 9.
- Gale, H. S., 1914, Salines in the Owens, Searles and Panamint Basins, southeastern California: U. S. Geol. Survey Bull. 580L, p. 251-323.
- _____, 1946, Geology of the Kramer borate district, Kern County, California: Calif. Jour. Mines and Geology, v. 42, p. 325-378.
- Godlevsky, M. N., 1937, Mineralogical investigation of the Inder Borate deposits: Memoires de la Societe Russe de Mineralogia, LXVI, 2, p. 315-368.
- Hanks, H. G., 1883, Report on the borax deposits of California and Nevada: Calif. Min. Bur. Rept. 3, pt. 2, 111 p.
- Libby, W. F., 1954, Chicago radioactive dates V: Science, v. 120, no. 3123, p. 739.
- Longwell, C. R., 1949, Structure of the Northern Muddy Mountain area, Nevada: Geol. Soc. America Bull., v. 60, no. 5, p. 935.

- Mason, Brian, 1952, Principles of geochemistry: New York, John Wiley and Sons, p. 41.
- Meixner, Heinz, 1953, New Turkish borate deposits (with a general paragenetic classification of all borate minerals): Berg- und Huttenmann. Monatsch montan Leobem. v. 98, p. 86-92.
- Miller, B. L., and Singewald, J. T. Jr., 1919, The mineral deposits of South America: New York, McGraw-Hill Book Co., Inc.
- Muessig, Siegfried, and Allen, R. D., 1957, Escurrite ($2\text{Na}_2\text{O} \cdot 5\text{B}_2\text{O}_3 \cdot 7\text{H}_2\text{O}$), a new sodium borate from Argentina - occurrence, mineralogy, and associated minerals: Econ. Geology, v. 52, no. 4, p. 426-437.
- Noble, L. F., 1941, Structural features of the Virgin Springs area, Death Valley, California: Geol. Soc. America Bull., v. 52, p. 941-999.
- Palache, Charles, Berman, Harry, and Frondel, Clifford, 1951, Dana's system of mineralogy, v. II, Borates: New York, John Wiley and Sons, p. 320-321 and p. 334-368.
- Singewald, J. T., Jr., 1943, Bibliography of economic geology of South America: Geol. Soc. America Special Paper 50.
- Smith, G. I., and Pratt, W. P., 1957, Core logs from Owens, China, Searles, and Panamint Basins, California: U. S. Geol. Survey Bull. 1045A.
- Stipp, H. E., and Marks, A. L., 1957, Boron, in Minerals Yearbook 1955: U. S. Bur. Mines, preprint, p. 9-10.
- Turrentine, J. W., 1926, Potash, a review, estimate, and forecast: John Wiley and Sons, New York, 188 p., quoted in Calif. Div. Mines, Mineral Information Service, v. 10, no. 10, p. 1-5.
- Ver Planck, W. E., 1956, History of borax production in the United States: Calif. Jour. Mines and Geology, v. 52, no. 3, p. 273-291.

Weld - 2548

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Washington, D. C.

March 12, 1958

For IMMEDIATE RELEASE

The Geological Survey is releasing in open files the following report. Copy is available for consultation in the Geological Survey Library, 1033 General Services Bldg., Washington, D. C.

Borate deposits of the Mojave region, California, by Ward C. Smith. 30 p.

* * *