Recent South American Borate Deposits

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ABSTRACT

Recent South American borate deposits lie in the high Andes in Argentina, Bolivia, Chile, and Peru. Two types occur: spring and playa deposits. The deposits are more extensive and richly developed than elsewhere in the western world and throw important light on the genesis of older, less well-exposed deposits.

Spring deposits comprise cones and aprons of ulexite ($Na_2O \cdot 2CaO \cdot 5B_2O_3 \cdot 16H_2O$)*; borax* ($Na_2O \cdot 2B_2O_3 \cdot 10H_2O$) *occurs at one place. Most spring deposits occur on metamorphic clastic rocks with no evidence of buried bedded borates nearby. Recent nearby volcanic rocks are rhyolitic to basaltic. Most deposits have associated calcareous tufa. A source related to volcanism is clearly indicated.*

Playa deposits are predominatly of ulexite, but inyoite ($2CaO \cdot 3B_2O_3 \cdot 13H_2O$) *occurs in Peru and borax in several Argentine playas. Ulexite occurs near surface as thin discontinuous beds and nodules in salt or gypsum matrix with sand or clay. Irregular distribution of deposits, lack of high shore lines, and lack of integrated drainage systems seem to rule out weathering of bedrock as the source of boron. Spring activity is widely evident. One isolated playa, Turilari, contains borax in green clay with much carbonate, and high Li, As, Sr. It is an undeformed small-scale replica of the Kramer deposit, California.*

INTRODUCTION

Most of the borate deposits that have attracted and have furnished the bulk of the borates of commerce are buried and occur in deformed Tertiary and Quaternary rocks. A most remarkable example of such deposits is the largest known one in the world, the Kramer deposit, California, discussed in this symposium by Barnard and Kistler. Other such deposits occur in Turkey, Russia, and South America.

The deposits to be discussed here lie well exposed at the surface and occur in Recent sediments. Because of their recency, unaltered nature, and extensive development, they afford some insights of genesis that we cannot get from the buried, mineralogically altered deposits. As will be seen, these surficial deposits are interesting in that they show that at least some of these "evaporites" have a local origin and do not necessarily crystallize from standing bodies of water.

The deposits lie in the high Andes on both sides of the main cordillera at altitudes of 3,000 meters to about 4,600 meters. The eastern deposits lie in what is called the Altiplano, or Puna. The climate of the area can best be described as raw; it is characterized by high diurnal temperature changes and high cold winds. Rainfall ranges from a few inches to about 12 inches per year, in northwestern Argentina (see Catalano, 1930a). Figure 1 shows the distribution of deposits.

Figure 1. Index Map.

Two types of deposits are discussed -- spring deposits, and those occurring in playas or salares. Spring deposits occur in two areas of Argentina and one of Peru and comprise perhaps 15 individual springs. The playas number 35, in Chile, Argentina, Bolivia, and Peru.

Most of the following observations are based on about nine months' field and office work in 1955, unpublished and published literature, together with work in borates elsewhere, which admittedly has influenced my thinking. As will become apparent, there are glaring deficiencies in the data, such as lack of regional geologic knowledge and lack of chemical analyses. The intent of this paper is not to describe all the deposits or even single ones in any detail, but, rather, to present some of the data in summary form, mainly so as to throw light on the origin of the older buried deposits.

Regional geologic data are quite scanty, and, therefore, generalizations are difficult to make. However, the known data do allow us to sketch a general geologic setting. Physiographically, the region is characterized by broad linear valleys commonly having playa floors separated from each other by linear north-trending mountain masses: it is much like our Great Basin. Most deposits occur in a terrain of Miocene to Quaternary volcanic and sedimentary rocks that is interspersed with north-trending ribs of older, meta-clastic rocks. Except for the youngest volcanic rocks, of which the many recent volcanos and other volcanic masses are formed, the younger rocks tend to underlie the valleys, much as in our Great Basin. The 1950 G. S. A. geologic map of South America shows the older rocks as Permian. However, in places these rocks contain trilobites and are probably of early Paleozoic age. In other places they are known to be Precambrian (Turner, 1964).

In Chile, a few playas are in areas of Jura-Cretaceous volcanics. Here, also, are extensive areas of Pliocene and Quaternary rhyolite. In Argentina, linear outcrops of Tertiary continental sediments occur along the margins of several playa basin; these sediments contain bedded borates and evaporites in several places (Turner, 1964; Catalano, 1926, 1930b; Pratt, 1961).

SUMMARY

In summary, one can say that the altiplano is characterized by having young volcanic rocks, the most recent of which are chiefly basaltic.

MINERALOGY

The following minerals comprise the primary borates found in the spring and playa deposits.

Ulexite	-	$Na_2O \cdot 2CaO \cdot 5B_2O_3 \cdot 16H_2O$
Borax	-	$Na_2O \cdot 2B_2O_3 \cdot 10H_2O$
Inyoite	-	$2CaO \cdot 3B_2O_3 \cdot 13H_2O$

SPRING DEPOSITS

So far as I can ascertain from the literature, nowhere else in the world are borate spring deposits so well developed as in Argentina. These deposits consist of cones and aprons of ulexite around vents, from some of which cool to hot waters are still issuing and presumably still depositing borate. Gas accompanies the water in several places. In form, these deposits have all the diversity found among recent calcareous tufa and siliceous sinter deposits.

Rio Alumbrio deposits. The Rio Alumbrio deposits (Barnabe, 1915, pp. 20-22), about 15 kilometers northwest of Coranzuli, Argentina, are among the most spectacular borate spring deposits in South America, if not in the world (Figs. 2, 3, 4). They are of small size, containing a few hundred to a few thousand tons of ulexite; there are about 11 of these deposits in an area of a few square kilometers. They lie at an altitude of about 4,200 meters. They are mineralogically quite pure, being composed almost entirely of ulexite. Calcite, in the form of calcareous tufa, is a late stage mineral; it forms the cone of one of the deposits (Figs. 3 and 4) and occurs in others as irregular thin beds overlying most of the ulexite. Gypsum or other sulfates do not appear to occur.

Most of the springs which deposited the borate are now extinct but at the large deposit shown in Figs. 3 and 4 a spring is bubbling vigorously at a temperature (in 1955) of 59° F. The water is salty. The gas in the spring is probably CO_2. A rough crust of calcite coats the linear fissure in which the spring is bubbling.

Trilobite bearing argillite, slate, and quartzite, probably many thousand feet thick, form the bedrock for the Alumbrio deposits. Just to the south of the largest deposit (Figs. 3, 4) and also to the east, is a Tertiary sandstone whose extent and thickness are not known but are probably not great. No borate deposits or occurrences are known in this unit. Widespread volcanics are the most recent rocks in the area. Of these, the youngest are basaltic and occur in the prominent volcanos of the Coyaguaima volcanic complex. A prominent light gray quartz-biotite flow is slightly older and occurs widely in the same area.

Drainage from the deposits is down the Rio Alumbrio eventually into the Laguna de Guayatayoc, where thin and sparse deposits of ulexite are known.

Volcancito. Volcancito ("little volcano") is a small tabular ulexite deposit that lies about 6 kilometers west of the Alumbrio deposits in the flat valley bottom of a minor tributary stream of the Rio Blanco (Fig. 5).

Three prominent ulexite-tufa cones are on the upstream side of the deposit; springs from them were obviously the source of the ulexite. Considerable noisy spring activity still occurs at each of the cones, hence the name of the deposit.

The uppermost and largest cone has no spring vent but internal bubbling could be heard at its top. It is formed of ferruginous calcareous tufa that overlies ulexite along its downstream flanks. The middle cone (Fig. 5), a few tens of meters to the east, consists of ferruginous calcareous tufa and has a spring vent of about a half-meter diameter filled with fragmental very ferruginous tufa. When this cone vent was dug out water was seen to be bubbling vigorously about 30 centimeters below the cone lip. The water was very cold; according to local word-of-mouth, this spring was hot in 1924. The lower cone consists predominantly of ulexite. It has a vent about 30 centimeters across from which odorless gas was issuing. Very ferruginous tufa lies in the vent, and some of it is coated by halite.

The deposit is about 200 meters long, 40 meters wide, and up to 2 meters thick. The ulexite of the deposit is quite pure, fluffy, and saturated with water from the springs, which is salty. A thin bed of tufa, deposited mainly from the upper cove, overlies the middle of the deposit; this is shown in Fig. 5 as the dark area that separates the two white areas of ulexite.

Red mudstones and light colored sandstone and claystone underlie part of the deposit; these sediments are overlain by an extensive quartz-biotite flow. The east side of the deposit is flanked by the same argillite-slate series that underlies the Alumbrio deposits. The contact between younger and older rocks runs under the deposit; it appears to be a depositional one.

Drainage from Volcancito joins that from the Alumbrio deposits and flows into Laguna Guayatayoc. No ulexite occurs upstream from the deposit, but efflorescences of ulexite and other light-colored evaporites occur downstream.

Coyaguaima. Coyaguaima (also known as the Edith mine; Ahlfeld, 1948; Catalano, 1930b) is a spring deposit much like those already described except that some borax accompanies ulexite. The deposit lies on the north flank of the Coyaguaima volancic mass at about 4,600 meters; it is about 30 kilometers north of Alumbrio and about 80 kilometers due west of Abra Pampa.

Coyaguaima consists of three separate deposits draped along the lower valley walls on the south side of the Rio Coyaguaima (Fig. 6). Each deposit has at its head a small cone together with aprons of ferruginous calcareous tufa; spring activity has ceased. Country rock around the deposits is the argillite series found at the deposits to the south. No Tertiary sediments are known in the region although Tertiary and Quaternary volcanics are widespread.

Fluffy wet ulexite having 1 to 3 per cent halite is the predominant mineral. Calcareous tufa is irregularly distributed and lies both over and under the ulexite. Borax occurs disseminated and as small crystals and irregular masses in the upper part of the eastern deposit; perhaps 3 per cent of this deposit comprises borax. The deposit is up to 2 meters thick and contains about 10,000 tons of borate.

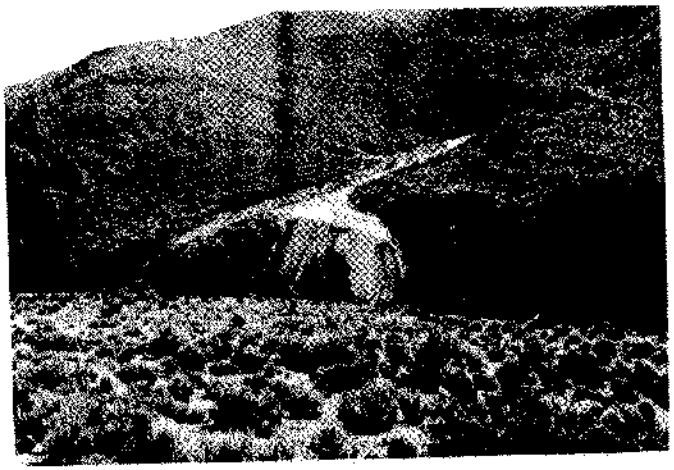

Figure 2. Rio Alumbrio spring deposit, Argentina. The light-colored material is ulexite.

Figure 3. Largest of the Alumbrio spring deposits. In left center of picture is a well-developed cone, now extinct, formed of ulexite and calcareous tufa. Cerro Supisaimo is in the upper center.

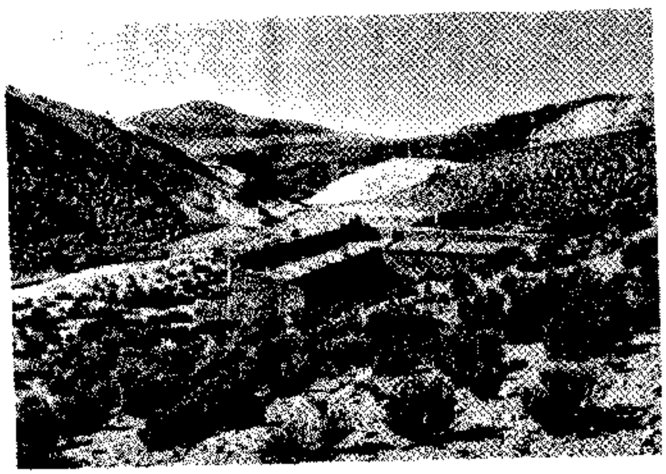

Figure 4. Deposit shown in Figure 3. Note the small cone on left skyline. The larger deposit is predominantly ulexite and has a vigorously bubbling spring in its flat top.

Figure 5. Volcancito spring deposit, Argentina. Middle cone is shown in lower center of picture. Prominent cliff is formed of extensive quartz-biotite flow. Minor perennial stream is on left edge of ulexite, which is white.

Drainage from the deposit reaches the Atlantic through the Pilcomayo and Parana rivers. Crusts of ulexite occur at many places downstream from the deposit.

Other deposits. Other small spring deposits occur at Antuco, Argentina (Reichert, 1907, p. 29), and at Chillicolpa, Peru (Jochamowitz, 1917, p. 63). Both lie in volcanic terrain, consist predominantly of ulexite, and have thermal spring activity associated with them.

PLAYA DEPOSITS

There are 35 playas (Fig. 1) known to contain borates in Argentina (Catalano, 1926), Chile (Leiding, 1942), Peru (Jochamowitz, 1917), and Bolivia (Ahlfeld, 1941). Almost all occupy individual basins having separate drainages. They range in size up to several 100 square kilometers and contain from a few thousand to several million tons of crude borates (see especially Leiding, 1941).

Springs are common within the playa basins (Fig. 7), and some of them are hot; unfortunately, no analyses are available, but many of them are salty. Salar de Zenobia, Chile, has hot springs and geysers along its margins. Salar de Maricunga, Chile, and Salar de Cauchari, Argentine, have travertine and tufa cones and terraces along their margins. Salar de Aguilar, Chile, has several geysers along its eastern edge.

All the playas are wet beneath the surface, and many have "lagoons" on them all or part of the year (Fig. 8). At most playas water fills prospect holes rather quickly. The playa surfaces are quite variable: some are smooth whereas others are rough and hard, due to complex erosion and solution of surface salts. At several playas, e.g., Ascotan and Carcote, Chile, and Laguani and Uyuni, Bolivia, there are old shore lines 10 meters and more above the surface of the playas. Most playas, however, have no visible shore lines and there is no evidence that the borate in them is a desiccation product from standing water.

Nearly all the playas contain only ulexite as the borate mineral. It occurs in two forms: in thin layers or beds, and in potato-like nodules (locally) called "papas" that range in size from granules to those of a man's head (Fig. 9). Both forms are generally quite patchy in areal and vertical extent and lie at or within 2 to 3 meters of the playa surface in a water-soaked matrix of clay, silt, and fine sand that in most places also contains varying amounts of halite and gypsum. In some playas the matrix is mostly finely crystalline gypsum; in others, mostly halite and gypsum. So far as I know, carbonate is sparse or absent in the playa deposits. In a few places, the ulexite lies under a surface layer of halite up to about 30 centimeters thick. Internally, the ulexite masses are clean or are veined or contaminated by matrix materials. The ulexite zones range up to about 2 meters in thickness and contain up to about 20 per cent B_2O_3 with an average of 50 weight-per cent of water.

Many of the Chilean playas have a high content of gypsum whereas the gypsum content in the Argentine playas is generally much lower. Where the sulfate comes from is not known, but almost certainly much of it results from the oxidation of volcanic sulfur. The fact that there are more volcanic sulfur deposits on the Chilean side of the Andes than on the Argentine may be corroborative evidence of the origin of some of the sulfate.

Much of the ulexite at Salar de Ascotan, Chile, lies in a matrix of diatomaceous earth. According to K. E. Lohman, of the U.S. Geological Survey (written communication, Jan. 3, 1956), the flora contains forms found in hot spring waters.

Borax occurs as crystals and irregular aggregates in salty red silt and sand in Salares Cauchari and Rincon, Argentina. Ulexite occurs at other places in these playas; the borax is not of wide extent.

Inyoite underlies a small area along the east side of Laguna Salinas, Peru, near a hot spring along the edge of the playa (Muessig, 1959).

Of special interest is the Turilari playa, Argentina, where borax crystals occur in green bentonitic clay, just as at the Kramer, California, deposit (Muessig, 1958). The deposit is in an isolated basin having a small drainage area. The clays contain large amounts of carbonate, lithium, and arsenic, as do those at Kramer.

Figure 6. Middle spring deposit, Coyaguaima, Argentina. Now extinct cone lies at upper right of photograph. Two men in center of picture give scale.

Figure 7. Un-named saline playa a few miles northwest of Salar de Pastos Grandes, Argentina. Extinct springs have formed cones of calcareous tufa and deposited salines in the playa.

Figure 8. Salar de Ascotan, Chile. White surface is chiefly gypsum sand; dark surface on far shore is a shallow "lagoon." Stripe at left is track of Antofagasta-Bolivia railway.

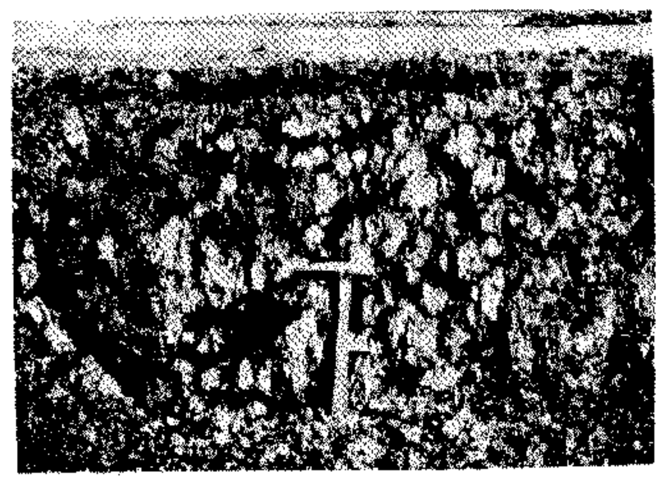

Figure 9. Typical occurrence of ulexite "papas" in matrix of wet red silty sand. Salar Cauchari. Argentina.

Table 1. Partial chemical analyses of clays from Kramer, California, and Turilari, Argentina. Analyses by Hy Almond, U.S. Geological Survey (in weight per cent).

	Kramer	Turilari
CaO + MgO	17.2	16.4
CO_2	8.0	10.1
As	0.06	0.10
SrO	0.10	0.34
Li_2O	0.41	0.31

As at Kramer, the carbonate at Turilari occurs as very fine-grained dolomite and calcite.

The borax of the Turilari deposit must have crystallized from the standing water of a shallow lake whose mineralized source must have been local springs within the basin. I view this deposit as being a small-scale recent replica of the Kramer deposit.

ORIGIN

The evidence seems clear to me that the important sources of the boron found in the deposits are the local thermal springs. The playa deposits can be considered as spring deposits only slightly removed from their immediate source. It further seems probable to me that the boron and chloride are of volcanic origin.

Weathering of bedrock for major constituents over large areas seems ruled out because: 1. Many of the playas have no extensive drainage areas. 2. There are many playas completely devoid of borates that have the same peripheral country rock as borate-rich playas. This latter fact argues strongly for an origin of the salts from local sources, that is, from springs or other hydrothermal sources.

Leaching of buried borate deposits by spring systems is possible, but there is no evidence of this. The only two bedrock deposits known, at Pastos Grandes (Catalano, 1927) and Tincalayu, Argentina (Muessig and Allen, 1957), are far removed from most of the Recent deposits.

ANALOGY TO OLDER DEPOSITS

If the secondary affects of alteration and deformation are not considered, then the mineralogy and geometry of the Death Valley colemanite deposits indicate that they originated as spring deposits. They are high in carbonate and contain no chloride and very little sulfate.

The Callville Wash, Nevada, colemanite deposit, which contains much gypsum and is quite regularly bedded, probably originated in a playa.

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