Preliminary Descriptive Model of Lacustrine Borates

BRIEF DESCRIPTION

Deposit synonyms: Tincal deposits, borax deposits, playa borates, bedded borates, B-bearing lacustrine brines.

Principal commodities produced: Borax pentahydrate, borax decahydrate, boric acid, colemanite, anhydrous borax, ulexite.

By-products: Typically none, but other commodities may be spatially and genetically associated, especially in playa environments.

End uses: Fiberglass, borosilicate glass, soaps and detergents, flame retardants, agriculture, metallurgy, advanced composite materials, nuclear shielding, refractories, abrasives, medical, other.

Descriptive/genetic synopsis: Borate minerals precipitated from brines in permanent or semi-permanent hydrologically stratified or shallow lakes in arid to semi-arid climates. May include borates deposited as crusts or crystals in playas or as precipitates from thermal springs found within the lake basin. Borate may also be present in economic concentrations in brines within the lacustrine or evaporite sediments. Diagenesis may lead to higher grade deposits through dehydration and mineral partitioning. Several sub-types of this deposit type are frequently distinguished based on mineral form, mineral type, and (or) fine geologic divisions. These subtypes include borax-kernite deposits, bedded colemanite (ulexite), playa ulexite, and boron-bearing playa-lacustrine brines. In some basins, multiple forms of mineralization are known. The borax-kernite deposits are the most rare and most economically important.

Typical deposits:

Kramer (Boron), USCA *(borax, kernite)*
Emet, TRKY *(colemanite)*
Laguna Salinas, PERU *(ulexite)*
Searles Lake, USCA *(brine)*

Relative importance of the deposit type: Massive, bedded lacustrine deposits, especially borax-kernite deposits, are the major source of borates.

Associated/related deposit types: Li-, K-, Mg, sodium sulfate-, and (or) sodium carbonate-bearing brines, lacustrine evaporite deposits (gypsum, halite), hectorite, lacustrine diatomite, zeolites.

REGIONAL GEOLOGIC ATTRIBUTES

Tectonostratigraphic setting: Convergent plate boundaries and extensional terrains with associated volcanism.

Regional depositional environment: Closed or semi-closed basins, typically structural basins.

Age range: Tertiary to Recent.

LOCAL GEOLOGIC ATTRIBUTES

Host rock(s): Lacustrine sediments and evaporites, especially siltstone, limestone or calcareous shale, and gypsum.

Associated rock(s): Contemporaneous, commonly bimodal, calc-alkaline volcanic flows and tuffs.

Ore mineralogy: ± borax ± kernite ± ulexite ± colemanite ± probertite ± tincalconite ± priceite ± szaibelyite ± brine ± others.

Gangue mineralogy: May include gypsum, dolomite, orpiment, realgar, calcite, anhydrite, thenardite, trona, hectorite, zeolites, native sulfur, aragonite, stibnite, celestite, halite, potash, others.

Alteration: Diagenesis leads to recrystallization of many borate minerals (cation and hydration changes).

Structural setting: Basins are commonly fault-controlled.

Ore control(s):

- Closed to semi-closed structural basins at time of deposition;
- Boron source within basin drainage;
- Arid to semi-arid climate;
- Contemporaneous volcanism;
- Water inflow over time is large enough to introduce significant quantities of dissolved material;
- Preservation of soluble borates by overlying clay or other insoluble unit.

Typical ore dimensions: Most borate-bearing bodies form elongate lenses with the lengths of the largest known mineralized areas exceeding 4 km in plan view. Deposit thickness may approach 100 m. More typical borate-bearing bodies are hundreds of m in length and less than 10 m thick.

Typical alteration/other halo dimensions: N/A

Effect of weathering: Older deposits reexposed at the surface may undergo hydration or dissolution of borate minerals that can eventually lead to destruction of the deposit.

Effect of diagenesis/metamorphism: Metamorphism destroys deposits. Diagenesis leads to removal of water, Na, B, and Ca from deposits. In initial stages, the net effect of diagenesis is higher grade deposits. Over longer periods of time and extreme conditions, diagenetic changes contribute to destruction of deposits.

Maximum limitation of overburden: Unknown, but some deposits with more than 100 m of overburden have been mined.

Geochemical signature(s): B $\pm$ Li $\pm$ Sr $\pm$ As

Geophysical signature(s): No distinctive signatures, but various techniques may be useful for delineating shape or structure of known deposits and their environments. For instance, B-bearing horizons produce large negatives (absorbs neutrons) relative to some host rocks using down-hole neutron logging techniques.

Other exploration guide(s):

- Presence of contemporaneous volcanic rocks and (or) thermal springs within basin drainage;
- Efflorescences of soluble saline minerals, especially borates.

The following features are indicative of potential lacustrine host environments:

- Aragonite laminae in muds indicates a local saline environment or stratified lake. Dolomite or the presence of minerals with contrasting solubilities (like halite and aragonite) within the muds could indicate a saline environment or a stratified lake (Smith, 1966);
- At basin perimeter, alluvium (generally thin) interbedded with lacustrine sediments would indicate lake contraction and increasing salinities towards basin center. Sediment unconformities or interbedded soils at the perimeters would also indicate periods of lake evaporation (Smith, 1966);

- Collapse brecciation of lacustrine sediments and (or) development of sinks and pits may be indicative of soluble minerals at depth.

Most readily ascertainable regional attribute: Presence of lacustrine sediments in a closed basin with spatially associated contemporaneous volcanic rocks and (or) thermal springs.

Most readily ascertainable local attribute: Borate mineral (commonly ulexite) efflorescences at the ground surface. However, a lack of surficial borate expression is not a negative feature.

ECONOMIC LIMITATIONS

Physical/chemical properties affecting end use: Cation (Na, Ca) of product may determine or limit usage. Arsenic content may restrict use of some borate ores by the glassware industry if the arsenic cannot be easily removed from the borate mineralization.

Compositional/mechanical processing restrictions: Unknown.

Distance limitations to transportation, processing, end use: Borates are a high value product and transportation costs are not commonly a significant limiting factor.

OTHER--ENVIRONMENT

For some deposits, As may be of concern as a waste product.

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