Exploration Potential and Economic Significance of Puga Valley Borax Deposit, Ladakh, India

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Abstract—Borates are compounds that contain boron, a chemical element. Borax is an important compound of borates. The uses of borates to mankind are known form very early times but common use came in the late 19th century. Borate minerals are now used extensively worldwide in chemical, glass, ceramics, LCD, high-yield crop fertilizers, wood preservatives and specialty products. Majority of the world production of borates is coming from USA and Turkey where thorough exploration has been done and significant deposits are discovered. Many regions especially in Asian and European countries like China, India are yet to be fully explored for commercial mining of borates. Puga valley of Ladakh in India is one of the examples. Preliminary exploration has been carried out in this region by Geological Survey of India (GSI) during 1970s but afterward no one has looked into the exploration and economic significance of this area. Ample scope exists for exploration in this region. Asian countries, in fact, are driving the consumption growth of borates swiftly. The demand and supply is completely met by USA and Turkish producers. India is totally dependent on import to meet domestic need and if Puga valley can be put on production scale, it can nourish India’s demand to some extent. In this paper, an attempt has been made to depict exploration potential and economic significance of the Puga borax deposit, Ladakh, India.

Key words: Borates, Borax, Exploration, Puga, Ladakh, India

I. INTRODUCTION

Approximately 150 minerals contain the element boron (B). These minerals are broadly divided into three broad groups according to their origin and geological environments [1]: a) skarn minerals related to intrusive, mainly silicates and iron oxides; b) magnesium oxides related to marine sediments; and c) hydrated sodium and calcium borates related to continental sediments and volcanic activity. Groups A and B are the source minerals for the Russian and some of the Chinese production. Group C are borax, kernite, colemanite, and ulexite which provide the source for most of the world's production from Turkey, South America, and the United States [1]. The Puga Valley deposit, which is the largest known occurrence in India, is of Group C type.

Borax is by far the most important mineral for the borate industry. Borax in large tonnages is present in the deposits at Boron, CA; Kirka, Turkey; and Tincalayu, Argentina. Kernite, the metamorphic phase of borax, has a higher B2O3 content than borax. Colemanite is the preferred calcium-bearing borate used by the non-sodium fiberglass industry. Ulexite is the usual borate found on or near the surface, in playa-type lakes and marshes of Recent to Quaternary age throughout the world, where it occurs as soft, often damp, masses of fibrous crystals [1]. Major borate deposits all over the world are found in tectonically active extensional terrain associated with plate boundaries [1] – [2]. Most of the commercial deposits are thought to be associated with continental sediments and volcanism of Neogene age. The estimated world resources of Boron minerals are about 210Mt, in terms of boric acid [4].

A large number of minerals contain boric oxide, but the following ones have highest industrial utility from a worldwide commercial standpoint:

- Borax (Tincal) - NaB4O7·10H2O
- Kernite - Na2B4O7·4H2O
- Ulexite - NaCaB4O7·8H2O
- Colemanite - Ca2B6O11·5H2O
- Sasoline - H5B8O16
- Boracite – MgB2O7·Cl

II. LITERATURE REVIEW

A. Puga Valley Deposit, Ladakh:

Puga Valley (Fig 1) is situated south-east of Leh at a distance of about 200km in the Ladakh region of NW India at an altitude of 4000m. Leh is the district headquarters of Ladakh and approachable by metaled roads from Srinagar and Manali. Borax occurrences in Ladakh region are reported at many places like between Rupshu and Chushul, Chumathang, Puga and are known from very early times [5]. Other deposits are also reported from Tibet [6] between Hundes and Manosarovar though no details are available. The Puga Valley deposit is the largest known so far in India as investigated by GSI [7], extends over a strike distance of 7kms.

The earliest mention of this deposit is found in the writings of European workers as early as 1563. The borax trade from this region continued uninterrupted till late 19th century [6] when the area lost prominence due to transportation difficulties and due to new sizeable finds in USA, USSR, and Turkey.

Preliminary exploration has been carried out by GSI in this region during 1970s and GSI has reported some resources. Perhaps afterward no one has carried out exploration for borax in this area and of course on a commercial scale. Exploration technology has changed significantly since last three decades. Implying latest technology, this area can be explored in a much better way now and more resources can be discovered. And this perhaps, will result in mining of borates commercially from this region and it will have impact on import of borates in India. High cost is involved in importing of borates to meet domestic need.
B. Geology:

Geologically, the Puga region is divisible into three distinct NW-SE trending belts, each separated from the other by major tectonic features (Fig 2) [8] – [9]. Northern tectonic belt comprises of sedimentary rocks belonging to Indus group and lie unconformably over the Ladakh Granites. The central belt, known as the ‘Indus Suture Zone’ is characterized by a large thickness of basic, ultrabasic and sedimentary rocks belonging to Sumdo group. This belt is bounded by the Mahe fault in the north and Zildat fault in the south.
The southern belt consists of thick succession of sedimentaries, metasedimentaries and metamorphics with intruded granites. The general direction of tectonic transport and intensity of metamorphism increases from north to south as a result of which rocks exposed in the southern belt are highly deformed and exhibit medium to high grade metamorphism.

The Puga Valley is part of the central tectonic belt, characterized by the volcanic sedimentary assemblages of rock type belonging to the Sumdo group, bounded by prominent faults. These faults act as a conduit for transportation of the hot water from deeper levels [8]. The Puga valley is covered by the recent and sub-recent deposits such as glacial moraines, eolian sand and scree, which are encrusted with borax, sulphur and other hotpring deposits [10].

This loose valley-fill material extends to subsurface up to 15–65 m depth. Thereafter, the hard re-consolidated breccia lies and extends up to the depth of the basement. The basement rock consists of paragneisses and schists and known as Puga Formation probably belonging to Palaeozoic age [11] – [12].

Geothermal springs form surface encrustation style borax deposits which are located on either side of a zone of granitoids and ophiolites within the Indus Suture Zone. The borax deposits of Puga are associated with volcano sedimentary assemblages of Tertiary age. Puga Valley deposits occur over an area of about 7km long and 1km wide. The valley floor is covered by recent silts and clays, with thin borax and sulphur encrustations and fault breccia; whereas on the valley sides there is a thick cover of scree [7].

C. Mineralization and Resource:
The borax deposit of Puga Valley comprises mainly Kernite with chlorides and sulphates of sodium and potassium. Other borax minerals reported from the area are Ulexite and Colemanite. The Kernite mineralization is found in both crystalline and amorphous state and is associated with lacustrine and silty clays. The encrustation thickness varies from 3 to 25mm but is thought to average only 3mm [7], [13].

The genesis and replenishment of the borax mineralization are related to the geothermal activity in the area. The tourmaline bearing granitoids of the area might also contribute to the borax source. The hot springs water shows high concentration of $\text{B}_2\text{O}_3$ content as high as 1300ppm. The average replenishment of borax in the area is 0.261 tonnes/100 sq. m per year [13]. While this tonnage computes to potential for some 5000t/yr (over a 2km$^2$ areas) which represents ~5% of Indian imports, the thin and likely irregular encrustation nature of the deposits means it is not amenable for large scale mining. The estimated total resource (GSI, 2005) is very small, being less than 100Kt (see Table 1 below) [4]. So there is a need to explore this area in detail to prove a minable resource. Detail exploration and investigation probably can add more resources and reserves.

III. ECONOMIC SIGNIFICANCE OF BORATES IN INDIAN CONTEXT

Borax is not produced in India presently. The domestic requirements of boron minerals are met solely through imports of crude borate which is refined in the country for producing borax and boric acid [4]. The demand of borax in Indian market is increasing day by day. India imports borax at high cost to fulfil the needs, especially for its extensive use in nuclear industry, military, atomic, chemical, agricultural and domestic industries. The entire domestic requirements of boron minerals are met solely through imports of crude borate, which is refined in the country for producing borax and boric acid. The country imported annually 95,047 tonnes approximately in 2012-13 of borax for internal consumption. Imports of boric acid are around 12,841 tonnes in 2012-13 [4].

The consumption of borax in the organised sector was at 22,800 tonnes in 2012-13 [4]. Chemical and glass industries were the major consumers accounting for about 93% borax consumption. Consumption of borates is increased in 2013 and further expected to increase in the coming years, spurred by demand in the Asian and South American agricultural, ceramic, and glass markets. World consumption of borates was projected to reach 2.0Mt of $\text{B}_2\text{O}_3$ by 2014, compared with 1.5Mt of $\text{B}_2\text{O}_3$ in 2010 [14]. Demand for borates was also expected to shift slightly away from detergents and soaps toward glass and ceramics.

Here, an attempt has been made to understand and depict comparative analysis of the major borate deposits of the world in relation to reserves, grade, mineralogy and geological setting. It is shown in the Table 1. The data from the table clearly suggest that majority of the reserves are located in USA and Turkey and production is governed by American and Turkish producers. Overall they fulfil the supply and demand of borates production globally.

<table>
<thead>
<tr>
<th>Deposit</th>
<th>Reserves (Mt) with ref (year)</th>
<th>Grade% ($\text{B}_2\text{O}_3$)</th>
<th>Mineralogy</th>
<th>Geological setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boron, California (CA), USA</td>
<td>140 (1991)</td>
<td>Borax, kernite</td>
<td></td>
<td>Tertiary sequence consist of continental sediment and volcanics</td>
</tr>
<tr>
<td>Death Valley, CA, USA</td>
<td>16 deposits range from 0.181 - 13.6</td>
<td>18 – 24</td>
<td>Ulexite, colemanite</td>
<td>Tertiary continental sediment.</td>
</tr>
<tr>
<td>Searles lake, CA, USA</td>
<td>40 (1991)</td>
<td>1.2 Na borates – borax</td>
<td></td>
<td>Playa sediments of Quaternary</td>
</tr>
</tbody>
</table>
Pros and Cons associated with Puga Valley from exploration and mining perspective

### A. Pros:
- The geological set up and environment in Puga is favourable for the genesis of borate deposits.
- Presence of mineralization in the form of kernite is good as it contains high B_2O_3 content. GSI reports 44% kernite in some of the crude borax. These signatures are good to go for further exploration.
- Locally available geothermal energy is available for extraction and refinement of borates. It can save cost in processing of borates.
- Area is known to be safe for working.

### B. Cons:
- Inferring resources 0.074 Mt (2005) of reconnaissance category by GSI is tiny, when compared with other deposits of the world (refer Table 1). Deposits are very thin (only mm scale) reported so far.
- Puga area has been explored to some extent with partial success for borates by GSI in 1970’s; the study also included potential settings in the range beyond Puga.
- The Puga borax deposit is located in high altitude area. Accessibility is not so easy.
- Climate conditions are harsh and extreme. The working season is very limited, only approximately four to six months out of a year.
- The area is also under surveillance of defence ministry, being close to the international border with China.

### V. FUTURE OUTLOOK
The future outlook and demand for borax appears positive. Increase in usages of ceramic tiles will keep consumption of boron minerals high [4]. Demand as a fertilizer will also remain high and consumption in fibre glass industry may also rise. Asian nations are deriving the consumption growth rapidly.

### VI. CONCLUSION
The comparison analysis in the Table 1 above clearly suggests that the grade is available in Puga but the tonnage is very limited based on the early exploratory history.
- Given the exploration done by GSI, it is unlikely that a world class deposit could exist.
- But certainly the area deserve for further exploration given the type of mineralization and grade.
- Strategically it can support Asian market trade.
- India is totally dependent on import of borates to meet domestic need and if Puga put on production scale, it can nourish India’s demand to some extent.
- Mining of borates commercially in India will have impact on import, relatively cost-effective.

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### REFERENCES
http://www.portal.gsi.gov.in/portal/page?_pageid=108,721676&_dad=portal&_schema=PORTAL