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BORON MINERALS

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GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES

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4 Boron Minerals

Boron minerals occur mostly as borates which are deposited from volcanic gases or hot springs near volcanic activities. The deposits, predominantly of borax and sassolite are formed as a result of drying up of shallow saline and alkaline tertiary lakes called 'Playa'. The principal boron minerals are borax–hydrated sodium borate ($Na_2O.2B_2O_3.10H_2O$), kernite (rasorite)–hydrated sodium borate ($Na_2O.2B_2O_3.4H_2O$), colemanite– hydrated calcium borate ($Ca_2B_6O_{11}.5H_2O$) and ulexite–hydrated sodium calcium borate ($NaCaB_5O_9.8H_2O$). Besides the above four boron minerals of commercial importance, two minerals, viz., sassolite (H_3BO_3)–the natural boric acid and boracite ($Mg_3B_7O_{13}Cl$) are less important.

Borax is, presently, not produced in India. However, it was obtained since ancient times from the lakes in Jammu & Kashmir in India. 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.

RESERVES/RESOURCES

Economically viable deposits of borax have not been established in the country so far. The only deposit of little economic significance is reported from Puga Valley in Leh district, Jammu & Kashmir. As per NMI data, based on UNFC system, the total reserves/resources of borax as on 1.4.2015, has been estimated at 74,204 tonnes in Jammu & Kashmir. All resources are of Reconnaissance category viz., UNFC Code 334. Occurrences are also reported from Surendranagar district, Gujarat and Jaipur district, Rajasthan (Table-1).

USES

Glass and porcelain industries are the major consumers of borax and boric acid. It is an essential component of heat-resisting boro-silicate glass, glass fibres and industrial & optical glass. In glass, enamels and ceramics, it controls thermal expansion, improves durability, assists melting processes and adds to inorganic colours and decorations.

Borax is used in medicine (boric powder), leather processing, adhesive, corrosion inhibition, ferrous wire manufacture, flame-proofing and timber preservation.

Borax is used as a flux in brazing, welding, soldering and in the manufacture of artificial gems like, cubic boron nitride, (commercially called 'Borazon') which is equal to diamond in hardness and boron carbide, titanium boride and tungsten boride which are next to diamond in hardness.

Its easy solubility and property to soften hard water find applications in soaps, cleaners & detergents and for water treatment. Its mild alkalinity and germicidal nature, enable its use in manufacturing toothpastes and mouth washes. Borax is used as an antiseptic and emulsifying agent in Cosmetics Industry. As a decolourising agent, it is used in Vanaspati Industry. In Textile Industry, borax is used as a decolourising agent as well as for maintaining the alkalinity of solutions used for producing rayons. It prevents mould formation in citrus fruits. In agriculture, borax is used as an essential plant nutrient.

Boron compounds are used for fertilizers, algicides, herbicides and insecticides. Borax and boric acid are used in fire-retardant treatment and as food grain preservative, respectively.

Borate ester is used as dehydrating agent, special solvent and catalyst in Chemical Industry. In nuclear reactor, boron acts as neutron absorber. "Boron neutron capture therapy", a form of radiochemotherapy, is becoming increasingly important for treatment of certain forms of cancers and boron neutron capture synovectomy for treatment of arthritis.

Borates are consumed mainly in glass fibre for insulations and textile-grade fibre. They are also used as anti-knock agents in gasoline. Diborane (gas), pentaborane (liquid) and decaborane (solid) are potential jet and rocket engine fuels. Boron hydride also has potential value as rocket fuel. The high

Table – 1 : Reserves/Resources of Borax as on 1.4.2015
(By Grades/States)

(In tonnes)

Grade/State	Reserves	Remaining Resources						Total Resources (A+B)
	Total (A)	Pre-feasibility STD221	Measured STD331	Indicated STD332	Inferred STD333	Reconnaissance STD334	Total (B)	
All India : Total	**-**	**-**	**-**	**-**	**-**	**74204**	**74204**	**74204**
By Grades								
Unclassified	-	-	-	-	-	74204	74204	74204
By States								
Jammu & Kashmir	-	-	-	-	-	74204	74204	74204

Figures rounded off.

energy fuel value imparted by the addition of boron compounds has given considerable strategic significance to borates. Another use of borates is the invention of oxgano-sodium borate (liquibor) for use in hydraulic brake fluids.

Boron is an essential plant nutrient and boron compounds, such as, borax and boric acid are used as fertilizers in agriculture, although they are only required in small amounts, with excess being toxic.

SUBSTITUTES

Substitutes in applications, such as, soaps, detergents, enamels and insulations are available. In detergents, boron compounds can be replaced with chlorine and enzymes. Lithium compounds can be used to make enamels and glass products. Insulation substitutes include cellulose, foams and mineral wools. Substitution of borosilicate glass by plastic materials may reduce the use of boron.

Sodium percarbonate can replace borates in detergents and requires lower temperatures to undergo hydrolysis, which is an environmental consideration. Some enamels can use other glass-producing substances, such as, phosphates. In soaps, sodium and potassium salts of fatty acids can act as cleaning and emulsifying agents.

TECHNICAL POSSIBILITIES

A proprietary process called 'Hydrogen on Demand' has been developed using water and sodium borohydride. Hydrogen from the system can be used in fuel cells or internal combustion engines. A longer-life battery based on boron has also been designed. Synthetic diamond containing about 3% boron which is normally a semiconductor becomes superconductor at 4 K. Boron-doped diamond, thus, has numerous possible applications as it can carry electricity without resistance.

Improvements made in evaporating brine solutions are widening the choice of source. Production of boric acid through solution mining of colemanite is a possibility.

ENVIRONMENTAL CONCERNS

Natural borates are not very toxic to animals but can be toxic to plants though low levels of boron are essential for plant life. Boron-hydrogen compounds known as boranes which do not occur in nature are highly toxic and have posed problems in some industrial applications. Environmental concerns have hastened substitution in soaps and detergents. In Europe, borates continue to be listed under hazardous substances and the risk evaluated for their safety under conditions of normal handling and use related to classification and labelling already exists. The US Food and Nutrition Board announced that the essentiality data on boron was adequate to establish a daily tolerable Upper Intake Level for an adult at 20 mg boron.

INDUSTRY

In borax manufacturing process, crude sodium borate is dissolved in water, charged, oxidised, crystallised and centrifuged. Centrifuged material is then dried to get borax decahydrate.

Crude calcium borate lumps are crushed and wet-ground with mother liquor to make slurry. This slurry is decomposed with sulphuric acid to give calcium sulphate and boric acid. Boric acid is separated by filtration, purified, cooled and centrifuged to produce boric acid granules which are powdered as per demand.

Borax Morarji Ltd, Ambernath, Thane district, Maharashtra, is engaged in refining of imported crude borates to produce borax and boric acid. The annual production capacity for all grades of borax and boric acid are 24,000 MT at Dahej, GIDC in the State of Gujarat. Apart from two other producers, National Peroxide Limited (NPL) located at Kalyan district, Maharashtra, is the largest producer of Hydrogen Peroxide in the country.

During the year, the Company completed the expansion of its plant situated at Kalyan which resulted in an increase in the plant rated capacity from 95,000 MT per annum to 1,50,000 MT per annum based on 50% (w/w) Hydrogen Peroxide levels.

NPL is a pioneer in Hydrogen Peroxide Industry in India and has been at the forefront in development of technology, brand image and market share in the country. Indo Borax and Chemical Limited operates borax and boric acid plants at Pithampur, Madhya Pradesh.

Ferroboron is a boron ferroalloy containing 0.2% to 24% boron used primarily to introduce small quantities of boron into speciality steels.

WORLD REVIEW

The world reserves of boron in terms of boric oxide are furnished in Table-2.

Turkey was the leading producer of borates followed by USA, Kazakhstan, Chile, China and Bolivia (Table-3).

To provide a generalised view of the development in various countries, the contrywise description sourced from latest available publication of Minerals Yearbook 'USGS' 2017 has been furnished as below.

Table – 2 : World Reserves of Boron (By Principal Countries)

(In '000 tonnes of boric oxide)

Country	Reserves
World: Total[1]	**xx**
Argentina, crude ore	NA
Bolivia, ulexite	NA
Chile, ulexite	35000
China, boric oxide equivalent	24000
Germany, compounds	NA
Peru, crude borates	4000
Russia, datolite ore	40000
Turkey, refined borates	1100000
Kazakhstan, unspecified	NA
USA	40000

***Source**: USGS, Mineral Commodity Summaries, 2021.*
1 World totals could not be calculated because production and reserves are not reported in a consistent manner by all countries.
xx*: Not applicable*

Table – 3 : World Production of Borates (By Principal Countries)

(In metric tonnes)

Country	2017	2018	2019
Turkey	2494627	3970486	4000000
USA[a]	1300000	1300000	1300000
Kazakhstan	500000	500000	500000
Chile	607076	398411	352255
China[b]	70000	75000	250000
Bolivia	223515	232268	214500*
Peru	-	100552	111108
Argentina	129918	71212	80000*
Russia*	75000	80000	80000
Iran[c]	1150	1200	1200*

***Source:** BGS, World Mineral Production, 2015-19,*
a: Soblor used by producers, b: B_2O_3 equivalent.
**: Estimate, a: Sold or used by producers, b:B_2O_3 equivalent, c: Years ended 20 March following that stated.*

Turkey

The first known instances of borate mining in Turkey date to Roman times, with borate mining continuing to this day. Approximately 73% of the world's boron reserves are in Turkey, with the Kirka deposit at Eskisehir reported to be the largest tincal deposit in the world. The main borate-producing areas of Turkey, all controlled by the state-owned mining company Eti Maden AS, were Bigadic (colemanite and ulexite), Emet (colemanite), Kestelek (colemanite, probertite, and ulexite) and Kirka (tincal). Production of refined borates has increased since 2008 owing to continued investment in new refineries and technologies. A recent examination of plant species in boron-rich areas of Turkey revealed a number of indicator plants, which may be used for boron prospecting in Turkey or in similar biome areas elsewhere in the world. Eti Maden projected a borate production capacity of 5.5 Mt with an anticipated sales income of $2.5 billion by 2023.

Argentina

Argentina was the third-ranked producer of boron minerals in South America in 2017. Borate deposits are located primarily in the Puna region, which includes the northwestern tip of Argentina, the southeastern corner of Peru, the southwestern corner of Bolivia, and the northeastern border of Chile. The principal markets for borates produced in Argentina were in Brazil and, to a lesser degree, domestic consumers.

Borax Argentina S.A. (a subsidiary of Orocobre Ltd), the country's leading producer of borates, operated the Tincalayu Mine, the largest open pit operation in the country, which is 4,100 m (13,500 feet) above sea level. The deposit consisted primarily of borax, with rare occurrences of ulexite and 15 other borates. Borate production in 2017 was estimated to be 39,000 tonnes.

Minera Santa Rita S.R.L. (MSR) operated mines in Catamarca, Jujuy, and Salta Provinces and operated a processing plant in Campo Quijano, which produced granular deca- and pentahydrate borax, technical-grade boric acid powder, and various grades and sizes of natural boron minerals. MSR exported the majority of its mined borates to 28 countries through the Port of Buenos Aires and by land to Brazil.

Chile

The largest ulexite deposit in the world, Salar de Surire, was operated by Quiborax SA, a Government entity with reserves estimated to be 1.5 million tonnes (Mt). Chile was also the leading borate-compound producer in South America with production of 36,000 tonnes of boric acid in addition to 1,00,000 tonnes of borate-derived agrochemical products.

China

China has low-grade boron resources and since the demand for boron was expected to increase in China, imports from Chile, Russia, Turkey, and the United States were also expected to increase during the next several years. More than 100 borate deposits are found to occur in 14 Provinces in China. The northeastern Province of Liaoning and the western Province of Qinghai accounted for more than 80% of the resources, mostly in the form of sassolite and tincal. China's boron resources average about 8% B_2O_3 as opposed to the reserves from Turkey and the United States that average from 26% to 31% and 25% to 32% B_2O_3 respectively.

Serbia

Erin Ventures Inc. (Canada), initiated proceedings to begin borate mining in Piskanja, a mining region in Serbia approximately 250 km (155 miles) south of Belgrade. The deposit is primarily composed of colemanite and ulexite with estimated reserves of 11.8 Mt. Exploration began in early 2016 with two drill holes that indicated B_2O_3 content between 22% and 35% (Erin Ventures Inc., 2016). In 2017, Erin Ventures began the next phase of exploration with four drill holes to assess potential mineral body propagation.

FOREIGN TRADE

Exports

Exports of borax (total) increased considerably by 26% to 2,983 tonnes in 2019-20 from 2,360 tonnes in the previous year. Exports of natural borate in 2019-20 increased substantially to 214 tonnes from 105 tonnes in the previous year. In 2019-20, exports of sodium borate were at 775 tonnes and other borates at 1,994 tonnes. Exports of Borax (total) were mainly to USA (32%), Italy (11%), Nepal (9%), Poland (8%), Argentina (7%) and Syria (5%). Exports of boric acid increased by 15% to 1,525 tonnes in 2019-20 from 1,321 tonnes in the previous year. Exports were mainly to Nigeria (14%), Bangladesh (12%), Iran (11%), Nepal (8%) (Tables-4 to 9).

Imports

Unlke exports, imports of borax (total) decreased slightly by 3% to 1,76,421 tonnes in 2019-20 from 1,81,628 tonnes in the previous year. Imports of natural borate also decreased slightly by 1% to 84,699 tonnes as compared to 85,217 tonnes in the previous year. In 2019-20, imports of sodium borate were at 81,530 tonnes and other borates 10,192 tonnes. Borax (total) was mainly imported from Turkey (64%), USA (21%), Spain and Bolivia (5% each). Imports of boric acid decreased by 26% to 4,826 tonnes in 2019-20 from 6,535 tonnes in the previous year. Boric acid was imported mainly from Turkey (49%), Singapore (27%) , USA (11%) and Peru (9%). Import of boron was negligible in both current and the previous year (Tables-10 to 15).

Table – 4 : Exports of Boron (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**++**	**1971**	**++**	**92**
USA	++	1894	++	29
UK	++	27	++	25
Bangladesh	-	-	++	25
Portugal	-	-	++	12
Singapore	++	49	-	-
China	++	1	-	-

Figures rounded off

Table – 5 : Exports of Borax (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**2360**	**238104**	**2983**	**359857**
USA	505	95100	940	175741
Italy	158	23177	315	41462
Poland	40	5974	240	30818
Bangladesh	137	13829	154	18372
Nepal	179	8193	274	11734
Australia	40	9440	64	10862
Oman	20	4587	45	9774
Syria	24	1175	156	6813
Argentina	47	1503	210	6526
South Africa	1	582	37	6189
Other countries	1209	74543	547	41568

Figures rounded off

Table – 6 : Exports of Natural Borate (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**105**	**1887**	**214**	**6804**
Argentina	47	1503	210	6526
Kuwait	-	-	4	272
USA	-	-	++	5
Egypt	-	-	++	1
Saudi Arabia	-	-	++	1
Kenya	-	-	++	1
Nepal	4	344	-	-
Bangladesh	54	35	-	-
UK	++	5	-	-

Figures rounded off

Table – 7 : Exports of Sodium Borate (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**1243**	**61645**	**775**	**54233**
USA	15	5195	25	17353
Nepal	154	6505	251	9872
Thailand	100	4586	100	4579
Myanmar	88	3736	88	3669
Nigeria	3	125	42	2910
Canada	++	56	8	2860
Cameroon	5	253	33	2051
Bangladesh	2	172	61	1855
UAE	75	2592	48	1687
Australia	-	-	24	1182
Other countries	800	38424	95	6214

Figures rounded off

Table – 8 : Exports of Borax: Other Borates (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**1012**	**174572**	**1994**	298820
USA	490	89905	915	158383
Italy	158	23177	315	41462
Poland	40	5974	240	30818
Bangladesh	81	13622	93	16517
Oman	19	4082	45	9771
Australia	40	9440	40	9680
Syria	24	1175	156	6813
South Africa	1	582	37	6189
Saudi Arabia	3	652	16	2848
UAE	45	6868	29	2677
Other countries	111	19096	107	13663

Figures rounded off

Table – 9 : Exports of Boric Acid (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**1321**	**107106**	**1525**	121969
Nigeria	160	14345	218	17901
USA	93	12459	67	11857
Nepal	105	7775	129	9909
Bangladesh	110	5389	189	8740
Iran	-	-	168	8577
Kenya	36	2766	88	6980
Bhutan	52	4019	74	5025
Angola	19	1516	54	4688
Tanzania	4	333	58	4425
Sri Lanka	14	1464	52	4309
Other countries	729	57041	427	39558

Figures rounded off

Table – 10 : Imports of Borax (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**181628**	**5886239**	**176421**	**5644323**
Turkey	116714	3475577	112539	3295226
USA	34085	1254940	37463	1336547
Spain	11144	446621	8521	308061
China	1439	143482	1519	170647
Bolivia	9742	158750	9434	143418
UK	544	45348	682	132379
Argentina	2303	106053	2045	62675
Singapore	1082	41335	1663	59882
Austria	262	20191	424	34950
Malaysia	3260	112745	920	30176
Other countries	1053	81198	1212	70362

Figures rounded off

Table – 11 : Imports of Natural Borate (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**85217**	**2206203**	**84699**	**2157325**
Turkey	66306	1713644	65016	1672501
Spain	8829	323353	8328	295846
Bolivia	9742	158750	9434	143418
Argentina	198	5868	1160	29936
Chile	142	4560	684	10171
USA	++	16	37	3330
Oman	-	-	13	1420
Peru	-	-	28	692
China	-	-	++	7
Guinea	-	-	++	4
Other countries	++	13	-	-

Figures rounded off

Table – 12 : Imports of Borax: Sodium Borates (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**86687**	**3101908**	**81530**	**2776163**
Turkey	45318	1561371	42985	1427883
USA	32502	1170215	35851	1236246
Malaysia	3114	106431	920	30176
Argentina	1273	39564	780	23678
UK	454	15736	355	13003
Netherlands	138	15559	108	12369
Spain	2315	123257	189	10183
Singapore	1080	40619	216	6784
Germany	17	5226	4	6300
China	105	6671	56	4305
Other countries	372	17260	67	5236

Figures rounded off

Table – 13 : Imports of Borax: Other Borates (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**9723**	**578128**	**10192**	**710835**
Turkey	5090	200562	4538	194842
China	1334	136811	1463	166335
UK	90	29613	326	119377
USA	1583	84709	1576	96970
Singapore	2	715	1447	53098
Austria	262	20191	424	34950
Peru	194	15912	140	10142
Argentina	832	60621	105	9061
Slovenia	114	6131	114	6463
Australia	++	3202	1	4122
Other countries	222	19660	58	15475

Figures rounded off

Table – 14 : Imports of Boric Acid (By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**6535**	**284859**	**4826**	**210516**
Turkey	3151	139033	2344	101845
Singapore	735	32140	1281	55425
USA	2313	96156	513	21678
Peru	203	8211	421	17668
Indonesia	-	-	210	9424
China	100	6802	50	3363
Germany	12	1207	5	877
Japan	++	7	1	111
Italy	-	-	1	108
UK	++	3	++	12
Other countries	21	1299	++	6

Figures rounded off

Table – 15 : Imports of Boron
(By Countries)

Country	2018-19 (R)		2019-20 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**++**	**3315**	**++**	**2192**
USA	++	182	++	1061
Canada	++	940	++	502
Germany	++	95	++	337
Belgium	++	301	++	162
UK	++	267	++	131
China	++	1513	-	-
Japan	++	19	-	-

Figures rounded off

FUTURE OUTLOOK

Consumption of borates is expected to increase, spurred by strong demand in agriculture, ceramic and glass markets in Asia and South America. Continued investment in new refines and technologies and the continued increase in demand were expected to fuel growth in world production for the foreseeable future. In 2013, the European Union (EU) added borates to the Registration, Evaluation, Authorisation and Restrictions of Chemicals (REACH) Restricted Substances List, following an EU study that determined continuous exposure to humans may be harmful. The ruling required detergent makers to decrease their use of boron (Lismore, 2012). Consumption of boron-based fertilizers is expected to increase as the demand for food and biofuel cropsis on the rise. Higher crop prices have enabled farmers to invest in advanced farming techniques and higher grade fertilizers.

Consumption of boron nitride is expected to increase owing to the development of high-volume production techniques coupled with the creation of new technologies requiring boron nitride. The properties intrinsic to cubic boron nitride, such as, hardness (second only to diamond), high thermal conductivity, and oxidation resistance, make it an ideal material for a variety of emerging applications. Hexagonal boron nitride is used in producing ceramics, creating intermetallic composites, imparting thermal shock resistance, improving machinability and reducing friction.