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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 1.4.2020, 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 1.4.2020 (P)
(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).

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

(In '000 tonnes of boric oxide)

Country	Reserves
World:Total[1]	**xx**
Turkey, refined borates	1200000
Russia, datolite ore	40000
USA	40000
Chile, ulexite	35000
China, boric oxide equivalent	21000
Peru, crude borates	4000
Argentina, crude ore	NA
Bolivia, ulexite	NA
Germany, compounds	NA

***Source**: USGS, Mineral Commodity Summaries, 2023.*
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	2019	2020	2021
Turkey	8555690	2819111	4057299
USA[a]	1300000	1300000	1300000
Kazakhstan	500000	500000	500000
China[b]	250000	380000	380000
Chile	352255	288103	363032
Bolivia	214500*	258143	312906
Peru	111108	43645	246362
Argentina	181818	134604	130000
Russia*	80000	80000	80000
Iran[c]	2519	1300	1300

***Source:** BGS, World Mineral Production, 2017-21,*
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.*

To provide a generalised view of the development in various countries, the contrywise description sourced from latest available publication of Minerals Yearbook 'USGS' 2018 has been furnished as below.

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). Eti Maden opened warehouses and logistic centers with a company based in Hong Kong to distribute their products from a location closer to the majority of their customer base. Production of refined borates was expected to increase over the coming years owing to investment in new refineries and technologies. Eti Maden continued to invest in the production of boron carbide, boron nitride, and ferroboron owing to their importance in many industries, including the electronics, iron and steel industries. In 2018, Eti Maden and China's Dalian Jinma Boron Technology Group Co., Ltd signed a Memorandum of Understanding to build a boron carbide processing facility in Balikesir. Although this facility will process mostly boron carbide, boron nitride and ferroboron were also projected to be processed. As a result of boron carbide's numerous uses in the defense industry, it was expected to become a significant export for Turkey.

Argentina

Argentina was estimated to be the second-ranked producer of boron minerals in South America in 2018. 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 throughout South America Borax Argentina S.A. (a subsidiary of Orocobre Ltd.), the country's leading producer of borates, operated the Tincalayu and Sijes Mines, the largest open pit operations in the country, which are 4,100 m (13,500 feet) and 4,540 m (14,900 feet) above sea level, respectively. Record-high production was reported at Borax Argentina's boric acid plant and Tincalayu open pit operation. Tincalayu deposits consisted primarily of borax, with rare occurrences of ulexite and 15 other borates with a reported production of 36,553 tonnes in 2018. Orocobre was reviewing an expansion study for their Tincalayu operation. The expansion could possibly increase Tincalayu's refined-borate-processing capacity from 30,000 metric tonnes per year (tonnes/year) to approximately 120,000 tonnes/year of borax dehydrated equivalent.

The expansion review also includes a boric acid plant with a capacity of 40,000 tonnes/year. A project to build a gas pipeline to supply the expanded plant was approved in early 2018. 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

Chile was the leading borate compound producer in South America with boric acid production estimated to be 100,000 tonnes and ulexite production estimated to be 600,000 tonnes in 2018. The largest ulexite deposit in the world, Salar de Suirire, was operated by Quiborax SA, a Government entity with reserves estimated to be 1.5 million metric tonnes (Mt). Almost all the material mined at this location was exported in 2018. Quiborax operations have a boric acid production capacity of 36,000 tonnes/year, in addition to 100,000 tonnes/year capacity of borate derived agrochemical products. In May 2018, the 14-year-long dispute between the Bolivian Government and Quiborax came to an end with a ruling in favor of Quiborax. The Bolivian Government must now pay Quiborax $ 48.6 million for the land seized in 2004 that was used for the company's ulexite mining and revoked mining concessions.

China

China has low-grade boron resources. More than 100 borate deposits 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 in comparison with reserves from Turkey and the United States, which average from 26% to 31% and 25% to 32% B_2O_3, respectively.

Serbia

Erin Ventures Inc. (Canada) entered into a strategic partnership with a London-based commodity investment company, acquiring funds needed to continue development of the Piskanja Borate Project. Piskanja is 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 Million tonnes. Rio Tinto continued a prefeasibility study in Jadar Valley, in 2018. The deposit contains both boron and lithium ore. Rio Tinto was planning to conduct assessments that will consider the socioeconomic effects of constructing a mine and processing facility on the local communities, in conjunction with environmental assessments.

FOREIGN TRADE

Exports

Exports of borax (total) increased considerably by 57% to 4725 tonnes in 2021-22 from 2996 tonnes in the previous year. Exports of natural borate in 2021-22 decreased substantially to 44 tonnes from 55 tonnes in the previous year. In 2021-22, exports of sodium borate were at 1534 tonnes and other borates at 3147 tonnes. Exports of Borax (total) were mainly to USA (37%), Italy (12%) and Nepal (8%). Exports of boric acid decreased by 29% to 1384 tonnes in 2021-22 from 1952 tonnes in the previous year. Exports of boric acid were mainly to Nigeria (23%), Nepal (12%) and USA (5%) (Tables- 4 to 9).

Imports

Imports of borax (total) increased slightly by 15% to 223368 tonnes in 2021-22 from 194448 tonnes in the previous year. Imports of natural borate also increased by 21% to 101337 tonnes as compared to 83207 tonnes in the previous year. In 2021-22, imports of sodium borate were at 111210 tonnes and other borates 10821 tonnes. Borax (total) was mainly imported from Turkey (60%), USA (21%), Bolivia (10%), Spain (3%) and China (4%). Imports of boric acid increased to 7412 tonnes in 2021-22 from 6897 tonnes in the previous year. Boric acid was imported mainly from Turkey (61%), Singapore (37%) and China (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	2020-21 (R)		2021-22 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**5**	**525**	**++**	**6093**
USA	++	117	++	5749
Australia	-	-	++	265
Austria	-	-	++	48
Korea Rep of	-	-	++	27
Nigeria	-	-	++	4
Turkey	-	-	++	++
Nepal	5	198	-	-
Sudan	++	131	-	-
UK	++	51	-	-
France	++	20	-	-
Other Countries	++	8	-	-

Figures rounded off

Table – 5 : Exports of Borax
(By Countries)

Country	2020-21 (R)		2021-22 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**2996**	**414601**	**4725**	**656472**
USA	1391	263087	1775	364542
Italy	304	36116	607	86073
Poland	140	17212	209	32208
Bangladesh	74	15598	255	27515
Nepal	187	9063	404	24618
Spain	-	-	140	20941
Malaysia	75	3524	360	14730
UAE	81	7070	127	12382
Australia	44	5355	144	12347
Saudi Arabia	58	4009	202	10209
Other Countries	642	53567	502	50907

Figures rounded off

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

Country	2020-21 (R)		2021-22 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**55**	**5633**	**44**	**3489**
Nepal	-	-	40	3210
Kuwait	12	753	4	143
USA	-	-	++	71
Bangladesh	-	-	++	61
UAE	2	360	++	4
Oman	27	2417	-	-
Saudi Arabia	14	2073	-	-
Zambia	++	18	-	-
Nigeria	++	12	-	-

Figures rounded off

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

Country	2020-21 (R)		2021-22 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**741**	**56265**	**1534**	**104106**
USA	25	21815	38	22962
Nepal	151	6519	294	16839
Malaysia	75	3509	360	14590
Australia	24	1310	144	12325
Saudi Arabia	44	1936	200	9738
Bangladesh	++	149	113	5863
Thailand	-	-	80	4600
UAE	49	1806	81	3651
Myanmar	88	4016	72	3426
Jordan	22	974	59	3325
Other Countries	263	14231	93	6787

Figures rounded off

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

Country	2020-21 (R)		2021-22 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**2200**	**352703**	**3147**	**548877**
USA	1366	241272	1737	341509
Italy	304	36116	607	86073
Poland	140	17212	209	32208
Bangladesh	74	15449	142	21591
Spain	-	-	140	20941
UAE	30	4904	46	8727
Oman	37	6904	26	6425
Nepal	36	2544	70	4569
Sri Lanka	22	3319	26	4372
South Africa	33	8130	20	3323
Other Countries	158	16853	124	19139

Figures rounded off

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

Country	2020-21 (R)		2021-22 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**1952**	**160749**	**1384**	**176162**
Nigeria	326	27384	319	37474
USA	50	9815	83	18999
Nepal	137	10942	162	18122
Ethiopia	19	2090	74	9286
Kenya	26	3054	70	9018
Bangladesh	16	2768	97	8695
Angola	23	2495	51	6255
Uganda	95	9335	43	5499
Congo D.Rep.	36	3533	39	5318
Tanzania Rep	28	2983	36	4782
Other countries	1196	86350	410	52714

Figures rounded off

Table – 10 : Imports of Borax (By Countries)

Country	2020-21 (R)		2021-22 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**194448**	**6337254**	**223368**	**7973967**
Turkey	111804	3426889	134629	4710621
USA	41604	1520214	47329	1769785
Bolivia	15020	235104	22450	423447
Spain	10461	417300	7293	305636
China	1348	158480	1041	127636
Malaysia	7467	252633	3348	123319
Argentina	3628	105296	2834	105537
Singapore	1898	71848	1697	90054
Peru	280	21552	952	79257
UK	220	45089	227	79096
Other countries	718	82849	1568	159579

Figures rounded off

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

Country	2020-21(R)		2021-22 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**83207**	**2113660**	**101337**	**2910832**
Turkey	54464	1379528	69190	2110887
Bolivia	15020	235104	22450	423447
Spain	10443	411949	7277	300454
Argentina	3280	87005	2356	73037
U S A	-	-	16	1491
Montenegro	-	-	22	752
Chile	-	-	26	739
Japan	++	74	++	25

Figures rounded off

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

Country	2020-21 (R)		2021-22 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**101477**	**3557620**	**111210**	**4188993**
Turkey	52927	1823516	60679	2284456
U S A	39794	1412759	45699	1659784
Malaysia	7392	249124	3348	123319
Netherlands	119	15073	551	41462
China	100	8445	300	28426
Peru	84	6442	224	18944
UAE	15	1271	100	10515
Singapore	719	25498	134	8906
Argentina	216	6727	162	6688
Germany	2	4132	1	4703
Other Countries	109	4633	12	1790

Figures rounded off

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

Country	2020-21 (R)		2021-22 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**9764**	**665974**	**10821**	**874142**
Turkey	4413	223845	4760	315278
U S A	1810	107455	1614	108510
China	1248	150035	741	99210
Singapore	1179	46350	1563	81148
U K	120	41847	227	79096
Peru	196	15110	728	60313
Slovenia	109	9186	356	31902
Argentina	132	11564	316	25812
Italy	23	4320	223	23809
Austria	262	23733	143	13923
Other Countries	272	32529	150	35141

Figures rounded off

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

Country	2020-21 (R)		2021-22 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**6897**	**313194**	**7412**	**378403**
Turkey	5581	251826	4557	228450
Singapore	1028	45874	2747	142600
China	40	2909	69	4941
USA	98	4924	39	1804
France	++	4	++	390
Germany	++	788	++	218
Peru	150	6814	-	-
Japan	++	50	-	-
Malaysia	++	3	-	-
UK	++	2	-	-

Figures rounded off

Table – 15 : Imports of Boron (By Countries)

Country	2020-21 (R)		2021-22 (P)	
	Qty (t)	Value (₹'000)	Qty (t)	Value (₹'000)
All Countries	**++**	**1899**	**++**	**2818**
USA	++	124	++	1449
Germany	++	158	++	997
China	++	591	++	340
UK	++	45	++	30
Belgium	++	131	++	2
Hong Kong	++	850	-	-

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.