Boron Mineral Resources in Korea

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Introduction

The unexpected discovery of kotoite, a boron mineral, at the Suan gold mine by the author during his studies on the geology and ore deposits of that mining district in Hwanghae-do, Korea, brought him also to study the boron mineral resources in various districts. About 1938, the stock of boron ore, which had been imported from the North and South American continents, became insufficient for the requirements of Japan. Moreover, later imports did not go smoothly and the question arose whether boron mineral resources within Japan and Korea might be sufficient for use of that time, pure borax and such crude borates as kernite and natural borax of North America, as well as ulexite from Chile and Argentina, were imported. These ores were of relatively high grade, containing 20–35% B_2O_3.

As the imported ore consisted of minerals which were formed on the surface of arid regions such as in California and the Andes, it was evident that similar ore could hardly be found in Japan, Korea or Manchuria. For this reason, even though the ore was not of very high grade, all boron minerals containing any amount of B_2O_3 became the subject of discussion. That is, all localities where tourmaline, danburite, ludwigite, kotoite or szaibelyite occur were investigated. At the same time, new methods of manufacturing borax and boric acid from these minerals were also studied. The manuscript of this report was completed in 1944.

Brief descriptions of the geology and ore deposits of some localities which came to the front at that time are given here. Detailed descriptions of kotoite were published in other paper (WATANABE, 1967).

The author wishes to express his gratitude to the late Professor Takeo Kato, and to Messrs. Iwao Tateiwa, Rokuro Endo and Chuzo Kondo, for their great help and guidance.

1. Boron Minerals and their Uses

More than fifty kinds of natural minerals containing boron are known, but only about ten have been used in the manufacture of boric acid and borax.

Table 1

Important mineral		B_2O_3 (%)	Chief producer
Sassolite	$B(OH)_3$	56.4	Italy
Borax	$Na_2B_4O_7 \cdot 10H_2O$	36.5	U.S.A.
Kernite	$Na_2B_4O_7 \cdot 4H_2O$	51.0	U.S.A. (California)
Colemanite	$Ca_2B_6O_{11} \cdot 5H_2O$	50.8	U.S.A.
Boracite	$Mg_3B_7O_{13}Cl$	62.2	Germany
Hydroboracite	$CaMgB_6O_{11} \cdot 6H_2O$	50.5	U.S.S.R.
Inderite	$Mg_2B_6O_{11} \cdot 15H_2O$	37.3	U.S.S.R.
Szaibelyite	$MgHBO_3$	40–43	U.S.S.R.
Priceite	$Ca_5B_{12}O_{23} \cdot 9H_2O$	49	Turkey

About 1940, the world output of crude ores for manufacturing borax and boric acid had reached 300,000 tons a year, with North America supplying 80 to 90% and the remainder coming from South America (Argentina, Peru and Chile). Ores from North America consist principally of kernite and natural borax, which occur as stratified deposits in the arid regions of California, Nevada and Oregon. This ore can be easily treated, as it consists of borax, which is relatively soluble in water, and kernite (20–35% in B_2O_3 content), which is soluble in both brine water and weak acid. Some of this ore was imported by Japan and then exported to Korea after being refined to borax and boric acid. Colemanite had been a principal crude boron mineral ore until about 1927, when kernite was discovered, and is not now mined.

Most boron ores from South America are composed chiefly of ulexinite, which is mined in the neighborhood of dried-up and salt lakes in the desert near the Andes Mountain Range. This was also imported by Japan and greatly utilized.

Turkey was the important producer in Europe, where priceite (or pandermite) was mined. In the U.S.S.R., various boron minerals containing magnesia were mined in the neighborhood of Inder Lake, north of the Caspian Sea. In Italy, boric acid was recovered from hot springs. In Germany, B_2O_3 was recovered as a by-product from boracite (or stassfurtite), which occurs in rock salt, and supplied to satisfy the European demand.

As described above, the boron resources mined at that time were only of such minerals as were readily soluble in water, or were easily treated with weak acid. Insoluble magnesium borates and boron-bearing silicates were not thought of as mineral resources.

Minerals such as borax and other crude borates, which are unstable in humid regions, do not seem to have been formed on a large scale in Japan and Korea, probably because of few arid regions even in past times. Thus, the discovery of ore deposits such as the above was thought to be nearly impossible. As a result, other boron minerals came to be considered, and their modes of occurrence minutely investigated.

Table 2

	1	2	3	4	5	6	7	8	9	10
	Sangnong	Sangnong	Sangnong	Sangnong	Tanch'ŏn	Kinsei	Ilgwang	Ilgwang	Haman	Miryang
SiO_2	36.77	38.54	35.34	36.36	35.94	37.59	31.20	35.08	61.25	35.55
TiO_2	1.03	—	—	—	0.31	0.38	0.51	—	0.12	1.51
Al_2O_3	30.70	23.37	36.04	33.70	34.36	34.20	26.81	26.31	8.69	25.62
Fe_2O_3	0.38	13.93	8.54	7.34	0.41	3.64	15.01	14.37	11.58	0.50
FeO	6.62	—	—	—	7.25	8.65	—	—	—	18.21
MnO	0.10	1.37	—	—	tr.	—	0.51	—	0.15	0.14
CaO	2.34	2.49	1.41	1.60	0.39	0.51	1.97	3.74	4.20	0.80
MgO	7.71	5.90	8.40	6.10	5.76	0.29	2.27	4.29	1.63	4.19
B_2O_3	8.34	8.20	10.40	9.03	9.46	6.76	8.05	7.04	0.2	9.15
K_2O	0.84	} 0.94	—	0.54	0.34	3.74	0.84	} 4.95	0.44	0.08
Na_2O	2.21	}	—	2.44	2.55	1.43	1.95	}	0.60	1.83
H_2O	3.23	3.69	—	2.94	3.02	3.09	2.59	—	3.66	3.38

(1) Magnesium tourmaline (High-grade ore) Sangnong Mine, S. Hamgyŏng; accord. to N. Yamamoto
(2) Magnesium tourmaline (High-grade ore) ibid.; analysed by the Takeda Med. Inc. Co.
(3) Magnesium tourmaline (High-grade ore) Korea (Copper ore from Sangnong?). accord. to Kaneko and others.
(4) Magnesium tourmaline (High-grade ore) ibid.
(5) Magnesium tourmaline (Dravite)(High grade ore) Tanch'ŏn. S. Hamgyŏng; accord. to N. Yamamoto
(6) Iron tourmaline Kinsei Mine. Kangwŏn; accord. to N. Yamamoto
(7) " " Ilgwang Mine. S. Kyŏngsang; accord. to N. Yamamoto
(8) Iron tourmaline ibid.; accord. to S. Nagai
(9) Tourmaline-bearing quartz (Low-grade ore) Haman Mine. S. Kyŏngsang; accord. to N. Yamamoto
(10) Iron tourmaline Miryang, S. Kyŏngsang; accord. to N. Yamamoto

a. Tourmaline

Tourmalines have a very complex chemical composition, and are divided roughly into the following three.

Elbaite	$Na\ (Al,Li)_3\ Al_6\ (BO_3)_3\ Si_6O_{18}\ (OH)_4$
Dravite	$NaMg_3Al_6\ (BO_3)_3\ Si_6O_{18}\ (OH)_4$
Schorlite	$NaFe^{II}{}_3Al_6\ (BO_3)_3\ Si_6O_{18}\ (OH)_4$

The constituents average 32–38% SiO_2, 20–40% Al_2O_3, 9–11% B_2O_3, 0.5–1% F and 2–3% H_2O, and sometimes contain alkali, including Na_2O, Li_2O, K_2O, etc. (0–5%), magnesia (0–14%), and iron oxide (1–20%).

Chemical analyses of tourmalines from Korea are tabulated in Table 2. below:

As is obvious in Table 2, tourmalines from Sangnong and Tanch'ŏn in North Korea are of the magnesian variety, while those from various localities in South Korea are mainly of the ferroan variety.

Tourmalines occur most commonly in acidic igneous rocks as granite, especially in pegmatite, aplite and hypothermal quartz veins or iron deposits, as well as in the neighboring contact metamorphic rocks. The richness in magnesia of tourmaline in North Korea seems to be in some genetic relation to the fact that magnesia-rich rocks, including magnesite, dolomite and magnesian pelitic schists are abundantly distributed all over the northern districts of Korea.

The B_2O_3 content of tourmaline is not high, attaining only about 9%. Tourmaline is a relatively stable mineral, making it difficult to recover B_2O_3. Japan, however, succeeded in making boric acid from this mineral, recovering B_2O_3 by treatment with either HCl or H_2SO_4 after heating at high temperature (800°C), or by heating it together with soda ash. Though the process may increase the production cost, at any rate it succeeded in recovering B_2O_3 on an industrial scale. In this process, it became clear that alkali tourmaline and magnesia tourmaline are more easily decomposable than iron tourmaline, and accordingly their treatment is somewhat easier than the latter. This may have been an important reason why the Sangnong tourmaline was investigated.

b. Kotoite

Kotoite is a magnesium borate having the composition $Mg_3B_2O_6$. It was first discovered in the Holgol (or Hol Kol) deposit of the Suan gold mine, Hwanghae-Do, and it occurs in contact metamorphic rock formed through pneumatolytic action. The B_2O_3 content of kotoite is 36.5%; however, the mineral does not occur singly but always with calcite, forming kotoite-marble, in which case the B_2O_3 content is no greater than 9–12%. Although kotoite is difficult to dissolve in water and in dilute hydrochloric acid, in general, it becomes easily soluble in water when heated together with soda ash, enabling one to separate out the boric acid content. Institute of the Hitachi Manufacturing Co. then established factories at Inch'eon and P'yeongyang, and produced borax using the above method. There ore used, so-called Kotoite, was really rock which may be called "Kotoite-marble".

For further details on the mode of occurrence and properties of kotoite, readers are referred to another report (WATANABE, 1967).

c. Szaibelyite

The mineral is a hydrated magnesium borate, $HMgBO_3$ or $2MgO{\cdot}B_2O_3{\cdot}2H_2O$, containing as much as 40% B_2O_3. It is hardly soluble in water like kotoite and occurs in the contact metamorphic zone in dolomite regions, forming at times massive metasomatic ore bodies. This mineral is also found in Manchuria, near Korea, and other districts, and some occurrences contain a considerable amount of boron, and were actually mined in part. In Korea, it was found in association with ludwigite, but in small amounts.

Some of the rocks with szaibelyite contain 10–15% B_2O_3, and at times, 25% B_2O_3. These ores can be treated, on the whole, similar to kotoite, and may also be treated directly with acids. It is highly possible that the mineral will be found in North Korea in the future.

d. Ludwigite

Ludwigite is a borate mineral having the composition $4MgO{\cdot}Fe_2O_3{\cdot}B_2O_3$, and occurs in pneumatolytically metamorphosed rocks on the contact between dolomite and granite. The ore contains 15–17% B_2O_3, and occurs in association with iron and copper in the deposit. Though it has been found in Namjŏng (Tul mijŏng), Holgol and in the Ŭnsan gold mine, it is small in amount and ore deposits are not large enough to be developed as a of boron in Korea. In Manchuria, ore from Hua-tung-kou and other localities have come to the front sources of boron.

e. Other boron minerals

Although axinite (5% B_2O_3), danburite (28.6% B_2O_3) and datolite (9–11% B_2O_3) are all boron-bearing silicates, little notice was taken of them because of their low boron content and the difficulty involved in treatment. Of them, danburite occurs in abundance at Toroku, in Kyushu, Japan, and was once mined to some extent. In addition, johachidolite, a boron-bearing mineral with fluorine, was found at Sangpa'l-tong, Kilchu-gun, Hamgyŏng-pukto, North Korea, and a mineral called suanite was discovered from Holgol, however, they have no significance as a source of boron.

2. Geology and Ore Deposits

(I) Johachidolite from near Sangp'al-tong

Sangp'al-tong in Changbaeng-myŏn, Kilchu-gun, Hamgyŏng-pukto, is located near the boundary between Hamgyŏng-pukto and Hamgyŏng-namdo. At Sangp'al-tong, nepheline dikes cut the limestone. Recently, a new mineral-bearing boron, named johachidolite, has been discovered in the above dike, but the amount or quality of the ore present has not yet been determined.

(II) Sangnong Mine (Tourmaline)

General view: The Sangnong mine is located near the middle reaches of the

Namdaae-ch'ŏn (river), running through the northeast part of Hamgyŏng-namdo. Gold, copper and cobalt ores had been prospected in this mine for three years prior to 1948, when Keizaburo NAKAMURA, a geologist of the Geological Survey of Korean G.G., found a large amount of tourmaline contained in the country rock of ore deposits in the region. The ore deposit consists of gold-copper-cobalt-bearing quartz veins running nearly parallel to the stratification of tourmaline-bearing schist. The impregnation deposits nearby the veins also contain

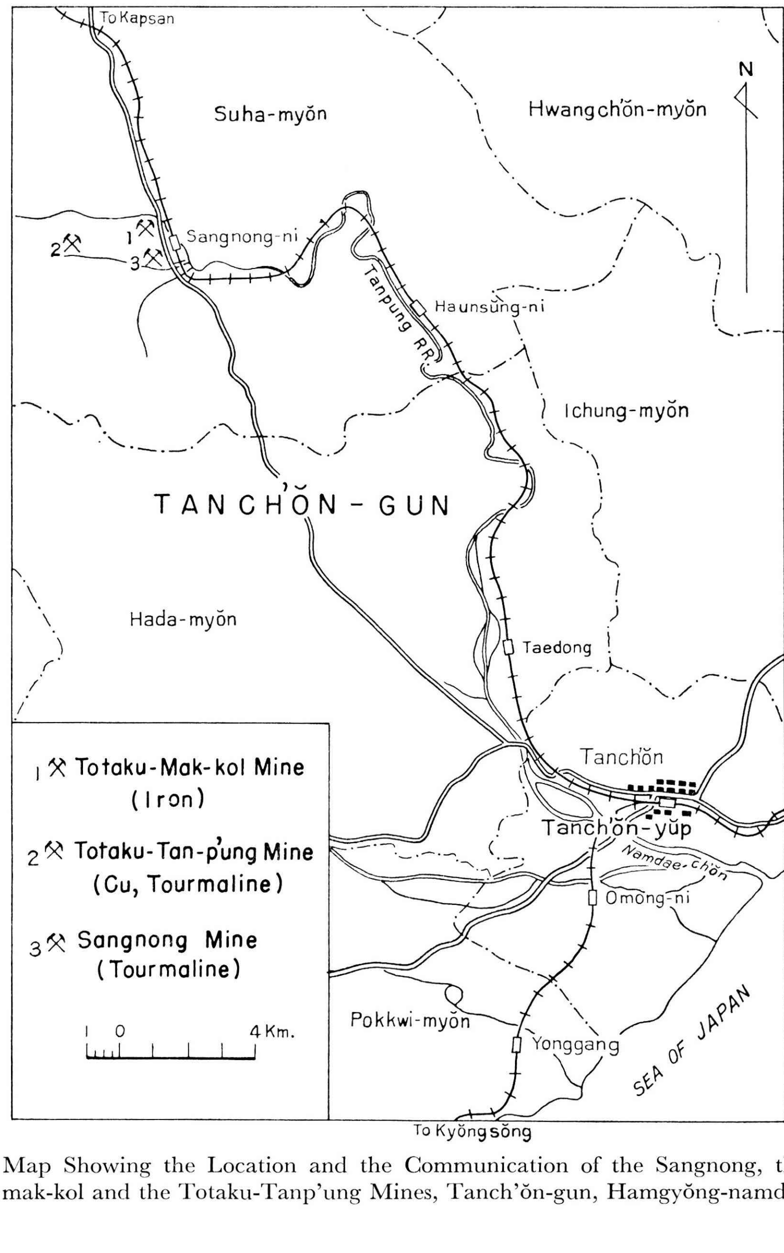

Fig. 1. Map Showing the Location and the Communication of the Sangnong, the Totaku-mak-kol and the Totaku-Tanp'ung Mines, Tanch'ŏn-gun, Hamgyŏng-namdo.

gold, copper and cobalt, but the quality of the ore is not high enough to be worked independently.

The country rock containing tourmaline, which may be called tourmaline schist and locally consists almost entirely of tourmaline, is generally 2–3% in B_2O_3 content. As rock of such quality is impossible to treat as boron ore, the tourmaline had to be concentrated up to 7–8% B_2O_3 ore by means of the flotation method. The reserve of tourmaline schist minable as boron ore was confirmed to be greater than several hundred thousand tons, and a dressing plant which can treat about 100 tons of ore a day was constructed. The adjacent claim to this mine is the Tanp'ung mine (worked by Totaku Co.), where a wider distribution of tourmaline schist is found. Accordingly, the tourmaline resources of this district are very great. If the ore dressing had been successful in treating tourmaline, no anxiety would have been felt about tourmaline resources as far as quantity is concerned. Tourmaline from this region belongs to the magnesia-rich one, and it is said that both the acid and alkali methods are adaptable to the production of boric acid.

Survey and references: The author visited this region in 1943. As for regional geology, Yoshio KINOSAKI of the Geological Survey of Korea carried out sheet mapping in 1937. Cobalt and tourmaline deposits were surveyed by Keizaburo NAKAMURA of the Geological Survey of KOREA.

After that, investigations of tourmaline deposits were made by Shigenori KIMURA of the Tokyo Shibaura Electric Co., and by Toshio ISHIKAWA and Mitsuo FUNABASHI of Hokkaido University. In 1944, Toshiya MIYAZAWA confirmed the wider distribution of tourmaline schist in the area of the Totaku Tanp'ang Mine west of the Sangnong Mine. The present paper is based upon these references, together with the author's own observations.

Claim:

Mine name	Sangnong Mine
Location	Sangnong-ni, Suha-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo
Ownership	Taka-aki OKAGE
Office	Okage Mining Office, Keijo-fu (Seoul), Naka-ku, Eiraku-cho, c/o Eiraku Bldg.

History The mine originated from the discovery of copper ore in a tunnel of the water-way for a power plant under construction. In 1941, the owner started prospecting for copper ore and found the auriferous copper deposit. However, the ore was of low grade and prospecting was continued. In July, 1941, it was found that the pyrrhotite of this deposit contained cobalt, which was in demand in Korea at that time. After examining the cobalt ore, K. NAKAMURA found that a tourmaline schist, recognized as a boron ore, was contained in the country rocks. He then renewed investigation and confirmed the presence of a huge amount of tourmaline schist; at the same time, pegmatites rich in potash feldspar was reported by him from the same claim. After that, tungsten ore was also discovered within the gold-copper-cobalt ore zone, and was worked later. As a matter of regret, in spite of the many varieties of ore present, no one ore was of high grade and the mine was compelled to adopt a complex method of refining. Responding to the urgent demand for boron in the spring of 1944, the construction of a 100 ton per day dressing plant was being pushed by the Korean Mining Promotion Company.

a. Location and communication

The Sangnong mine was located in the middle reaches of the Namdae-ch'ŏn (River), which empties into the Japan Sea at Tanchi'ŏn in the northern part of Hamgyŏng-namdo. Arriving at Tanch'ŏn by the Kyŏng-wŏn and Hamgyŏng lines from Kyŏngseong, change trains for Sangnong on the Tan-nong line, and leaving the train at Sangnong, one could reach the mine office on foot, which was in the village of Sangnong-ni about 1 km south of Sangnong station. The mine entrance was found on the north bank of the Namsan-ch'ŏn, a branch of the Namdae-ch'ŏn. The road between the station and the mine is level, with easy access.

b. Geology and ore deposit

Rocks in the mine area consist of mica schist, tourmaline-mica schist, tourmaline schist, quartz schist and crystalline carbonate rocks which belong to the pre-Cambrian crystalline schist system or Matenrei system. These formations strike N 70° W and dip 70° S in general, and are intruded by schistose granite, pegmatite and aplite. In this region, dikes of porphyrite, lamprophyre and basalt are also found. The general aspect of the topography in hilly near the deposit, however, along the Namsan-ch'ŏn a wide plain consisting of alluvial deposits and in somewhat higher places, older fluvial deposits are found. The gold-copper-cobalt deposit consists of impregnation zones parallel to the schistosity of the crystalline schists and fine veins running along the bedding plane of country rocks. These were all discovered through tunnel prospecting. The impregnation and vein zones are named the 1st vein (1.5 m wide and more than 50 m long), the 2nd vein 4 m wide and more than 130 m long) and the south vein (2 m wide and more than 20 m long). The 2nd vein, the principal impregnation zone, has been confirmed to continue 180 m in a tunnel; however, judging from the result of other prospecting, it can be assumed to run 500 m or more. Metallic minerals in the impregnation zone consist chiefly of pyrite, chalcopyrite, Co-bearing löllingite and Co-bearing arsenopyrite, which are more or less accompanied by gold. Along the impregnation zone, 2 or 3 bedded veins of varying thickness (between 2 and 20 cm) occur. The veins consist chiefly of quartz, often with sulphides such as arsenopyrite, chalcopyrite, pyrite and pyrrhotite which are quite concentrated in places. These sulphides are replaced by copper-cobalt ore at times, and scheelite accompanies them in rare occasions. The rock, which composes the main part of the impregnation zone, is brown to dark-brown or black schist, which consists chiefly of tourmaline and quartz and shows remarkable schistosity. The tourmaline-rich ore may be called tourmaline (tourmaline rock) and the tourmaline- poor ore may be called tourma-line-bearing quartz schist.

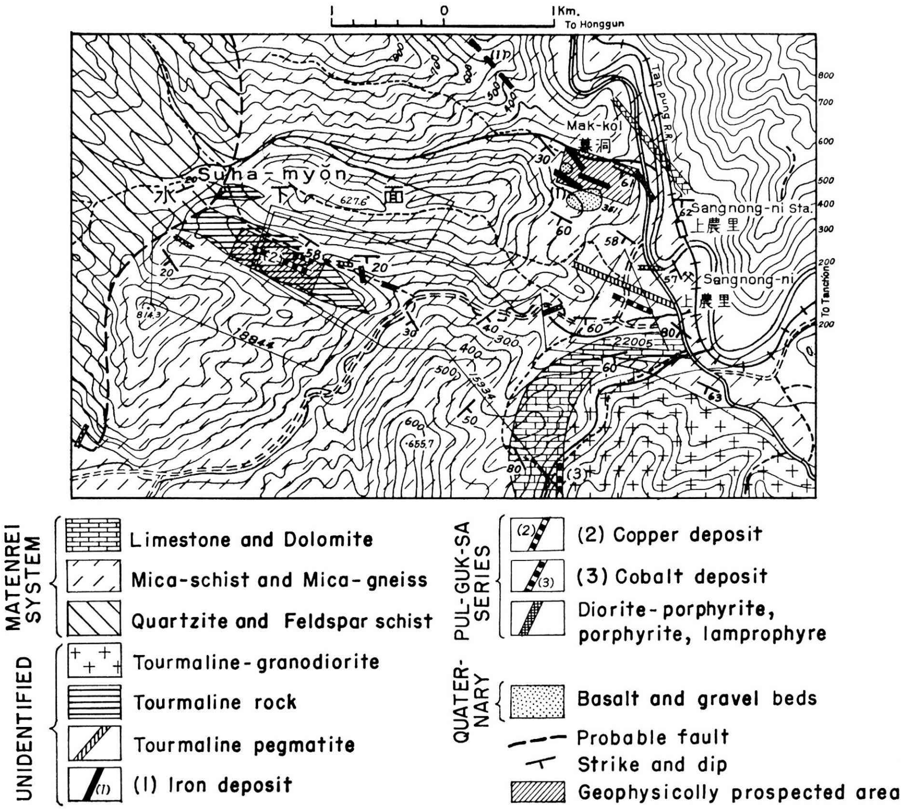

Fig. 2. Geological Map of the Suha-myŏn District Tanch'ŏn-gun, North Korea.

Makkol Mine Fe ⚒ (1)
Totaku Tanp'ung Mine Copper, Tourmaline ⚒ (2)
Sangnong Mine Tourmaline ⚒ (3)

c. Tourmaline deposit

The tourmaline and tourmaline-quartz schist occur as the country rock of the above deposit, chiefly in the vicinity of the sulphide impregnation. As they depart from the sulphide impregnation zone, the rock changes to mica schist. The so-called tourmaline schist consists mainly of quartz and tourmaline, and the tourmaline content reaches 20–30% or 2–3% B_2O_3. Occasionally the amount of tourmaline present reaches 70–80% or 8% B_2O_3; this sort of rock can be regarded as boron ore, however, the amount present is far less than that of the quartz-rich ore. The tourmaline schist contains certain amounts of biotite, muscovite and plagioclase. The tourmaline is deep bluish-brown, and very finely crystallized; it is 0.1 mm in width and 0.2 mm in length in general, and the crystals are commonly arranged parallel is the direction of schistosity. Sometimes the tourmaline schist is penetrated by finely folded veinlets consisting of quartz and feldspar.

The B_2O_3 contents of the tourmaline schist was measured by K. NAKAMURA as follows:

Table 3

(a)

Rich ore	Tourmaline schist, especially the part concentrated in tourmaline	9.80%
Medium ore	Tourmaline schist with feldspar-quartz veinlets	2.75 – 4.06%
Poor ore	Transitional part between tourmaline schist and mica schist	0.56 – 1.92%

(b)

Ore grade	Locality	B_2O_3
Richest ore	1st vein	9.80%
Rich ore	,, ,,	4.06%
Rich ore	,, ,,	3.85%
Medium ore	,, ,,	2.94%
Medium ore	,, ,,	2.75%
Medium ore	South vein	3.17%
Medium ore	,, ,,	2.25%
Poor ore	1st vein	1.92%
Poor ore	Northern part of the south vein	1.40%
Host rock	Northern part of the south vein	0.56%

As the determination of B_2O_3 content in the tourmaline schist was not carried out by systematic sampling, and therefore no assay map was prepared, it is difficult to estimate the average content. Judging from macroscopic observation as well as microscopic observation of the mineral constituents of the tourmaline schist about 2.5 m wide along the south vein and neighboring pegmatite, and about 1.5 m wide along the 1st vein, the average B_2O_3 content of the rock totaling 4 m in width is estimated at 3%.

General quality of ore: The tourmaline schist generally contains chalcopyrite, arsenopyrite (cobalt-bearing) and scheelite and forms a complex ore. The estimated contents of the rich part are as follows:

Gold, 5 g/t; Silver, 2 g/t; Copper, 0.8%; Cobalt, 0.2%; Tungsten, 0.3%; tourmaline, 3%.

Table 4. Reserves of Boron Ore (tourmaline schist).

	Width	Length	Depth	Sp. gr.	Reserve	B_2O_3(%)	B_2O_3(t)
K. NAKAMURA (May, 1943)							
Ore deposit	4 m	200 m	100 m	3	240,000 t (probable)	3	7,200
Rich and richest ore	—	—	—	—	48,000 t	4–9	—
K. NAKAMURA	9 m	120 m	85 m	3	275,400 t (probable)	2	5,508
South vein	2 m	(Tunnel)	(Boring)	—	—	—	—
1st vein	1.5 m	—	—	—	—	—	—
2nd vein	5.5 m	—	—	—	—	—	—
	9 m	500 m	200 m	3	2,700,000 t (possible)	2	54,000
T. ISHIKAWA	9 m	240 m	85 m	3	550,800 t (probable)	2 (estimated)	11,016
					1,944,000 t (possible)	2 (estimated)	38,880
WATANABE	5 m	240 m	85 m	3	550,800 t (probable)	2 (estimated)	11,016
					1,944,000 t (probable)	2 (estimated)	38,880
WATANABE	5 m	240 m	90 m	3	324,000 t (probable)	3 (estimated)	9,720
Report of the mine	60 m	450 m	100 m	3	8,100,100 t	Including poor ore	
	10 m	450 m	100 m	3	1,350,000 t		40,500

Development: As stated in articles on prospecting and history, the mine was opened to exploit copper ore which was discovered in a tunnel while constructing a power plant. The copper ore does not reach the surface of the ground. For this reason, tunnel prospecting was carried on from the beginning. That is, a tunnel (the 1st tunnel) was driven N.N.E. into the hill from the north bank of the Namsan-ch'ŏn, but no ore deposit was found until a point about 100 m from the entrance was reached. Then the 1st inclined shaft was sunk northward down to 30 m in the vicinity of the place now called "Dai-ichi kō" (First Deposit), crosscuts were driven northward and southward, each about 50 m from the bottom of the shaft, whereby the presence of tourmaline schist and a copper-cobalt impregnation zone were confirmed. The 2nd shaft is located 200 m WNW of the 1st shaft, or 90 m south of the horizontal tunnel. It was sunk from the older terrace deposit down to 30 m; the tourmaline schist and copper-cobalt deposits were also found in the tunnel at this level. The length and properties of the deposit were confirmed by driving tunnels roughly parallel to the strike of the impregnation, or the strike of the beds. A crosscut was also driven northward from the principal zone of the deposit, but it did not contact the expected copper-rich ore, and prospecting was abandoned. As the tourmaline schist and cobalt deposit came to the front, the mine prepared a "Main shaft" north of the 2nd shaft for excavation. Furthermore, the mine has carried on two drilling explorations from underground from which the impregnation zone was confirmed to continue at a depth of 88.5 m.

Mining: At the time when the author carried out the survey, excavation had not proceeded properly.

Ore dressing: The mined ore was relatively poor in quality. After breaking large lumps with a crusher, the ores are sorted by hand into copper ore, high-degree tourmaline ore, cobalt-arsenic ore and tungsten ore. The qualities of the hand-sorted ores are as follows:

Table 5

Copper ore of high-grade	Au	40 g/t
	Ag	15 g/t
	Cu	6%
Cobalt-arsenic ore	Au	20 g/t
	Cu	tr.
	Co	1%

At the time when the author visited the mine, a test mill for flotation, about 1 ton a day plant, was being built at the mine for the purpose of studying low-grade ore treating. By the end of spring 1944, the mine had succeeded to some extent in preparing concentrates of copper-cobalt ore and tourmaline ore. Some of this ore was used as test material for making boric acid at the Takeda Medical Industry Co., Ltd., and at the Tokyo Shibaura Electric Co., Ltd.

As the flotation method for tourmaline ore succeeded, the mine began to establish the main mill; it was under construction by the Korean Mining Promotion Co. at the time when the author carried out the survey there, and was scheduled for completion in the spring of 1945.

The capacity of the mill was to be 100 tons a day, the estimated annual production of tourmaline concentrate 8,000 tons and the grade of concentrate about 8% B_2O_3. If recovery was 70–80% and the grade of ore 3% B_2O_3, the annual production would correspond to 560–640 tons of B_2O_3.

Production and retained ore: The mine was still prospecting and had no marked production. In 1943, monthly production was 560 tons of low-grade ore (5 g/t Au, 0.8% Cu, 0.2% Co, 0.3% WO_3 and 3% B_2O_3), 60–70 tons of high-grade copper ore (2% Cu) and 0.5–0.7 tons of high-grade tungsten ore (60% WO_3). Monthly production was scheduled to increase up to about 1,100 tons from 560 tons sometime in 1944.

At the close of December 1943, the following ores were retained at the mine.

Table 6

Copper ore	2%	25 tons
,, ,,	0.6%	3,498 ,,
Scheelite	60% (WO_3)	1.4 ,,
,,	15%	5.3 ,,

(III) Totaku Tanp'ung Mine

Claim: Patent No. 15934

Location: Choga-dong, Sangp'ung-ni, Suha-myŏn, Tanch'ŏn-gun, Hamgyŏng-namdo

Ore: Au, Ag, Cu, Tourmaline

Ownership: Totaku Mining Co., Ltd., 195, 2-chome, Kogane-machi, Keijo-fu (Seoul)

Adjacent claim: Patent No. 18844, Au & Cu

Ownership: Fumiya Hori, 1, 2-chome, Chuo-bu, Kanko-fu (Hamhŭng)

a. Location and communication

The mine is located to the west of the Sangnong mine, and the place is of similarly easy access.

b. Geology and ore deposit

The geology and ore deposit are roughly similar to those of the Sangnong mine, but the distribution of tourmaline schist is more widely extended. According to a computation by Miyazawa, the tourmaline schist deposit is 1750 m long and 200 m wide, and the possible ore reserves (on a geological basis, tourmaline content 20–70%) reach 42 million tons. The grade of ore inferred is 35% tourmaline, or about an average 3.3% B_2O_3. Where the deposit is exposed a large amount of powdery tourmaline ore occurs. In the tourmaline zone, a copper deposit 0.3–0.5 m wide, 3–4% Cu, is found and was being prospected at the time of the survey.

The mine is a new one, discovered to the west of the Sangnong mine, and the properties of the tourmaline are roughly those found at Sangnong, but the occurrence of a large amount of powdery ore is rather advantageous at this mine. If the flotation method were applied as in Sangnong, it would be easy to obtain tourmaline concentrate. This is the largest tourmaline deposit of this type.

(IV) Utilization of tourmaline schist from near the Sangnong mine

The occurrence of tourmaline schist other than at the Sangnong mine has already been confirmed in the Tanch'ŏn district. Especially from neighboring claims, new discoveries of excellent tourmaline schist have been reported.

Working mines in the vicinity:

Sŏngjon mine (Cu, Co)
Kasin mine (Co)

The tourmaline schist found at these mines is very low grade, averaging about 3% B_2O_3. However, it is characterized by the homogeneity of rock as well as by its great amount, and in addition it occurs in association with gold, copper, cobalt and tungsten. According to recent experimental results, tourmaline can easily be concentrated by using the flotation method. A flotation mill with a 100-ton per day plant was constructed. The concentrate was sent to factories of the Tokyo Shibaura Electric Co. and the Takeda Medical Industry Co., and used in the manufacture of boric acid. In treating ore which contains not only tourmaline but also Cu, Co and W, an attempt was made to make use of these metals, separating them prior to the tourmaline. As the tourmaline schist was thought to be distributed very widely in this district, the ore reserves were considered sufficient to meet the demand at that time.

(V) Holgol (Hol Kol) Mine

General view: The Holgol mine, about 65 km east of P'yŏngyang, was formerly called the Suan gold mine, and was known as one of the three great mines in Korea in older time the present Suan Gold Mine corresponds to the former Namjong gold mine and is now worked for gold, silver, lead and molybdenum under management of the Nippon Mining Co. It is known also for the fact that the mine was once under the management of a non-Asian.
The mine has been continuously worked, and has produced a considerable amount of gold and copper ores.

Since 1930, the author has studied ore deposits in this district, and in 1938 discovered a large amount of magnesium borate in the principal ore body (North ore body) of the mine. The mineral was named kotoite by the author. The boron ore containing kotoite in the North ore body of the Holgol mine attains 8–10% B_2O_3. The mineral occurs in the marginal part of the gold-copper ore of the North ore body, and the mineral reserves are estimated at about 500 thousand tons. A test on the production of borax from this ore was conducted by the Institute of Hitachi Manufactory, and in 1941 the trial manufacture of borax from kotoite was started by the same company at Inch'ŏn. After that, the main mill was established and operated at P'yŏngyang.

From the nature of the ore it is difficult to raise the crude ore above 10% B_2O_3 However, it is easy to obtain concentrate above 10% B_2O_3 by a method of ore dressing.

Investigation and reference: Since 1930 the author has studied the Suan district, including the Holgol mine, 8 times. After the discovery of kotoite in 1938 he visited the mine 4 times, in 1939, 1941, 1942 and 1943, for the purpose of confirming the mode of occurrence of this mineral. During the same period, YAMAZAKI and YAMADA of the Central Institute of Korean G. G. also investigated the mine and Takao YAMAGUCHI of the Geological Survey of Korea reported drilling prospecting.

Table 7. Main Investigation of Kotoite.

Period	Investigator	Remarks
1939, Sept.	Takeo WATANABE	
1940	YAMAZAKI & YAMADA	Central Inst.
1941, April	Takeo WATANABE	
1942, June	,, ,,	
1943, June–July	Takao YAMAGUCHI	Geol. Surv.
1943, Nov.	Takeo WATANABE	

Claim:	
Mine name:	Holgol (Hol Kol) mine
Location:	Sugu-myŏn, Suan-gun, Hwanghae-do
Loc. of office:	Sŏktal-li, Sugu-wyŏn, Suan-gun, Hwanghae-do
Patent:	7881–7885; 7554
Ore:	Au, Ag, Cu, W and B
Ownership:	Pogwang Mining Co., c/o Chosen Seiren Bldg., No. 25, 1-chome, Taihei-dori, Keijo-fu (Seoul)

History: The mine was opened as early as 100 years ago (in the dynastic age of Korea), and was known as the royal gold mine. Mining and the extraction of gold were carried out by primitive methods. In 1901, Tahei YAMAGUCHI (a Japanese) obtained the mining rights, but was not successful in prospecting. In 1903, the mine again reverted to the royal family. After that, in 1904–1905, the mine was put under the joint control of Japan, Britain and the United States of America. Since 1906, when the Korean syndicate with British capital was established, mining was carried on by the Seoul Mining Company. The company systematically developed the mine, calling it the Suan Mine. That is, the company constructed a coal-power plant at P'yŏngyang, transmitted current to the mine, carried out mining, ore dressing and refining, and the annual production attained 2–3 million yen. Thus the mine came to claim the title of one of the three main gold mines in Korea. However, in 1919, when the mine was deepened at the level now called the 5th old tunnel, the ore was of low grade and became non-profitable. Then, the Suan mine stopped work and transformed its main force to the exploration of the deposit at Namjŏng. Thus the Suan mine was left unworked for a time. In 1928, Ha Tonggyun and several other Koreans obtained part of the non-Koreans' patented mining claim and formed the Holgol gold mining partnership. Then the remaining ore was disposed of and prospecting again continued, and at last an ore body of high-grade-gold-copper ore was discovered north of the formerly worked ore body. The ore body expanded progressively (going down) and developed to the present great ore body called the North ore body which contains kotoite. In November, 1934, the development of the mine passed to the present owner; thereafter the readjustment of old tunnels and mining of the North ore body proceeded in parallel. Thus the mine has been restored as an important mine in Korea under the name of the Holgol mine.

The first instance of discovery of boron mineral in this mine was that of ludwigite by Shannon, an American, during the period of foreign management, and in 1938 the author noticed the existence of the borate mineral which was named by him as kotoite. An investigation in 1939 made it clear that there was an enormous amount of mineral reserve. After that, at the time when boron material was needed, the kotoite ore was considered as a source of boron. In August 1941, the Hitachi Manufactory made a contract with the Holgol Mine and studied the use of kotoite in the Inch'eon Factory, and at last came to produce borax from kotoite at Inch'ŏn and P'yŏngyang. Meanwhile, in the Holgol mine, the mining of gold, copper and tungsten was continued as before.

Location and communication: The mine office is at Sŏktal-li, Sugu-myŏn, Suan-gun, Hwanghae-Do, and the working places at Pogwang-ni (Holgol) and Soktal-li in the same myŏn. To visit the mine from Kyŏngsŏng, first arriving atP'yŏngyang by the Kyŏng-Ŭi line, take a truck to the mine from Sŏn'gyo-ri station which is located on the south bank of the Taedong-gang (river), running in the southern part of P'yŏngyang, or take a mine truck from Chunghwa station on the Kyŏng-Ŭi line to Yul-li, Hwanghae-do, through Sangwŏn-ŭp, P'yŏngan namdo. The roads mentioned above are relatively even, and one may use a bus between P'yŏngyang and Suan. Though the relief in the area between Yul-li and the mine office is rather steep, the road for truck haulage has already been constructed, and one can now drive 75 km or 60 km, respectively, from P'yŏngyang or Chunghwa to the mine in 5–6 hours. As there is a steep pass reaching 200–400 m in relative height between Yul-li and Sŏktal-li, it is difficult for a car using substitute fuel to get through.

Geology and ore deposit: The mine is in the eastern area, consisting of a pre-Cambrian formation called the Shogen (Sangwŏn) system which is distributed widely over the region from Sangweon, to Yul-li. The Holgol mine is in the contact zone between the Suan granite and the slate and dolomite of the Shogen system. The principal deposit occurs in crystalline dolomite in contact with granite, and can be said to be a gold-copper deposit of the usual contact metasomatic type. As seen on a geologic map near the Holgol mine, the valley running south to north by the village of Holgol is a fault valley; on the west of the fault metamorphosed slate occurs, and in the valley and to the east dolomite of the Sidogu series, Shogen system is widely distributed. At the head of the Holgol valley, there is a small ridge extending east and west which consists of Suan granite and Holgol granite of the aplitic type, and the contact zone is found on the north of the ridge extending east and west. The N-S fault along the Holgol valley (called Holgol fault) dips 55°–60° towards east and a distinct slickenside is exposed on the ridge.

The deposit occurs in the contact zone mentioned above and is divided into two parts; one consists of the East and West ore bodies which have been worked since foreign control, and the other is the North ore body (also called the New ore body) which was discovered when Koreans obtained control. The West ore body is found near the junction of the Holgol fault and granite contact, and is composed of irregular flat-shaped ore bodies arranged roughly along the fault as well as along the granite contact. Two types of deposits are found. One, along the granite contact zone, is a gold-copper deposit of distinct pyrometasomatic type associated with typical skarn minerals such as deopside and phlogopite. The other, along the N-S fault, consists of two deposits—one a high-temperature type with skarn minerals such as garnet and phlogopite, and the other a hydrothermal type without skarn minerals, but consisting of light colored sulphides (chalcopyrite, pyrite, and tetrahedrite) and dolomite, popularly called "Chiaderagi". The principal ore body is a pyrometasomatic deposit extending east to west roughly along the boundary between the dolomite and garnet skarn zone in the eastern part of the granite contact. The North ore body is a large ore-pipe found in dolomite north of the East and West ore bodies, and is a pyrometasomatic deposit containing borate minerals such as kotoite and ludwigite. In this deposit, various minerals are distributed in concentric arrangement; gold, copper and bismuth ores are in the central portion, and a special marble containing kotoite is in the outer zone. The latter contains many small pipe-like and spherical massive gold-copper ores of skarn type. Thus the kotoite-marble, together with the gold-copper-bismuth skarn, form a large ore-pipe.

At the time when the author visited the mine, a large part of the East and West ore bodies had already been exhausted and gold-copper ore and kotoite marble of the North ore body were being mined at the 700 shaku level.

Kotoite occurs mainly in the outer zone of the ore-pipe of the North ore body, and subordinately in the margins of the East and West ore bodies.

In the North ore body, the outer zone between the 1,000 shaku and 600 shaku levels contains relatively few other rocks and forms a homogeneous boron-ore of about 10% B_2O_3. The boundary between kotoite-marble and crystalline dolomite is distinctly observable in tunnels, although it is uneven and irregular. The boundary between kotoite-marble and gold-copper-bismuth-diopside skarn-ore is also distinct, but on occasion the latter is so irregularly distributed in the kotoite-marble that the distribution is difficult to show on a map. In short, the gold-copper ore of the North ore body is a kind of skarn-ore contained in the "Kotoite-marble" ore-pipe and is concentrated in the central portion of the pipe. Therefore, the spot already worked for gold-copper ore in the North ore body corresponds to the portion consisting chiefly of skarn-ore; a large amount of kotoite-marble with skarn ore remains in the outer zone.

Characteristics of the main ore bodies in the Holgol deposit are tabulated below.

Table 8

	Strike shoot dip	Width	Length	Depth	Gangue	Ore mineral
East ore body (Skarn body)	E-W 70–90° S	10–30 m	Max. 90	300 m from surface	Diopside Chondrodite Phlogopite Garnet Datolite Tremolite Kotoite Ludwigite Calcite	Pyrite Pyrrhotite Chalcopyrite Bornite Bismuthinite Native bismuth Native gold
West ore body (A)	E–W 80° S	Flat pipe-like			Diopside Chondrodite Phlogophite Garnet Ludwigite Kotoite Calcite	Pyrite Chalcopyrite Gold Bismuth-bearing minerals
(B)	N–S 55–65° E	Flat		50 m from surface	Dolomite Calcite	Gold Pyrite Chalcopyrite Tetrahedrite Galena Sphalerite
North ore body	50–80° E	Large pipe		300 m from portal level	Diopside Clinohumite Phlogopite Calcite Ludwigite Kotoite	Chalcopyrite Bornite (upper) Cubanite Bismuth-bearing mineral Gold

Tonnage of kotoite-marble: At the time when the author surveyed the mine, it was being worked for gold-copper ore and no prospecting for kotoite-marble was going on. Moreover, in many places gold-copper ore bodies, which are irregular by shape, had been depleted and determination of the exact tonnage of marble present was not easy. The following tonnage was computed on the basis of an underground geologic map, in which case unmined portions were also taken into account (according to an investigation carried out in 1942).

Table 9

	Level	Length	Width	Area	Average	Height	Volume	Weight (Sp. gr. - 2.8)
Unmined portions of Au-Cu ore bodies	600 shaku	40 m	25 m	1,000 m^2	1,550 m^2	30 m	46,500 m^3	130,200 ton k(43,400)t
	700	65	30	2,100	1,800 m^2	30 m	54,000 m^3	151,200 ton k(50,400)t
	800	75	20	1,500				
	(K means tonnage of kotoite-marble. For the mined portions, kotoite-marble is assumed to be 1/3 of the calculated tonnage)							
	800	40	10	400 m^2	400 m^2	30	12,000 m^3	k (33,600)
	900	40	10	400	300 m^2	30	9,000 m^3	k (25,200)
	1,000	20	10	200				Total K (158,900)
	(K means tonnage of kotoite-marble)							
	Probable reserve of kotoite-marble between the 900 shaku and 800 shaku levels							k (30,000)
	Probable reserve of kotoite-marble in the eastern part at the 1,000 shaku level							k (1,000)
	800	15	5	75		12	9,000 m^3	2,520
	600	40	25	1,000	500	30	15,000 m^3	42,000 t k (14,000)
	500	0	0	0				
								Total K (206,420)t

East ore body portal level .... (0.5 × 15 × 6 × 2.8) K(150)
North ore body between portal and 1,000 shaku levels................ (0.5 × 2 × 50 × 2.8) K(5600)
West ore body near 1,000 shaku level............................ (20 × 10 × 10 × 2.8) K(5600)
Sum K(6000)

(K denotes tonnage of kotoite-marble)

Remarks: Although the average B_2O_3 content is unknown, it is inferred to be 10%. Therefore, 20 thousand tons of B_2O_3 can be recalculated into 54,800 t. of borax, or 35,600 of boric acid.

Calculation by Takao YAMAGUCHI *(Aug.* 1943*)*: From borehole drilling in prospecting for kotoite marble, YAMAGUCHI made a calculation of the tonnage. Through drilling, it became clear that kotoite marble occurs also at the 500 shaku level. First, YAMAGUCHI measured the area of sections in the North ore body from plans for various levels.

Level	Area of section
1,000 shaku	150 tsubo (500 m^2)
900 "	400 " (1,320 ")
800 "	470 " (1,560 ")
600 "	800 " (2,640 ")
600 "	130 " (430 ")
500 "	120 " (400 ")
	(inferred)

From the above, the volumes of the ore body between two levels were obtained as follows:

Level	Volume
1,100–1,000	about 5,500 m^3
1,000– 900	29,000
900– 800	47,500
800– 700	68,500
700– 600	45,500
600– 500	4,700
	200,700

Thus the total volume of the ore body was calculated at about 200 thousand cubic meters. Assuming the volume of gold-copper ore to be 1/6 of the entire ore body and the specific gravity of kotoite-marble to be 3.0, a reserve of about 500 thousand tons was obtained.

Author's note: Although the gold-copper ore is assumed to compose 1/6 of the entire ore body in YAMAGUCHI's calculation, it should be about ¼ in reality. Moreover, the portions already mined are also contained in the area of section, and must be excluded. An estimate by the mine in 1943 was 400 thousand tons.

Development: The present administrator began mining in December 1934; since then prospecting, mining, dressing and refining have been carried on up to this day. Recent annual production has been 136–270 kg Au, 122–1400 tons Cu (lump concentrate) and 600–800 tons Cu (fine concentrate), attaining more than a million yen per year.

(a) Prospecting is going on at the base of the North ore body and in the unmined part of old tunnels.

(b) Since the country rock is very hard, no supporting timbers were required in mining any ore body, and step-up, step-down methods were adopted, and in part the shrinkage method, in which mined parts are filled with waste, was also supplied. In mining, stopers, jackhammers and light hand drills were used; in part, high-grade ore was mining by hand (drilling). Monthly production was 7,500 tons cude ore, in which 2,500 tons scheelite and copper ores from Namsan near Sŏktalli were included.

(c) Underground haulage: Copper-bearing boron ores from the North ore body and old tunnels are brought up to the horizontal tunnel, and passing through the

Ogiri-ko (main-haulage level) are sent to the crushing plant by mine car of 1-ton capacity. Electric locomotives powered by storage batteries are used.

(d) Transportation; The gold-copper concentrate and part of the boron ore were transported by gasoline-powered trucks from the mine to Yul-li. From there, they were transshipped to cars with substitute fuel to be sent to Chunghwa station on the Kyŏng-Ŭi line. The larger part of the boron ore was sent by cable from the mine to Yul-li, and thereafter sent directly to the P'yŏngyan factory. Both ways, the distance between Holgol and Yul-li is 64 km for which a truck needs 30 liters of gasoline, and the distance between Yul-li and P'yŏngyan is 100 km for which a car using substitute fuel requires 5 bags of charcoal. It is also said that 35 2.5– to 3.0–ton dump trucks were estimated to carry 1,000 tons of ore a month using the road at that time (about 1 ton per day per truck).

(e) Recent production:

(i)	Ore, mined	1942	41,113 t
(ii)	Ore, dressed and refined	”	41,038 t
(iii)	Production		
	Amalgamated gold	362,325 kg	
	Lump concentrate	254,000 t	
	Fine concentrate	666,000 t	
(iv)	Sales in 1942		
	Unrefined gold	166,168 kg	425,325.71 yen
	Lump concentrate	236,251 t	79,107.08 ”
	Fine concentrate	638,419 t	477,206.93 ”
	Total		981,639.72 yen

The Holgol mine reserves are 200,000 or more tons of boron ore (10% B_2O_3) accompanied by a gold-copper ore deposit. The gold-copper ore of the Holgol mine has been worked for more than 30 years, and annual production still reaches several hundred yen at present. In recent years, however, the mine was worked with the objective of increasing copper production. In mining the boron ore, it was necessary to take care to avoid any serious hindrance in carrying on the mining of gold-copper ore. Fortunately, prospecting for boron ore coincides with that for gold-copper ore, and it is profitable to carry on prospecting simultaneously for both. In mining, it is sometimes difficult to separate the mining-faces of gold-silver-copper ore and boron ore; however, in the case of high-grade ore, they can be mined in their respective faces, and also the hand-sorting of ores can be partly carried out underground. Thus, it was possible to mine both ores selectively and no special mining equipment was required.

The boron content of the ores attained 10–11% B_2O_3 in high grade ore, and 5–6% B_2O_3 in low grade ore, which is mixed with rock materials and gold-silver ore. The latter can hardly maintain 8% B_2O_3 by strict hand sorting. The yield with hand sorting may not be greater than 25–50% if boron concentrate, or kotoite concentrate, could be obtained above 25% B_2O_3 by any method, the difficulties of transporting and various treatments would be surmounted. The study of ore dressing is an important subject in increasing the production of boron ore. As for truck haulage, in order to send 1,000 tons of boron ore per mouth from the mine to P'yŏngyang (the road for about 80 km was in bad condition), a 2-ton capacity truck must go and return 500 times; one return trip requires 30 liters of gasoline and 5 bags of charcoal. Thus, total expenses come to:

gasoline: $30 \times 500 = 15{,}000$ li
cost: 11.5 yens $\times 500 = 5{,}750$ yen
charcoal: $5 \times 500 = 2{,}500$ bags
cost: 17.2 yens $\times 500 = 8{,}600$ yen
14,350 yen

If the ores could be concentrated into 1/4 the amount, and therefore 25–30% B_2O_3 by ore dressing, the return trips would be reduced to only 125 times; 11,480 yen could be dispensed with or 11,350 liters of gasoline and 625 bags of charcoal a month. Moreover, it was thought that the trucks would be reduced and the yield of the refinery increased.

The boron ore was sent to the Inch'ŏn factory of the Hitachi Manufactory and the P'yŏngyang factory of the Chosen Special Chemical Co., Ltd. The factories were capable of accepting a total of about 1,500 tons of ore a month, or 1,200 tons at P'yŏngyang and 300 tons at Inch'ŏn, and it was imperative that the B_2O_3 content be not less than 8%. The actual yield of the factory treating kotoite was roughly 20% at maximum, and if the hand sorting factor was taken into account, the recoverable B_2O_3 was only 1/10 of the B_2O_3 content of ores.
Improvement in yields, both in ore dressing and in refining, was given attention. In later days, several hundred tons of boron were produced at P'yŏngyang.

(VI) Kinsei (Kŭmjŏng) Mine

The Kinsei Mine is in Ponghwa-gun, Kyŏngsang-pukto. The mine was managed by the Kinsei Mining Co., Ltd., and was one of the greatest gold mines in Korea, However, it is being left unworked at this time. The tourmaline-bearing pegmatites discovered in this mine was once thought of as a source of boron; however, no formal estimates of the ore reserve were made and particulars on the deposit are not known.

(VII) Ilgwang Mine

General statement: This is a copper mine under the management of the Sumitomo Mining Co., and is located northeast of Pusan, Kyŏngsang-namdo. The ore deposit worked is composed of networks of tourmaline-quartz-copper veins in biotite granite. About 150 kg of copper ore is being treated per day by the flotation method, and the tourmaline (0.7% B_2O_3) has been treated as waste. The Sumitomo Mining Co. is said to have recognized the possibility of recovering tourmaline by the flotation method and planned to put it in to operation.

Investigation and reference: Though the author did not investigate the deposit, Hideki IMAI recently surveyed and studied the region.

History: Since 1931, the mine has been managed by the Sumitomo Mining Co., and since 1937 has been worked continuously up to the present time.

(a) Location and communication: The mine is in Ilgwang-myŏn, Tongnae-gun, Kyŏngsang-namdo, and is located about 30 km northeast of Pusan. Traveling from Pusan to Chach'ŏn by train for Kyŏngju the mine may be reached by going west about 2 km by truck or on foot.

(b) Geology and ore deposit: The Keisho (Kyŏngsang) formation of the Mesozoic era is distributed widely in the district, and is intruded by granite, porphyries and porphyrites which are assigned to late Cretaceous intrusives. The ore deposit occurs as stockworks of ore veins in a small intrusive mass of granite about 1 km in diameter. The stockworks are concentrated in the areas which are called the "North body" and "South body" which attain 40–50 m in diameter.

The ore deposit shows characteristics of the high temperature type, containing tourmaline, quartz, garnet, apatite, zirkon, etc., as gangue minerals, and tungsten-bearing and antimony-bearing minerals as ore minerals. The host rocks, or granite, has generally also been altered and, in some places, has suffered severe tourmalinization. The ores mined are rich in chalcopyrite and magnetite and contain 0.6% Cu and 40–50 g Ag; tourmaline is always present also, although the content is less than 10%.

(c) Tourmaline: Tourmaline occurs as black columnar or fibrous crystals, and is the most important mineral among gangues. From the properties, it is considered a kind of iron tourmaline. The tourmaline reserve has not been investigated and no particulars are known.

(d) Development: The mine has been worked regularly by the Sumitomo Mining Co. since 1937. Mining is carried on by the open-pit method where the shrinkage method is used jointly. The ores are treated in a flotation plant of 150-tons-a-day capacity and are concentrated to about 14% Cu. It is said that a flotation plant of 300-tons-a-day capacity is now being constructed in accordance with a plan to increase copper production. As for the tourmaline, a test was made to treat the tourmaline (about 0.7% B_2O_3) contained in the tail of the copper ore flotation, and it is said that concentrate of 8.73% B_2O_3 was obtained from the ore of about 2.3% B_2O_3.

The tourmaline of this mine is contained as a gangue mineral in copper veins as is the case at the Yakuoji mine; therefore, it has heretofore been treated waste. As the tail of copper ore flotation contains 0.7% B_2O_3, if tourmaline concentrate can be obtained from the tail by any suitable treatment (for instance by flotation using sodium oleate), the difficulty of crushing the ore would be done away with and, therefore, the Ilgwang mine would become fairly profitable. The main point was in what yield the tourmaline concentrate of 7–8% B_2O_3 can be recovered from the low grade tailing. If the B_2O_3 content of ore is assumed to be 6.8–1%, and 100 tons of the ore are treated daily, the quantity of B_2O_3 in the ore is 0.8–1 ton.

If 50% of the above B_2O_3 can be recovered, the concentrate of tourmaline obtained daily would contain nearly 0.5 ton of B_2O_3. Then, the amount of B_2O_3 given by the concentrate can be estimated at 150–180 tons a year. When it is recalculated to the amount of tourmaline, it becomes 1500–1800 tons. Thus, obtaining the tourmaline as a by-product of the mine was seen to be important (if the flotation plant of 300 tons a day is completed, the amount of B_2O_3 produced would become more than 200 tons).

(VIII) Haman Mine

The Haman mine, together with the Ilgwang mine, are the important gold-copper mines in Kyŏngsang-namdo, Korea. The mine was under the management of the Showa Mining Co. The ore deposit consists of tourmaline-quartz-copper veins occurring in the Mesozoic formation and granite. The copper veins often contain cobalt-minerals and have been considered also as a cobalt deposit. The ore veins occasionally contain tourmaline and resemble those of both the Yakuoji and Ilgwang mines. The copper ore is treated by the flotation method; however, it is not known how much tourmaline is contained in the tail of copper flotation.

The author surveyed the district in May, 1942, and did not find the tourmaline content of the ore to be very high; the deposit was considered hopeless for the production of boron ore.

3. State of Utilization and Conclusion

The treatment of various kinds of boron mineral was made in several factories by using the different methods tabulated below:

Uses at that time:

(1) Ampoule glass, (2) Optical glass, (3) Vacuum-tube glass, (4) Fire-proof and heat-resist out glass; Chemical glassware, (5) Enamel for ceramicware, (6) For enamelled ironware, (7) For soldering, (8) Medicine; Toilet articles; Photography; Leather-cloth; Uranium pile; For regulating the velocity of neutrons; Antiseptics.

In short, if boron ore which can be easily treated is imported freely from North and South America, tourmaline, kotoite and other boron minerals which are troublesome to treat would be of no value as sources of boron.

Table 10

Ore	Factory	Treating method	Product	Preparation or additon
Tourmaline (Sangnong)	Osaka Indust. Inst.	H_2SO_4 method	Boric acid	$CaCO_3$, H_2SO_4
Kotoite	Hitachi Centr. Inst.	HCl method	,, ,,	HCl
Tourmaline	Aviat. Light Metal Inst. (Toho Sanken)	Alkali method Acid method	Borax, Alumina Boric acid	Soda ash, limestone Limestone, H_2SO_4
Danburite	,,	Alkali method	Boric acid, iron ore	
Kotoite	Nagai Inst., Tokyo Univ.	Acid method	Boric acid	$CaSO_4$, HCl
Tourmaline	,,	Acid method Alkali method	The same as Toho Sanken	
Kotoite	Inch'ŏn and P'yŏng-yang factories, Chosen Sepec. Chem.	Alkali method, less than 300t/month.	Borax	Na_2CO_3 limestone
Tourmaline (Sangnong)	Kanzakigawa fact., Takeda Med. Indust.	H_2SO_4 method	Borax, H_2SO_4	Limestone, H_2SO_4
Tourmaline	Toshiba Chem. Inst.	$AlCl_3$ method	Boric acid, $AlCl_3$	HCl
Tourmaline (Mitsubishi Obira)	Mitsubishi Min. Inst.	H_2SO_4 method		Lime, coal
Danburite	Toshiba, Matsuda Inst.		Ampoule glass	

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