Nonmetallic Deposits in Manchuria

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(1) Coal[1]

Coal is by far the most important mineral product in Manchuria. Out of the total annual production of coal—nearly 23 million tons in 1944— 58 per cent comes from the Mesozoic coal fields, 29 per cent from the Cenozoic, and only 13 per cent from the Palaeozoic fields. In total world production, 81 per cent is contributed by the Palaeozoic fields, only 2 per cent by the Mesozoic and 17 per cent (including lignite) by the Cenozoic fields. The predominance of Mesozoic instead of Palaeozoic coal fields is a unique feature of Manchuria. This applies to the Russian Far East, too, as was pointed out by Prigorovsky[2] in 1937. Prigorovsky denoted this as the Pacific type of coal genesis as distinguished from that of other parts of the world.

The Mesozoic and the Cenozoic coal fields are distributed more or less uniformly throughout Manchuria, whereas the Palaeozoic coal fields are developed only in South Manchuria, *i.e.*, south of the great east-west tectonic line. The Mesozoic fields are nothing but a southern extension of those of Siberia, and the Palaeozoic ones an eastern extension of those of North China, the former overlapping the latter in South Manchuria.

The Mesozoic and Cenozoic fields are of an intermontane or a limnic type, and both the coal-bearing formations and the coal seams themselves often attain a great thickness, one to several thousand meters for the coal-bearing formations and from fifteen to more than one hundred meters for a single coal seam. But the area of the fields is limited and the thickness of both the coal-bearing formations and the coal seams variable within a short distance. Each of these fields originated as an isolated basin in a tectonic depression, so the sequence of coal seams in one field is usually different from that of the neighboring fields. The Mesozoic strata are characterized by arkose and tuffaceous materials and in many places contain thick volcanic lava and agglomerates both in the lower and upper portions, and also a conglomerate with huge boulders up to several meters in diameter.

[1] The production quantities mentioned in this article are a rough estimate of the maximum outputs immediately before and during world War II.

[2] A lecture given at the XVIIth International Geological Congress in Moscow, 1937, which the writer attended.

The Palaeozoic fields are of a littoral type, with the thickness of the coal-bearing formations only 200–450 m. The thickness and lithologic character are remarkably constant over a wide area, and one may naturally infer that Palaeozoic coal fields were once great continuous fields which, by later tectonic movements, were divided into the smaller, separate fields of the present.

The sequence of the strata and coal seams are stikingly similar among neighboring fields, not only in South Manchuria but also in North Korea and North China. The sandstones are quartzose and the shales kaolinitic.

Such differences in the mode of genesis of the Mesozoic and Palaeozoic coal basins account for differences in mining methods as well as in the properties of the coal. Difficulties in mining thick seams (15–100 m) and in protecting weak tunnel walls and working faces (due to the weakness of bentonitic beds) are drawbacks of the Mesozoic fields. Coal ashes of the Mesozoic coal are often bentonitic and consequently have a low melting point (1,100°–1,200°C), whereas those of the Palaeozoic are kaolinitic and highly refractory. Sometimes the low refractoriness of the Mesozoic coal ashes prevents their use for making coke, in spite of the strongly caking nature of the coal itself (like the coal from some seams in Pei-piao fields) or in an extreme case, even for boiler heating (like the coal from Lin-kou west of Mi-shan), because the ashes easily melt into clinkers which choke the grate openings.

Table 1. Coal Ratios in Important Coal Fields in Manchuria.

Coal fields	Coal ratios (%)
Fu-shun (T)	0.7–10
Hao-kang (M)	4.2
Sung-shu-chen and Wan-kou (P)	3.0
Pen-hsi-hu (P)	2.8
Hsi-an (M)	2.5
Pa-tao-hao (M)	1.8
Yen-tai (P)	1.3
Hsiao-shih (P)	1.2
Fu-hsin (M)	1 – 2
Pei-piao (M)	1.0
Mi-shan (M)	1.0
Fu-chou (P)	1.0
Chiao-ho (M)	0.6

(P)—Palaeozoic coal fields
(M)—Mesozoic ,,
(T)—Tertiary ,,

The coal ratios (a percentage ratio of the thickness of the coal seams to the total thickness of the coal-bearing formations) of more important fields are listed in Table I.

The coal from the Palaeozoic fields is either high-grade bituminous or anthracite. The high-grade bituminous coal always cakes and is used for making coke. The coal from Mesozoic fields comprises all grades ranging from lignite to anthracite. A large field of Jurassic lignite is found in the Cha-lai-no-erh coal fields.

The Fu-hsin, Hsi-an, and most of the other smaller fields in central Manchuria of Jurassic or Jura-Cretaceous age produce bituminous coal, which is good for steam coal and also for cement and other ceramic industries. But they usually contain a rather large amount of water (7–10 per cent), and accordingly are of low calorific value.

Mesozoic fields in northeastern Manchuria, *e.g.*, Hao-kang, Fu-chin, Mi-shan, produce good caking coal. Other Mesozoic fields, distributed more or less erratically in central Manchuria, produce caking coal (Pei-piao, Wa-fang-tien), or anthracite (Tien-shih-fu-kou).

Table 2. Coal Reserves of Important Coal Fields in South and North Manchuria—Surveyed and Revised in 1943 by the Government Committee.

Age	Coal field	Province	Coal properties & fuel ratio	Reserves (mil. m. tons)	Area of coal field (km²)
M	Ai-hun	Hei-ho	L 1.0	3.9	—
M	Cha-lai-no-erh	Hsing-an	L 0.9	404.7	500
M	Hao-kang	(Eastern Manchuria)	B 1.6	1,762.0	180
M	Fu-chin	(Eastern Manchuria)	B 1.8	50.4	350
T	San-hsing	(Eastern Manchuria)	B 1.0–1.2	162.3	40
M	Mi-shan	(Eastern Manchuria)	B 1.6	370.4	1,500
M	Mu-leng	(Eastern Manchuria)	B 1.4	16.9	35
M	Tung-ning	(Eastern Manchuria)	(B) 1.0	5.4	350
M	Lao-hei-shan	(Eastern Manchuria)	(B) 0.9	114.3	—
T	Hun-chun	Chien-tao	L 0.8	10.1	200
M	Lao-tou-kou	Chien-tao	B 1.1	14.3	5
M	San-tao-kou	Chien-tao	B 1.2	28.6	100
M	Tu-shan-tzu	Chien-tao	B 1.2	114.3	—
M	Huo-shih-ling	Chi-lin	B 1.0	11.9	20
M	Ssu-mi-kou	Chi-lin	B 1.0	0.8	—
M	Chiao-ho	Chi-lin	B 1.3	37.8	500
T	Shu-lan	Ssu-ping	L 0.8	(200.0)	200
M	Hsi-an	Ssu-ping	B 1.1	224.0	25
M	Ya-tzu-Chuan	Ssu-ping	A 7.0	4.1	—
T	Fu-shun	Feng-tien	B 1.1–1.8	582.9	40

P	Pen-hsi-hu	Feng-tien	B 3.2	225.2	40
P	Tien-shih-fu	Feng-tien	B 3.2	20.9	60
M	Tien-shih-fu	Feng-tien	A 6.1	57.9	
P	Niu-hsin-tai	Feng-tien	A 6.8–11.6	53.2	20
P	Yen-tai	Feng-tien	A 6.0	29.8	20
M	Wa-fang-tien	Feng-tien	B 2.5	0.3	5
M	Wa-fang-tien	Feng-tien	A 8.0		
P	Fu-chou	Feng-tien	A 7.0	4.5	10
M	Sai-ma-chi	Feng-tien	B 2.9	56.9	180
			A 6.5		
P	Tieh-chang	Tung-hua	B 2.9	(58.5)	—
P	Wu-tao-chiang	Tung-hua	B 3.3	(155.2)	17
M	Lin-tzu-tou	Tung-hua	B 1.8	10.5	20
P	Sung-shu-chien	Tung-hua	B 2.3	88.8	30
P	Wan-kou	Tung-hua	B 2.0	25.3	8
M	Shan-sung-kang	Tung-hua	B 1.6–2.3	25.6	—
M	Fu-hsin	Chin-chou	B 1.2–1.6	1,423.0	1,100
M	Pa-tao-hao	Chin-chou	B 1.2	59.1	20
M	Pei-piao	Chin-chou	B 1.5–2.0	173.3	65
P	Nan-piao	Chin-chou	B 4.5	191.7	60
M	Hsi-yuan-pao-shan	Jehol	L 1.0	106.3	—
M	Tung-yuan-pao-shan	Jehol	L 1.0	35.0	—
P	Hsing-lung	Jehol	B 2.3	18.6	20
	Total:			6,941.2	

P: Palaeozoic M: Mesozoic T: Tertiary
A: Anthracite B: Bituminous L: Lignite

Tertiary coals are usually black lignite, but in Fu-shun bituminous coal of very good quality, some of it caking, is produced. This coal is used for gas production, locomotives, coke ovens, ceramic kilns, and for other industrial purposes. It was also used for experiments on artificial liquefaction of coal in Fu-shun.

In 1935, the total coal reserves of Manchuria were estimated at 4,600,000,000 metric tons. The estimates of reserves in Hao-kang and Fu-shin were revised following a recent survey and increased. The reserves in Hao-kang are now believed to be 1,700,000,000 metric tons or three times those of Fu-shun and to constitute the largest coal field in Manchuria. The total coal reserves of all Manchuria are estimated at 7,500,000,000 metric tons, immediately before the war. The coal reserves of all seams, 1,000 m or less in depth and 70 cm or more in thickness, of the important fields are listed in Table 2.

Total reserves of all the fields, inclusive of new fields discovered near Mi-shan (*e.g.*, Kuang-i) and all other minor deposits amount to a total of 7,500,000,000 metric tons.

The proportion among the fields of the various periods, of both coal reserves and area of fields, are shown in Table 3.

Table 3. Geologic Age Distribution of Coal Reserves and of Area of Coal Fields.

Age	Coal reserves (metric tons)	Per cent	Area of coal field (Square Kilometers)	Per cent
Palaeozoic	700,000,000	9	500	7
Mesozoic	5,800,000,000	78	5,800	85
Tertiary	1,000,000,000	13	520	8
Total	7,500,000,000	100	6,820	100

The predominance of the Mesozoic fields is clearly shown in the above list.

(2) Oil shale and natural oil indications

Both Mesozoic and Tertiary coal-bearing formations are intercalated with oil shale beds. The Mesozoic oil shale beds are usually thinner and of a poorer grade, but occasionally rich shales, such as those in Hua-tien and Lo-tzu-kou, are found. The Tertiary oil shale is represented by a thick bed in Fu-shun with a thickness of 120 meters, directly overlying the main coal seam. It can be traced for 16 km along its outcrop, rather a short distance for its great thickness. Another example of a Tertiary oil shale bed is the 20-meters-thick bed at San-hsing which, like the bed of Fu-shun, overlies a bituminous coal seam.

The Hua-tien shale is yellowish-brown and the richest part, about one meter thick, yielded as much as 23 per cent crude oil in a laboratory distillation test. There are a few other seams, but with shale of greatly inferior quality. The construction of a small-scale distillation plant was planned in Hua-tien during the war.

The Lo-tzu-kou shale is brownish-black with a finely banded texture just like the "mahogany shale" or the richer portion of the oil shale beds in the Green River formation of Utah and Colorado. The oil yield of the richer beds obtained by laboratory tests is about 10–12 per cent. The total reserve is larger than that of Hua-tien and is believed to be several million metric tons, but the richer shale is limited both in area and reserves.

The Mesozoic coal seams in Tung-ning and Lao-hei-shan contains partings of oil shale beds. It burns easily with an unusually large amount of smoke, and upon proximate analysis, gives low fuel ratios such as 0.9–1.0. These are due to the presence of oil shale partings. The coal itself is bituminous.

Oil shale in Fu-shun has been known since 1909. After twenty years of extensive experimentation both in laboratories and in pilot plants, a big distillation plant was erected. It incorporates a series of vertical retorts with an internal heating system which was Fu-shun's own device. The total reserve of the oil shale amounts to over five billion metric tons. The crude ore used in the distillation plant is only the richer portion of the shale and has to be stripped in open pit mining of the coal. The average crude-oil yield is 5.5 per cent. Although the oil yield is very low, the cost of the crude ore is kept extremely low by means of large-scale mechnization of mining and transportation. It can be said that economic success in the industry depends upon this mechanization in the handling of bulky and cheap materials. For example, the Scottish shale treated by the Anglo-Persian Oil Company in Lothians, Scotland, yields 8 per cent and the Esthonian shale treated by the government plant averages 18 per cent. Ores in both countries are mined underground.

Natural oil indications are known from the Fu-hsin and Cha-lai-no-erh coal fields. In Fu-hsin, traces of crude oil were first found in 1935. They consisted of oil stains in cores and drops of oil floating on the drilling fluid. A deep boring (planned depth 1,000 m) was begun in 1937 and oil indications were found at several horizons from a depth of 644 to 780 m, and a total of about 70 liters of crude oil was recovered from the circulating water. The formation is part of the Mesozoic Fu-hsin coal-bearing formation, situated below the horizon of the main coal seams. It is 500 m thick and consists of tuffaceous sandstone and agglomerate.

Asphalt was found in 1930 in Cha-lai-no-erh. It occurs either as seepage in porous sandstones or as amygdaloidal cavities in trachytic lava. In 1935, one deep boring (planned depth 1,000 m) and fourteen shallow borings (depth 200–300 m) were finished. One of the shallow holes encountered an oil sand 3 m thick. Next year, the deep boring reached a depth of 1,114 m. In 1937 and 1938, gravitational and seismic prospecting methods were used in examining the underground structures. Further prospecting with both diamond and rotary drilling was planned but not carried out owing to political conditions.

(3) Graphite

The most important graphite deposit is the Liu-mao deposit near the Mi-shan coal field. The rocks are crystalline limestone, paragneiss, graphite schist, and intrusive biotite granite and pegmatite.

The graphite deposits are of two types: one consists of a flaky graphite in an irregular vein form and is associated with such skarn minerals as diopside, scapolite, andradite, anorthite and titanite; the other consists of an "ore bed" of a graphite schist. The second type forms very large deposits.

The average of the values obtained by analysis of the ore treated in the flotation mill shows 18 per cent carbon. In 1944, about 500 metric tons of carbon for crucibles and 4,200 metric tons for electrodes were produced. Production capacity can be greatly enlarged in the future.

(4) Pyrite

Practically all the pyrite produced in Manchuria comes from two sources: one source is the flotation plants of metal mines, especially lead and zinc mines, and the other is the dressing plants of coal mines. In both cases, the pyrite is a by-product of other minerals. The normal demands for this mineral as raw material for sulphuric acid plants (Fu-shun, An-shan, Pen-hsi-hu, and Kan-ching-tzu in Kuantung Territory) amounted to over 200,000 metric tons, whereas production from all sources in Manchuria resulted in a grand total of only 30,000 metric tons. When shipment from Japan was interrupted, every effort was made to increase domestic production. But since most of the pyrite was obtained as a by-product, production could not be increased in a short time. Thus, the sulphuric acid plants (Manchuria Chemical Co., Kan-ching-tzu) were compelled to curtail or stop operations.

A new deposit of pyrite was discovered near the Wu-ta-lien-chih volcanoes, north of Chi-chi-har. The deposit is in a loose Cretaceous sandstone bed impregnated with pyrite nodules. The impregnation was traced for a wide area, but the nodules are scattered and sparse, and after many months of examination by means of test pits (10–30 m deep) the work was given up.

(5) **Aluminous shale and fire-clay**

Aluminous shale, or *Bando-ketugan,* occurs in two beds parallel to the coal seams in Palaeozoic coal fields, one ("A" bed) above and the other ("G" bed) below the coal seams. The bulk of the material of both the "A" and "G" beds is a kaolinitic fire clay or a flint-clay with a thickness of 2.5–10 m or more; the rich ores of the *bando-ketugan* with an alumina content of 55–70 per cent occur in flat lenses within this clay bed. The *bando-ketugan* lenses are nearly one meter thick and several scores and occasionally several hundreds of meters long. In the "G" bed the *bando-ketugan* is thicker but relatively limited in area.

The vertical distance between the "A" and "G" beds, the thickness of the productive coal-bearing formations, ranges from 250 to 450 m in different fields. Between these two *bando-ketugan* beds are several kaolinitic fire-caly beds. The total thickness of all these clay beds is over 20 m in most of the Palaeozoic coal fields. This is the largest development of kaolinitic clay and aluminous shale in the world. This is due to the fact that these coal basins are typical paralic basins and were subjected only to epeirogenic movements during their formation.

The flint fire-clay is made up of practically pure kaolinite (and halloysite), whereas the *bando-ketugan* is a mixture of kaolinite with varying amounts of aluminum hydroxide, usually as α-Al_2O_3 H_2O, or a diaspore. Upon analysis, the flint fire-clay, when pure, has an alumina content of 40–42 per cent, that is, a little more than that of a pure kaolinite, whose alumina content theoretically is 39.5 per cent. This excess, according to the writer's study, is accounted for by the presence of pholerite, an atomic isomorph of kaolinite which has a higher content of alumina. So the writer suggests placing the boundary of the flint clay and *bando-ketugan* at 45 per cent alumina in the proximate analysis, on a titanic acid and ferric oxide free basis, *i.e.*, on a SiO_2, Al_2O_3 and H_2O basis.

Only the "G" bed is found in Fu-chou, because the "A" bed has been removed by erosion. The "G" bed yielded high-grade ore, containing 60–70 per cent alumina, which was used for refractory materials such as Corhart, electrically melted and cast bricks.

In Yen-tai, Niu-hsin-tai and Hsiao-shih both the "A" and "G" beds occur; from these beds richer "ores" (averaging 55 per cent alumina and 10 per cent ferric oxide) were shipped to the Manchuria Light Metals Co. at Fu-shun for the production of aluminum. The production capacity of this company was about 15,000 metric tons per year. The metal produced was used for high-tension transmission lines from the water power plants at the Feng-man and Shui-feng dams to big cities in Manchuria.

(6) Magnesite

Magnesite is found in metamorphic rocks of the Ta-shih-chiao series of the Eo-Proterozoic Liao-ho system. It is coarsely-crystalline, white, pink, and grayish, and is associated with crystalline dolomite. The ore bodies are found in a zone extending from east of Ta-shih-chiao to east of Hai-cheng, a distance of over 40 km. A single ore body ranges in thickness from a few score to a few hundred meters and is 200–1,000 m long—large enough to permit modern large scale mechanized quarrying. The magnesite is secondary magnesite which was derived from dolomite by hydrothermal metasomatism.

The total reserves of magnesite are said to amount to several billion tons, and the reserves of rich ore—with less than 2 per cent SiO_2—to nearly 500 million metric tons. In Hamgyong-pukto, North Korea, there is the same type of deposit, with a nearly equal amount of ore reserves. So the combined area of South Manchuria and North Korea will be one of the leading sources in future of crystalline magnesite.

Calcined magnesite was produced in Ta-shih-chiao in vertical kilns, burned with anthracite; about 300,000 tons of magnesite clinkers were exported to Japan, the United States, and elsewhere in one year.

(7) Dolomite

Dolomite beds are found in many sedimentary formations of Pre-Cambrian and Palaeozoic age:—gray crystalline dolomite associated with magnesite, bluish-gray compact dolomite in the Kuan-tung series of the Sinian system, and bluish-gray compact dolomite in the Lower Ordovician series (the Wan-wan series). Of these, the second type is the most important. It is very well developed in the Kuan-tung Territory and is quarried for the manufacture of refractory materials and white paint dolomite plaster for walls.

The dolomite is believed to be a shallow sea replacement product of limestone, formed during or immediately after deposition by sea water containing magnesium ion. It occupies definite stratigraphic horizons over a wide area and there are enormous reserves.

(8) Limestone

Limestone is found in thick beds and is distributed in more stratigraphic horizons than dolomite in Manchuria.

The reserves are abundant. They are, as a rule, more or less magnesian and if more than 2 per cent magnesia is present, they are unsuitable for portland cement manufacture. But if proper horizons are selected for quarries, limestones of any of the periods listed in Table IV could be used for this purpose. Of these, the Neo-

Table 4. Geologic and Geographic Distribution of Limestone Beds in Manchuria.

Age		Type	Main localities
Eo-Proterozoic		Crystalline limestone associated with crystalline magnesite, dolomite	Ta-shih-chiao, Hai-cheng, Lien-shan-kuan, Wei-sha-ho, Mi-shan, Hao-kang
Neo-Proterozoic (Sinian)		Grayish-blue compact limestone associated with dolomite	Kuan-tung Leased Territory, Chuan-tou
Palaeozoic	Cambrian	Gray compact limestone	Kuan-tung Leased Territory, Huo-lien-chai Kang-ta-jen-tun
	Ordovician	Grayish-blue compact limestone associated with dolomite	Liao-yang (Shuang-miao-tzu), Pen-hsi-hu, Chuan-tou, Kuan-tung Leased Territory
	Carboniferous	Grayish-white crystalline limestone	Ming-cheng, Chi-lin, Erh-tseng-tien-tzu, Kuan-tung Leased Territory

Proterozoic and Ordovician in South Manchuria and the Carboniferous in Chi-lin Province are the purest and have the largest reserve.

The Showa Iron and Steel Works previously used the Cambrian limestone in Huo-lien-sai, but as the quarrying, proceeded SiO_2 in the limestone increased to more than 3 per cent and the quarry was abandoned. In recent years they used the neo-Proterozoic limestone in Kan-ching-tzu, Kuan-tung territory with about one per cent SiO_2. This difference of 2 per cent in SiO_2 content was said to justify the far longer haulage by rail. The Pen-hsi-hu Iron and Steel Works uses the Ordovician limestone in Pen-hsi-hu.

The Carboniferous limestone in Ming-cheng, south of Chi-lin, along the Mukden—Chi-lin Railway line is extremely low in SiO_2 (0.5–1.0%) and MgO (0.5–2.0%). This is the best quality in all Manchuria, and was to be used by the new Manchuria Electro-Chemical Co. at Chi-lin for the manufacture of carbide, etc.

(9) Talc

Talc is found in hydrothermal metasomatic deposits in crystalline dolomites, associated with the big magnesite deposit in the Ta-shih-chiao —Hai-cheng region.

The ore bodies are irregular in shape. The largest is in Ta-ling, 30 km southeast of Hai-cheng. The talc is white to rosy and very pure; thin slabs are often semitransparent.

The annual production amounted to 40,000 metric tons, nearly all of which was shipped to Japan.

(10) Asbestos

Asbestos is found in contact metasomatic deposits of two types: one in magnesian limestone, intruded by gabbro dikes (Ho-shang-tun, Kuan-tung leased territory, Tai-ping-fang, Jehol, and elsewhere), and the other in serpentinized limestone blocks caught by intrusive granites (Li-shu-kou, Ta-huang-kou, and elsewhere).

In the deposit of Ho-shang-tun, the asbestos is found in parallel veinlets in a zone one to two meters thick and 500 meters long of nephrite, which is contact metamorphosed limestone.

The content of asbestos varies from one to 3 per cent or, rarely, 4 per cent of the nephrite. The fibers are less than 3 cm long and are arranged perpendicular to the walls of the veinlets. The asbestos is a chrysotile of good quality.

At Tai-ping-fang, there are seven small deposits in a dolomitic limestone of Sinian age intruded by a gabbro. Small veinlets of asbestos are found in the mineralized zones, which are 0.5–2 m thick and 110–550 m long. The content of asbestos in the mineralized zone ranges from 1.1 to 3.6 per cent. The asbestos is a chrysotile with fibers 1–3 cm long.

The deposits of the second type are more irregular. They also produce a chrysotile with fibers 1–3 cm long. At Ta-huang-kou, a rare mineral, szaibelyite magnesium borate, was discovered in the asbestos deposit.

Asbestos was one of the most eagerly sought minerals during the war period. Although ore of as fine a quality as the ore produced in the Urals or in Canada was not discovered, the annual production of second grade ore (shorter fibers) amounted to 5,000–6,000 metric tons of refined products.

(11) Mica

Muscovite is found in pegmatites in the Pre-Cambrian mica schist and gneiss, and is generally associated with tourmaline; phlogopite is found among skarn minerals in Pre-Cambrian limestone in contact with intrusive granite or gneiss.

The pegmatite-type deposits are smaller and so are the dimensions of the muscovite crystals; as a rule, the contact-type deposits are more promising. Near Pa-wang-chao, the contact-type ore deposits are distributed within an area 20 by 15 km where a series of metamorphic rocks with dolomite are engulfed in gneiss. The dolomite is intruded by aplite and pegmatite dikes, and phlogopite and diopside are present along the area of contact. This area has recently been discovered and is worth further prospecting. It promises to be one of the largest phlogopite deposits in East Asia.

(12) Fluorite

Fluorite is usually found in quartz veins in granite, gneiss and quartz porphyry, and other rocks, and in rare cases in a contact metamorphic deposit (Ma-lu-kou).

Fluorite-bearing quartz veins are known from twenty or more localities and have been exhaustively prospected. Deposits near Lung-hua, Jehol Province, and Na-lo-mu-to, north of Hailar, are larger and more promising.

The ores as mined are mixed with quartz and sometimes with barite and need dressing in order to raise the CaF_2 content. We heard recently that an oil-flotation process had been successfully applied. In 1943 the production of ores with more than 93 per cent CaF_2 was 11,000 metric tons; with less than 93 per cent, it was 26,400 metric tons, for a total of 37,400 metric tons.

(13) Boron minerals

Ludwigite ($3MgO.B_2O_3.(Fe,Mg)O.Fe_2O_3$) was first found in the Hua-tung-kou copper mine. The mineral is in a dense, felt-like aggregate of dark bluish-black acicular crystals, in the skarn zone of the contact metasomatic copper deposit of the mine. Richer ores analyze at 15 per cent B_2O_3, the reserve of which is estimated to be only 1,000 metric tons, whereas reserves of ores containing about 10 per cent B_2O_3 are believed to amount to 4,000–5,000 metric tons. Several hundred tons of the richer ores were shipped to Japan for the manufacture of a boron glass (a special hard glass used for ampoules, etc.), as a substitute for imported borax.

Another rare mineral called szaibelyite ($10MgO.4B_2O_3.3H_2O$) was found in the Ta-huang-kou asbestos deposit in 1942. This mineral occurs in spots or irregular vein-like masses and is associated with asbestos, ludwigite, humite, and magnetite. Rich ores give 8–11 per cent B_2O_3. The amount of reserves of rich ore is calculated to be only several hundred tons, but that of poorer grades is very large—27,000 metric tons of ores with 4–5 per cent B_2O_3 and 200,000 metric tons with 2 per cent.

A tourmaline schist which contains an unusually large number of tourmaline crystals was found to the east of Ta-shih-chiao. The schist gives 6–9 per cent B_2O_3 on analysis. It is said that utilization of this schist was considered, but details are not known.

(14) Vein-quartz and feldspar

Vein-quartz is found either in pegmatites in association with feldspar or in quartz veins. Pegmatites are found abundantly in gneiss regions in the Kuan-tung leased territory and near Hai-cheng.

Among the larger pegmatites in Hai-cheng region are those with a zonal structure. The outer zones consist of smaller crystals of quartz and feldspars in an intimate graphic intergrowth, whereas the inner zones consist of an aggregate of the same minerals but with larger (20–30 cm in diameter) separate crystals. Only the inner zones are quarried for quartz and feldspar, because the minerals are easily separated by hand picking.

Feldspars in the outer zones are richer in potash and in this respect, better suited for glass manufacture than those in the inner zones, which contain less potash (6–7 %) and a greater amount of soda.

The vein-quartz in Kuan-tung leased territory was used for the manufacture of the gauge glass and cut glassware in the Nanman Glass Works in Ta-lien.

Feldspars with a high content of potash (11 %) were found in orthophyre dikes northeast of Tsao-ho-kou, Mukden—An-tung Line but were not utilized because of inconvenience of transportation.

(15) Quartzite

Quartzite occurs in thick beds in the Ta-ho-shang-shan series of the Neo-Proterozoic, or Sinian system in Kuan-tung leased territory, and elsewhere. When pure, it contains 99 per cent SiO_2 and 0.2 per cent iron and is good enough for window glass.

Quartzite in Lu-shun (Port Arthur) and in Ta-lien was extensively quarried and shipped to Japan for the manufacture of dinas (silica) bricks for coke ovens, etc.

(16) Natural soda

Natural soda, together with salt, occurs in saline lakes near Hailar and Tao-nan. Both are utilized by the natives. Beside Na_2CO_3, soda minerals occur in many forms; among them is a rare mineral, gaylussite ($CaCO_3.Na_2CO_3.5H_2O$).