Magnesite Deposits in the Districts of Ta-shih-chiao and Hai-cheng, Manchuria

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I. Introduction

Existence of magnesite deposits in Manchuria became known in 1913 when YOSHIZAWA, a chemist at the Central Laboratory of the South Manchuria Railway Company collected magnesite ore at Chuan-shan-tzu in Kai-ping county, Mukden Province. Subsequently, the Geological Institute of the South Manchuria Railway Company, the Geological Survey of Manchoukuo and the Manchuria Mining Development Company carried out geological survey and discovered numerous deposits of magnesite in such places as the Ta-shih-chiao and Hai-cheng districts (Niu-hsin-shan to Hei-shan) of Mukden Province, Ma-chou of Shang-nien in Fu-shun county, Wa-fang-tien in Hsiu-yen county, An-tung Province, Hei-lao-wu-shih and Hsiao-fang-shen in An-tung county, An-tung Province, in addition to the above-mentioned Chuan-shan-tzu. The deposits, especially in Ta-shih-chiao and Hai-cheng, were found to surpass, in both quality and quantity, the magnesite deposits in Germany, Austria and Italy which were believed to rank as top in the world. Thus, magnesite became one of Manchuria's largest products, along with soybeans and coal.

II. Location and Transportation

Distribution of the magnesite deposits in the Ta-shih-chiao—Hai-cheng districts extends over three counties, Kai-ping, Hai-cheng and Liao-yang, of Mukden Province. The Niu-hsin-shan deposit located about 7.5 km southwest of Ta-shih-chiao station marks the western end of the distribution area. Starting from Niu-hsin-shan the magnesite deposits extend N70°E for about 70 km with a maximum width 4 km. Known for magnesite deposit are; Pai-hu-shan, Hung-chi-shan, Kao-li-cheng-shan, Hou-pai-chai-tzu, Kuan-ma-shan, Sheng-shui-ssu, Hsiao-sheng-shui-ssu, Hsiao-kao-chuan-tun, Hsiao-kao-chuan-tun, Ping-erh-fang, Ching-shan-pai, Shui-chuan, Ching-shan-ssu, Chia-chia-pu-tzu, Hsia-fang-shen, Chin-chia-pu-tzu, Yang-chia-tien, Li-shu-kou, Hung-tu-ling-tzu, Fan-le-ma-yu, Hsi-

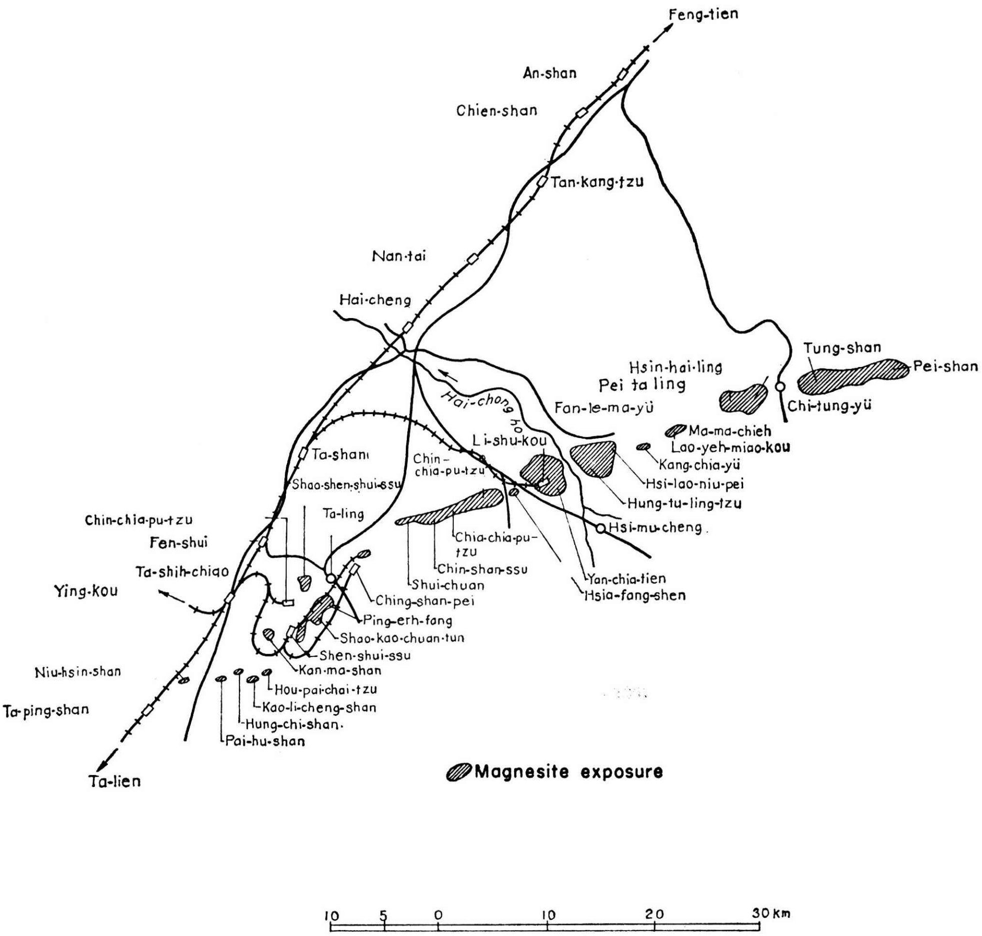

Fig. 1. Magnesite deposits area in Ta-shih-chiao, Hai-cheng district.

lao-niu-pei, Kang-chia-yu, Lao-yeh-miao-kou, Ma-ma-chieh, Pei-ta-ling, Hsin-kai-ling, Tung-shan and Hei-shan.

The Lien-ching Railway runs along the western margin of these deposits in a NE–SW direction, with such stations as Ta-ping-shan, Ta-shih-chiao, Fen-shui, Ta-shan, Hai-cheng, Nan-tai, Tang-kang-tzu, Chien-shan and An-shan. For transportation of ore, there are the branch railways, belonging to the South Manchuria Railway Company, between Ta-shih-chiao station and the Ta-shih-chiao plant for a distance of 1.5 km, and from the Ta-shih-chiao station to the Sheng-shui-ssu plant and to the Ching-shan-pai mine for 20 km; the electrified branch railway of the South Manchuria Mining Company between the Sheng-shui-ssu plant and the Hsiao-sheng-shui-ssu mine for 2 km; the branch railway of the Manchuria Talc Industry Company between Ta-shan station and the Yang-chia-tien mine for 28 km; the cablecar between the Sheng-shui-ssu plant and the

Ching-shan-pai mine for 8 km. From the highway between Hai-cheng station and Hsi-mu-cheng a truck road branches off to the Chin-tzu-pu-tzu mine. A truck road runs also from Fen-shui station to Hai-cheng station via Ta-ling, from Hai-cheng station to Fen-le-ma-yu, and from An-shan station to Chi-tung-yu.

Thus, the transportation between the sites of ore deposits and the Lien-ching Railway is convenient, and the ore is carried from those stations to the Ta-lien and Ying-kou ports.

III. Topography and General Geology

A. Topography

The area reported on is located on the western slope of the Liao-tung backbone range which trends in the Sinian direction, and has old or mature-stage topography.

The ridge of the range, starting from Niu-hsin-shan in the west and stretching roughly in a N70°E direction, is composed largely of dolomite and magnesite. The western part of the range is hilly land, but the range becomes higher and steeper toward the east. In the eastern part the southern slope is gentler than the northern slope. The land along the Lien-ching Railway has been dissected for the most part, leaving behind monadnocks in places.

Few of the drainage systems are notable. The Hai-cheng River, the Pa-li-ho and its tributaries (all being branch streams of the Liao-ho) flow through the central part of the area, and the western part is drained by the Ching-ho. They flow either parallel to or at right angles with the strike of the strata.

B. Geology

Geology of the area is represented by the Liaoho system, named by Saito (1937, 1938, 1943), comprising metamorphic rocks and sedimentary rocks of Archean age. The Liaoho system is divided into three parts, the upper (Kaiping series), the middle (Tashihchiao series) and the lower.

The upper and lower parts are composed chiefly of phyllite, locally accompanied by injection gneiss, mica schist and talc schist. The middle part is mostly dolomite containing *Collenia*-like fossils(?), and is intercalated with phyllite, sericite-chlorite schist and talc schist, striking N 60–90°E and dipping 30–50°S. These rocks are unconformably covered by quartzite of the Proterozoic Sinian system which is locally exposed on the ground surface. The Quaternary sediments, consisting of loess, sand and gravel, are distributed along the rivers and at the foot of the mountains.

Representative igneous rocks are granites. Small exposures of lamprophyre dikes are found in places. Most of the granites are gray, grayish white or pink granite gneiss which locally becomes dioritic. Where the granites intrude the Liaoho system, injection gneiss has been formed. Judging from the fact that the granites are unconformably overlain by the quartzite of the Sinian system, as well as on the basis of their lithologic character, the greater part of the granites can be correlated with the Late Archeozoic Kungchangling granite (SAITO, 1938; HADA, 1925, 1931; TSURU,—) that is widely developed in South Manchuria. The lamprophyre dikes are usually about 1 m in width, dark green (or grayish brown when weathered), fine-grained and compact. They intrude the rocks of the Liaoho system, but the age of intrusion remains unknown.

IV. Magnesite Deposits

A. Mode of Occurrence

Magnesite deposits occur in the dolomite of the Tashihchiao series, which extends from Niu-hsin-shan to Hei-shan in a N70°E direction for about 70 km with a maximum width 4 km. The dolomite stretches farther east, so that the occurrence of magnesite is possible in the eastern area also. (There is reliable information that magnesite deposits exist in the vicinity of Chi-chia-pu-tzu station on the An-feng Railway line).

Magnesite deposits are usually interbedded within dolomite, and the bedding plane is roughly parallel with that of dolomite. In some places, however, the deposits have an irregular massive form without showing any distinct bedding, as observed in the Hsiao-sheng-shui-ssu deposit and in part of other deposits. The boundary of the ore deposits is generally uneven except for the cases where the deposits are in fault contact with the country rock, namely, dolomite. Both ends of the bedded ore bodies terminate abruptly in an irregular plane, seldom thinning out. Ore bodies occasionally contain dolomite pebbles. In some parts of the footwall of the Ching-shan-pai and Sheng-shui-ssu deposits, brecciated magnesitic dolomite is found in the contact with the country rock.

The ore deposits are intruded everywhere by lamprophyre dikes and quartz veins. Talc veins are abundant along the boundary between the deposits and dolomite.

It is worthy of mention that ore deposits occurring at the apex of an anticlinal structure of dolomite are generally large and excellent in quality whereas those at the bottom of a synclinal structure are poorly developed and inferior in quality. This characteristic mode of occurrence, as exemplified by the deposits at Hsiao-sheng-shui-ssu, Ping-erh-fang and other places, requires further study.

B. Ore Grade

Magnesite of the report area is crystalline and has a white, grayish white, gray or pink tint. On a fresh surface magnesite has a strong glassy lustre by which it can be distinguished from dolomite. When weathered, dolomite assumes a gray or grayish white, massive and relatively smooth appearance while magnesite is usually gray to grayish yellow or grayish brown, and coarse sandy. Distinction with the naked eye between dolomite and so-called dolomitic magnesite (containing free dolomite so that the MgO content is too small to be economically mined) is difficult.

In comparison with magnesite ores of foreign countries the magnesite ore of this area contains less impurities, especially the CaO, Fe_2O_3 and Al_2O_3 contents are very small, although some parts abound in SiO_2 which may have been derived from talc. When lime and silica are less than 1% each, the ore is ranked as first class.

The magnesite ore of the report area is variable in character, and can be classified into the following three types:

(1) Sheng-shui-ssu type
(2) Hsiao-sheng-shui-ssu type
(3) Ching-shan-pai type

(1) Sheng-shui-ssu type

This is the most predominant type in the area. Ore occurring as bedded deposits at Sheng-shui-ssu and to its west belongs to this type. It is coarse-grained, white or grayish white, sometimes pink, and partially banded with gray and grayish black layers. A stylolitic structure is locally observed.

The major components (%) are as follows:

Ignition loss	SiO_2	$Fe_2O_3+Al_2O_3$	CaO	MgO
50.0	2.5	1.0	1.0	45.5

Because of the large content of SiO_2 the ore is unfit for dead burning.

(2) Hsiao-sheng-shui-ssu type

Microcrystalline, snow-white ore belongs to this type. Its fresh surface is hardly distinguishable from microcrystalline marble, but its strong lustre helps discriminate it from the latter. In most cases the ore of this type is irregular and massive in form.

The major components (%) are as follows:

Ignition loss	SiO_2	$Fe_2O_3+Al_2O_3$	CaO	MgO
51.0	1.0	1.0	0.5	46.5

It is best for clinkering because of the least amount of impurities such as CaO and SiO_2. This type is represented by the ore from E section of the Hsiao-sheng-shui-ssu mine. Part of the ore from Fan-le-ma-yu, Pei-ta-ling and Hsin-kai-ling belongs to this type. Similar ore is found at Wa-fang-tien of Hsiu-yen county, An-tung Province.

(3) Ching-shan-pai type

This is an intermediate type between (1) and (2). When fresh, the ore is white or pale pink, becoming grayish brown when weathered. It is medium- to coarse-grained and occurs where bedded ore and massive ore coexist.

The major components (%) are as follows:

Ignition loss	SiO_2	$Fe_2O_3+Al_2O_3$	CaO	MgO
51.0	1.0	1.5	0.5	46.0

In quality it is somewhat inferior to type (2), but a large content of Fe_2O_3 and the coarseness make sintering easy, so that the ore is good for dead burning.

This type is represented by the ore from the main body of the Ching-shan-pai deposit. Part of the ore from the Hsiao-kao-chuang-tun, Ping-erh-fang and Chin-chia-pu-tzu deposits also belongs to this type.

C. Ore Reserves

Estimated reserves of magnesite ore in the Ta-shih-chiao—Hai-cheng districts are as follows:

Name of deposit	Uses	Reserves (t)
Niu-hsin-tai	Calcined, partly dead burnt	2,000
Pai-hu-shan	Calcined	20,000
Hung-chi-shan	Calcined	500
Kao-li-cheng-shan	Calcined	200
Hou-pai-chai-tzu	Calcined	20
Kuan-ma-shan	Calcined	50,000
Sheng-shui-ssu	Calcined	50,000
Hsiao-sheng-shui-ssu	Dead burnt	50,000
Hsiao-kao-chuang-tun, Ping-erh-fang	Calcined, partly dead burnt	500,000
Ching-shan-pai	Dead burnt	50,000
Shui-chuan, Ching-shan-ssu, Chia-chia-pu-tzu, Chin-chia-pu-tzu	Calcined, partly dead burnt	2,000,000
Hsia-fang-shen	Calcined	3,000
Yang-chia-tien, Li-shu-kou	Calcined, partly dead burnt	1,000,000
Hung-tu-ling-tzu, Fan-le-ma-yu, Hsi-lao-niu-pai	Dead burnt and calcined	4,000,000
Kang-chia-yu	Calcined	20
Lao-yeh-miao, Ma-ma-chieh	Calcined	50
Pei-ta-ling, Hsin-kai-ling	Calcined and dead burnt	1,000,000
Tung-shan, Hei-shan	Calcined	1,500,000

D. Origin of the Deposits

Regarding the origin of the magnesite deposits in the Ta-shih-chiao—Hai-cheng districts, there are two different views. One maintains a primary precipitation origin and the other a sedondary replacement origin. In the genetical study of the magnesite deposits the following facts may be referred to:

(a) Magnesite is crystalline.

(b) Most of magnesite deposits occur in a bedded form or as irregular masses within dolomite.

(c) Their boundary with dolomite is always somewhat uneven.

(d) On some occasions, brecciated dolomite is found within the ore deposits, or in the footwall of the ore deposits as seen at Ching-shan-pai and Sheng-shui-ssu.

(e) Around the ore deposits are found large bodies of intrusive rocks which are supposed to be the Kungchangling granite.

(f) Pseudomorphs of clinochlore, probably derived from monoclinic augite, and pseudomorphs of limonite after pyrite are contained in the ore deposits.

(g) Tale deposits which are apparently of hydrothermal origin are often associated with magnesite deposits.

All these points suggest that dolomite is the country rock of the magnesite deposits in the districts of Ta-shia-chiao and Hai-cheng, and that the deposits are of hydrothermal replacement origin connected with the Kungchangling granite. Nevertheless, the formation mechanism of the deposits awaits further study.

Regarding the origin of the Hei-lao-wu-shih magnesite deposit in An-tung Province, Asano (1940) proposed the following interesting interpretation: Impure dolomite undergoes thermal and regional metamorphism——olivine-diopside rock or olivine-diopside dolomite is formed——hydrothermal action takes place under somewhat uneven pressure——talc rock, serpentine-talc rock, chlorite rock, tremolite rock and edenite rock are formed, giving rise to formation of magnesite deposits. However, this interpretation does not apply to the magnesite deposits of the Ta-shih-chioa—Hai-cheng districts because presence of any rocks corresponding to tremolite rock and edenite rock remains unknown there.

Although Kato (1943) and Saito (1938A) attached importance to the existence of lamprophyre dikes, the dikes are apparently unrelated to the origin of magnesite deposits so far as the observations at the Hsiao-sheng-shui-ssu and other deposits are concerned.

E. Mining

For the purpose of exploiting the magnesite deposits in the Ta-shih-chiao—Hai-cheng districts, the South Manchuria Mining Company was established in 1918 as an affiliated company to the South Manchuria Railway Company.

The company acquired the greater part of the mining concession and started mining of ore by the stepped (10–20 m) open-cut method. The Niu-hsin-shan deposit in the westernmost area was mined by the Showa Steel Works, and part of the Yang-chia-tien deposit in the central area was worked by the Kang-te Mining Company. In several other places the ore was exploited by small private companies. The principal mining places are as follows:

Name of deposit	Mode of occurrence	Ore grade (%)	Equipment	Average daily yield (t) in 1944
Niu-hsin-tai	Bedded	$CaO=1$ $SiO_2=2$		150
Kuan-ma-shan	Bedded	$CaO=1$ $SiO_2=2.5$	Hand-digging	300
Sheng-shui-ssu	Bedded	$CaO=1$ $SiO_2=2.5$	Compressor (100 HP) 1 Jackhammer 6	300
Ping-erh-fang (including Hsiao-kao-chuang-tun)	Bedded, partly massive	$CaO=1$ $SiO_2=2$	Hand-digging	500
Haiso-sheng-shui-ssu	Massive	$CaO=0.5$ $SiO_2=1$	Compressor (200 HP) 1 Compressor (100 HP) 4 Jackhammer 30 Drill-sharpner 1	800
Ching-shan-pai	Bedded, partly massive	$CaO=0.5$ $SiO_2=1$	Compressor (100 HP) 4 Jackhammer 20	300
Chin-chia-pu-tzu	Bedded, partly massive	$CaO=1$ $SiO_2=2$	Hand-digging	100
Yang-chia-tien	Bedded, partly massive	$CaO=1$ $SiO_2=2$		150

The annual production of the South Manchuria Mining Company since 1926 is listed below:

1926	13,400 (t)	1936	135,000 (t)
1927	20,300	1937	131,000
1928	26,600	1938	223,000
1929	33,900	1939	385,000
1930	31,300	1940	450,000
1931	25,200	1941	500,000
1932	43,400	1942	550,000
1933	48,000	1943	600,000
1934	58,000	1944	700,000
1935	90,000	1945	—

In 1944, in compliance with the demand of the Japanese Kuan-tung Army for increased magnesite production for wartime supplies, the South Manchuria Railway Company laid a branch railway between the Sheng-shui-ssu plant and the Ching-shan-pai mine. However, the war terminated before the operation aiming at the output of 1,000 kt per year was put into practice.

F. Uses

Magnesite is used for the following purposes.

(a) Dead burnt magnesia (heated at 1,500 to 1,600°C)
(magnesia, clinker, magnesia-brick) → (refractory material for open furnace and electric kiln in steel manufacture)

(b) Carbon dioxide (produced in calcination of ore)
(dry ice, liquified CO_2, refreshing drinks, other industries)

(c) Calcined magnesia (heated at 700 to 800°C)
magnesium chloride → metal magnesium
magnesium carbonate → (rubber compound, medicine, adulterant in tooth powder and cosmetics, paints, printing ink, polisher, filler)
magnesium sulphite → wood pulp manufacture
magnesium sulphate → medicine, rayon coagulant
magnesium nitrate → (solvent of regenerated silk, porcelain and glass manufacture, fertilizer manufacture)
Lignoid* → building and flooring
Matris* → building and flooring
Elasco* → building and walling
Rockstacco* → building and walling
(* commercial name)

G. Equipment and Capacity

(1) Magnesia

Shaft Kiln:—Magnesite ore and anthracite (Hongei coal from French Indo-China and Yang-chuan coal from North China) are packed alternately in a shaft kiln and heated at 1,500 to 1,600°C with the help of an air blower, thus producing magnesia, or magnesia-clinker. Approximately 20 to 30 tons of ore is used for one kiln. The process requires about 48 hours. Daily output of clinker is about 5 tons. The number of shaft kilns in the Ta-shih-chiao district is as follows:

Company	Location	Number of kilns
South Manchuria Min. Co.	Ta-shih-chiao Sheng-shui-ssu Fen-shui	29 72 4
Kang-te Mining Co.	Ta-shih-chiao Yang-chia-tien	6 5
Tien-on Kung-ssu (Co.)	Ta-shih-chiao	5
Fu-yuan Kung-ssu	Ta-shih-chiao	6
Hsing-yuan Kung-ssu	Ta-shih-chiao	3

Tunnel Kiln:—The South Manchuria Mining Company installed a tunnel kiln at Sheng-shui-ssu, but before yielding any notable results the company met the end of the war. Magnesia clacined in a rotary kiln is pulverized and air-dressed to get rid of impurities. Then it is compressed into square blocks, and placed in a tunnel kiln to be heated at 1,500–1,600°C. Magnesia-clinker is thus produced. The company had a low-temperature dry-distillation plant and a gas generator, producing Coalite (commercial name) and coal gas to be used as fuel for the tunnel kiln. The manufacturing process, comprising preliminary heating, incandescence and cooling, requires about 24 hours. Daily output is about 300 tons.

A tunnel kiln is superior to a shaft kiln in the respects that ore-dressing can be accomplished, addition of impurities from fuel can be prevented and successive heating can be performed.

(2) Calcined Magnesia

Reverberatory Kiln and Shaft Kiln:—Using coal as fuel, magnesite is heated at 700–800°C. About 6 hours are needed to obtain calcined magnesia. Daily output is about 10 tons by a reverberatory kiln and about 12 tons by a shaft kiln. The number of kilns for calcination in the Ta-shih-chiao district is as follows:

Company	Reverberatory kiln		Shaft kiln	
	Location	Number	Location	Number
S. Manchuria Min. Co.	Ta-shih-chiao Sheng-shui-ssu Kuan-ma-shan Kao-chuang-tun	13 9 26 20	Fen-shui	4
Kang-te Mining Co.			Yang-chia-tien	10
Shirakawa-gumi			Ta-shih-chiao	6
Hsing-yuan Kung-ssu			Ta-shih-chiao	2

Rotary Kiln:—The Sheng-shui-ssu plant of the South Manchuria Mining Company has two rotary kilns (the smaller one is seldom operated). Lumps or powder of ore are heated in a rotary kiln at 700–800°C to get calcined magnesia. Fuel for the larger kiln is coal gas produced by the appurtenant coal-distillation plant and gas generator. Calcination requires about 3 hours. Daily output of the larger kiln is about 600 tons and that of the smaller kiln is about 10 tons. A rotary kiln has the following advantages: Powder ore, which in the past was discarded as waste, can be calcined, consecutive operation can be performed, and it can be operated with a tunnel kiln which helps eliminate impurities.

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