Survey Report on the Bain-Bokto Iron Ore Deposit in Wulanchapu Mêng, Inner Mongolia

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I. Preface

In July, 1940, I surveyed the Bain-Bokto ore deposits for seven days while T. KAGAMI took charge of the topographic survey.

The deposit in Bain-bokto is excellent, in respect to both ore reserve and quality. It occurs, however, in a remote region that is still unexploited. I intend to introduce in this paper the results of my survey for future developments.

II. Location and Access

Bain-Bokto[1] is situated on the western extremity of Haerh-ha Yuchi (Taerh-hanpeilêchi) in Wulanchapu Mêng, and is adjacent to Maominganchi, in the west. The iron ore deposits occur some 48 km from the WNW of Pailingmiao,[2] where the government office of Wulanchapu Mêng is located.

A road extends westward for 34 km from Pailingmiao to Chungkung Mêng. Then, to its north for 14 km, there is an undulating grassy plain having no road and continuing far beyond the horizon. However, it is possible to establish a good road without artificial rolling or hardening of the road surface by running horses and vehicles daily. Along the way, there are river beds and swamps in several places. However, the Chungkung Mêng road is usually rather busy, so the road surface is generally hard enough for trucks, except during rainy season (see section on climate). It takes one hour and half to run from Pailingmiao.

There are four roads connecting Pailingmiao to important villages, i.e., Huhuhéto Line, Paotou Line, Chungkung Line and Hsisunite Line; each of Huhuhéto and Paotou lines are connected with the railway.

Pailingmiao is located about 156 km northwest of Huhuhéto (Suiyuan), along

1) Both Bain and Bokto mean fertile and holy place or sacred ground, respectively, in the Mongolian Language.

2) Pailingmiao is called Bato Hargan-Sumê in Mongolian. Bato means strong or stable, Hargan means gate of a castle, and Sumê means a manusoleum.

the Peking-Paoťou Railway Line and also, about 150 km north-northeast of Paoťou. The area along Pailingmiao to Wuchúan, some 111 km in distance, is occupied generally by grassy land, but swamps are rare. Trucks and other vehicles can therefore easily pass any time, except rainy season. However, the road between Wuchuan and Huhuhéto, 45 km distance, has a steep mountain path, crossing the Yinshan Mountain Range, and the road conditions are not favourable. Furthermore, the road between Pailingmiao and Paoťou is generally better than the road described above.

Trucks, camels and donkeys are used for traffic, and it takes four to five hours, to run by truck between Pailingmiao and Huhuhéto and also, between Pailingmiao and Paoťou.

III. History of Investigation and Problems Concerning Concession

In the 13th Year of Republic of China, Tingtaohêng of the National Geological Survey of China first investigated the area. As there is no fixed right of domain in Mongolia, as the rule, the land has been available freely for any inhabitant of the region. Recently, however, taxes have been imposed in some places.

The famous Bain-Obo is located on the summit of Bain-Bokto. As Obo is the mecca for Mongolians, it is strictly prohibited to plant or dig up the ground in the area, and therefore no application for mining, has been recorded up to date.

IV. Topography and Geology

There are rolling hills, generally 20–30 m high, near the ore deposits, and the dome shaped hill of Bain-Bokto-Agola,[3] some 100 m high, exist above these low hilly tracts.

Rocks occurring in the area, being composed of crystalline schist, siliceous limestone, and loess, and fluorite can be seen, even in the older rock series. Beside these, a contaminated diorite is exposed at the site, some 1 km to the south or the southeast of this area. The details of each rock series will be stated in the following.

(1) Crystalline Schist: These may be divided into alkali hornblende-quartz schist and graphite-sericite schist.

(a) Alkali hornblende-quartz schist is exposed in the northern extremity of this region, and is in direct contact with siliceous limestone, but the stratigraphic relation between these two is unknown, because they were bordered directly with a fault. The rock shows dark gray colour, often schistose, and consists mainly of quartz, plagioclase and alkali-hornblende. The alkali-hornblende mineral shows light purplish blue in colour, having small columnar crystal form, abundant in the rock and resemblance in appearance to cyanite minerals.

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3) Agola means a height.

(b) Graphite-sericite schist is overlaid by boulders or blocks of iron ores, south of the main ore body, and is peeped out in small area at the bottom of the dales or ridges. It is composed chiefly of small grained quartz, sericite and graphite, and often associated with biotite, showing schistose structure. The schistosity varies from N80°W to N80°E in strike, dipping more than 65° to the south. The structural relation between this rock and the siliceous limestone is obscure. The rock is traversed often by quartz or feldspar veins of 3 cm (max. 4.5 cm) in width, and accompanied frequently with fluorite, forming fluorite schist, in places where the content of fluorite minerals relatively abundant.

(2) Siliceous limestone, is exposed to a relatively wide limit at the north of the main ore body, but is covered with boulders or blocks of iron ores near the main ore body. The rock is light blue or dark bluish gray coloured, and massive. The bedding is undefined, in general, but so far as my observations could determine, the strike runs N25–30°E, dipping 40–55° southward, in the northern area. However, the bedding running eastwesterly with 40–45° dip to the south, in the southern area. Then, a fault may be supposed by reason of the discontinuity between these two areas. In addition, the limestone occurring near this supposed fault in the northwest of ore body I, being altered and alkali-hornblende, aegirine-

Table 1.

Number of Samples	Occurrences	CaFe	SiO_2	FeO	P	S	CaO	Ig. Loss	Sp. Gr.
4	Impregnated in compact iron ore, mixed hematite and magnetite	12.39	0.28	51.56	0.029	tr.	—	—	4.71
19	//	14.13	0.74	45.88	0.040	0.003	—	—	3.66
38	Impregnated in magnetite	15.73	0.08	36.24	0.034	0.001	—	—	4.37
9	Impregnated in hematite	43.23	0.26	30.84	0.034	0.001	—	—	4.70
35	Impregnated in low grade iron ores, replaced limestone	59.86	—	14.80	—	—	1.03	1.35	—
37	Impregnated in low grade iron ore, remaining rather large amount of limestone due to incomplete replacement	2.05* (?)	—	26.10	—	—	26.10	32.55	—

Note: * As the content of fluorite may be observed as 10–15% in naked eyes, this value will be doubtful.

augite, epidote and fluorite, are contained sometimes rather large amount in the rock.

(3) Loess, is a loamy grayish brown soil, and covers all of the preceding rocks.

Fluorite

Having a purple colour it occurs as disseminated or vein form in crystalline schist, limestone and iron ores, and is especially rich in the main ore body and their environs. The value of analysis of fluorite contained in iron ores, are as follows: (Analysed by the Central Laboratory of the South Manchuria Railway Co. Ltd.)

Except for the above-described occurrences, fluorite mineral could be detected obviously with the naked eyes at seventeen places. Fluorite veins in the fluorite schist and limestone are superior in tenor, and contain about 50% CaF_2.

Regrettably, due to lack of time I could not carry out field survey sufficiently, and could only prepare the extent of occurrences and an assay map of the fluorite-bearing ores, but also average contents of CaF_2% in iron ore deposits. However, it is probable that the ore is suitable for use in blast furnaces and open-hearth furnaces or converters. In my mind, the mine is the first example of an iron ore containing fluorite. After the survey, F. Homma stated that rare minerals could be found in these fluorite-bearing rocks.

V. Ore Deposits

The iron ore minerals are chiefly hematite with subordinate magnetite. The deposits formed by replacement, and small ore bodies around the main ore body, with incomplete replacement residual rock particles, may constitute a small or major part of the ore.

Two or three zones, containing quite a lot of aegirine, are found nearby.

Most of the ore bodies occur in limestone. However, a few of them, occur in graphite-sericite mica schists.

The ore can be detected, distinctly upon the exposure of hematite and magnetite enriched parts as shown on the geologic map (Fig. 1) and these ore minerals are mixed up intensely in places, forming compact ore mass.

Hematite is mainly dark gray in colour, with metallic luster and massive. It is accompanied by small amounts of scaly-type micaceous iron ore.

Magnetite is remarkably iron-black in colour, granular or massive, and magnetic.

The main ore bodies, such as I and II, being close contact with each other, are exposed in lenticular shapes in the southern part of the summit. Ore body I, is 900 m long from east to west, and averages 200 m, with maximum 300 m, in breadth. While ore body II, is 700 m long from east to west, and averages 100 m with maximum 150 m, in breadth. The dip of these ore bodies, tends to incline from 45°–60° forward the south.

There are seven small ore bodies in limestone and three in graphite-sericite

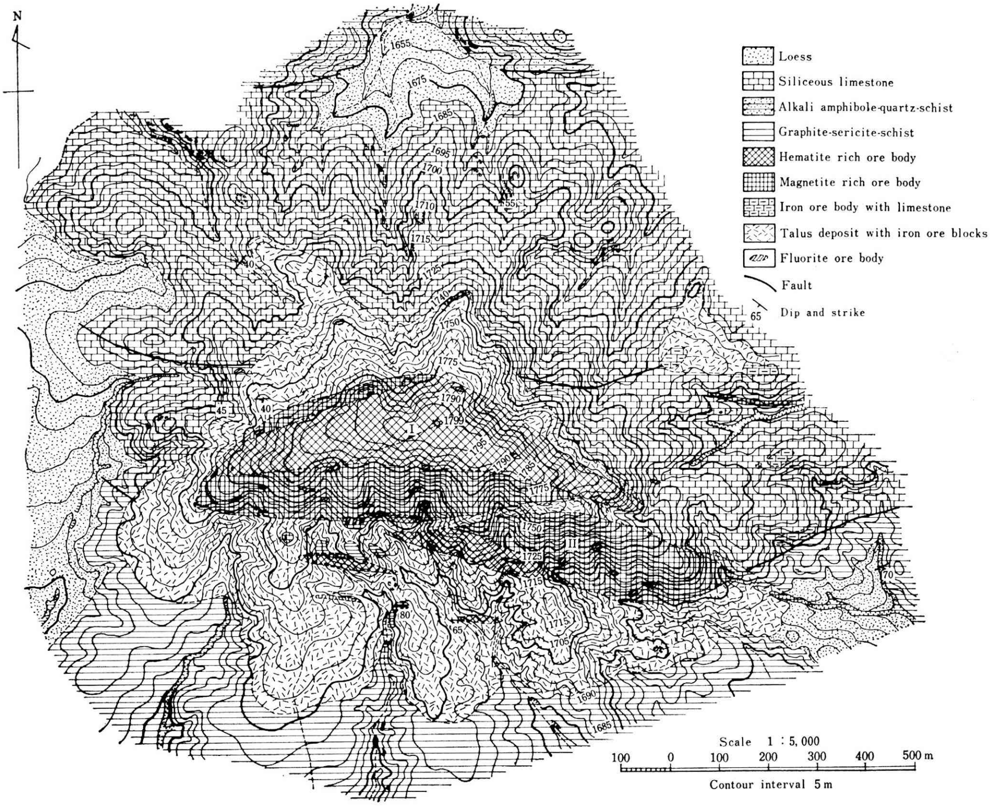

Fig. 1. Geological map of Bainbokto (Pai-yun-pokuto) iron ore deposit.

schist, so that the total sum of the small ore bodies is ten. The largest one among them, is 200 m long, and is some 20 m, in breadth; while the smallest one, is less than 10 m long, and is only 1 m, in breadth. Moreover, most of the small ore bodies are about 10 m long and 2–3 m in breadth.

These small ore bodies, which occur mostly near the main ore body, have either less or a lack of surface-soil capping and are well exposed. Therefore, open-pit mining is possible.

Boulders and Blocks

Boulders and blocks of iron ore are generally scattered irregularly around the northern and the southern parts of the main ore body. They are accumulated as angular-shaped ore masses, especially in the southwestern margin of ore body **I**, and can be mined by the open-pit method. Each ore size varies from the size of a fingertip to the size of a cow's head, but are mostly larger than a man's fist. The thickness of their accumulations is estimated to be more than 1 m.

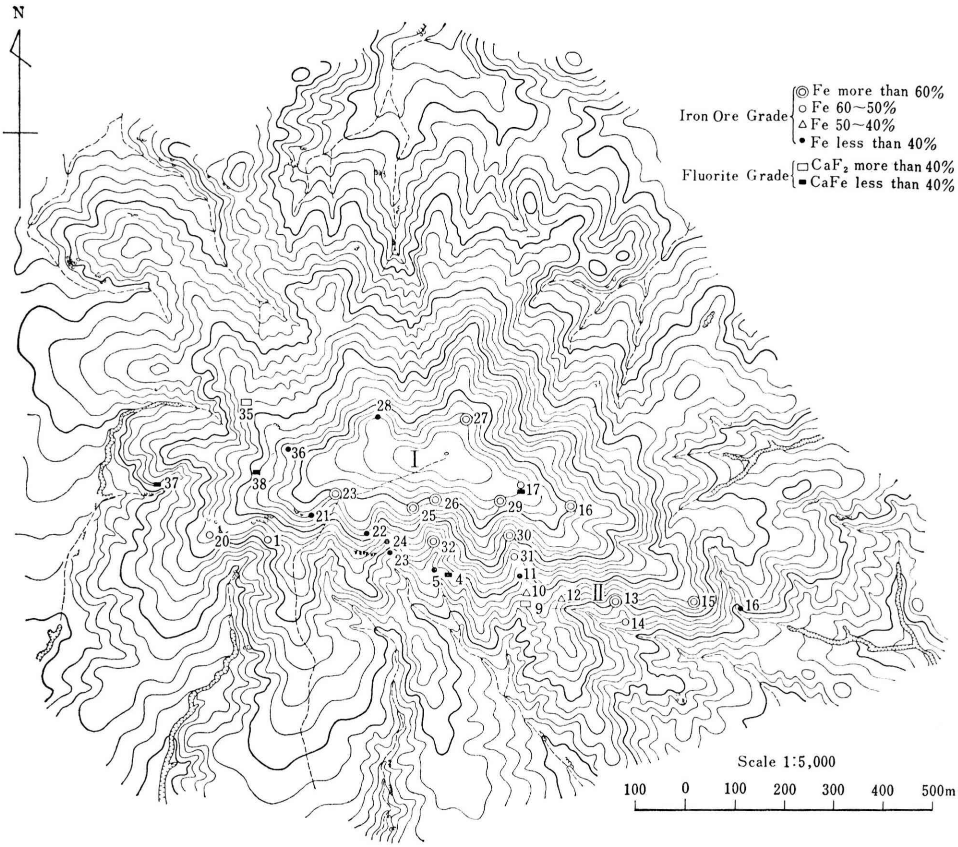

Fig. 2. Sampling localities of Bain-bokto (Paiyunpokuto) iron ore deposit.

VI. Quality and Ore Reserve

A. Quality

Chemical analysis of specimens was performed exclusively by the Central Laboratory of the South Manchuria Railway Co. Ltd.

Eighteen specimens were collected at random from the main ore body I, and the average contents revealed was 48.59% Fe, 9.98% SiO_2, 0.21% P, and 0.07% S, specific gravity was 4.43. These values do not indicate the highest quality, because of impure rock occurrences as described in the remarks concerning fig. 2: namely, seven specimens (39%) include moderately large amounts of siliceous limestone, fluorite or aegirine, and of low grade ores, varying from 20–40% Fe; their distribution is confined to specific areas. If these impure parts are excluded, the average value for other eleven speciments of relatively rich ore become 61.67%

Table 2. Chemical Composition of Ores Four the Main Ore Body I.

No.	Fe	SiO_2	P	S	Va	Cr	Ti	Cu	Mn	Ca F_2	Sp. Gr.	Remarks
1	52.67	0.18	0.059	0.089	—*	0.01	tr	—*	0.13	—	4.70	
17	51.56	0.28	0.029	tr	—	—	—	—	—	12.39	4.71	Contains fluorite
18	66.13	0.72	0.081	0.125	—*	—*	tr	—*	0.13	—	4.75	
20	53.63	0.34	0.212	0.147	—*	—*	0.244	—*	0.08	—	4.72	
21	26.87	47.30	0.383	0.058	—*	—*	Re	—*	0.06	—	3.36	Siliceous limestone of about 10% contained.
22	27.88	28.78	0.502	0.113	—*	—*	1.002	—*	0.04	—	3.68	
23	34.35	27.58	0.281	0.091	—*	—*	0.284	0.003	0.02	—	3.90	
24	20.29	30.50	0.335	0.061	—*	—*	tr	—*	0.22	—	3.42	Contains rather large number of aegirine augite bouders
25	64.10	0.76	0.367	0.069	—*	—*	tr	—*	0.13	—	4.87	
26	67.31	0.52	0.076	0.049	—*	—*	tr	—*	0.04	—	4.93	
27	66.24	0.38	0.046	0.053	—*	—*	tr	—*	tr	—	5.15	
28	39.90	9.08	0.488	0.088	—*	—*	tr	—*	0.01	—	4.13	
29	63.46	2.24	0.135	0.164	—*	—*	tr	—*	0.60	—	4.84	
30	64.74	2.36	0.155	0.027	—*	—*	tr	—*	0.02	—	4.82	
32	63.69	0.14	0.051	0.037	—*	—*	tr	—*	0.01	—	4.87	
33	64.91	0.82	0.063	0.096	—*	—*	tr	—*	0.05	—	4.88	
36	29.70	27.64	0.691	0.066	—*	tr	tr	—*	0.04	—	3.78	Siliceous limestone remained
38	36.24	0.08	0.034	0.001	—	—	—	—	—	15.73	4.37	Contains fluorite

Note: * Not determined.

Table 3. Chemical Composition of Main Ore Body II.

Specimen No.	Fe	SiO_2	P	S	Va	Cr	Ti	Cu	Mn	CaF_2	Sp. Gr.	Remarks
4	45.88	0.74	0.040	0.003	—	—	—	—	—	14.13	3.66	Fluorite contains
5	26.39	17.60	0.036	0.059	×	×	×	×	1.52	—	3.56	Limestone remained
9	30.84	0.26	0.034	0.001	—	—	—	—	—	43.23	4.70	Rather large amount of fluorite contained.
10	44.02	4.04	0.048	0.067	×	×	×	×	tr	—	4.43	
11	51.60	17.20	0.022	0.051	×	×	×	×	0.11	—	4.03	
12	40.17	7.34	0.104	0.045	×	×	×	×	0.04	—	4.36	
13	66.40	1.08	0.016	0.053	×	×	×	×	0.04	—	4.90	
14	55.56	4.66	0.031	0.037	×	×	tr	×	0.28	—	4.40	
15	55.02	2.48	0.384	0.096	×	Small.	tr	0.005	0.02	—	4.67	
16	37.23	0.48	0.455	0.032	×	×	Small.	×	0.54	—	4.32	Limestone remain
31	50.86	1.42	0.201	0.069	×	×	0.758	×	0.13	—	4.54	

Fe, 0.79% SiO_2, 0.11% P, and 0.07% S, specific gravity is 4.84. Thus, these values are roughly close to those of ore body I and generally, show higher quality.

The chemical compositions of eleven specimens collected in a similar way from the main ore body II, are given in Table 3.

The table gives an average composition of 45.82% Fe, 5.2% SiO_2, 0.12% P, and 0.06% S, and 4.59 for specific gravity. These values do not indicate quality higher than that of ore body I. Impurities, such as limestone or fluorite are also found. Then, if these impurities (six specimens, 54% of which have less than 45% Fe) are excluded, the average of five specimens of moderately rich ores become 55.89% Fe, 0.54% SiO_2, 0.13% P, and 0.061% S and 4.41 for specific gravity. It is difficult to determine the quality of the ore body as a whole, from these data, because specimens collected and analysed were only from a few places. However, it seems that the quality of ore body II is relatively inferior to that of ore body I.

In respect to the above-described two main ore bodies, ore less than 40% Fe occupy the localities from specimen No. 28–38 and from No. 21–24, in ore body I and from No. 5–12 in ore body II. Namely, low-grade ore occurs chiefly in the margin of ore body. The area occupied by low grade ore is about 10% of the total area of main ore bodies I and II.

Moreover, most of small ore bodies, scattered around the main ore bodies are in general, low grade, because they contain rather large amounts limestone remains or other impurities; however, in places more than 50% Fe can be found.

B. Ore Reserve

Ore from the main ore bodies I and II is available for working after the quality is assessed whenever the time for development can be decided, assuming that problems of the haulage have also been settled.

Ore body I, is 900 m, in length; 200 m in breadth; the relative height of the ore exposure is, about 65 m from the level of the nearby ground. Its specific gravity averages 33.

Ore body II, is 700 m, in length; 100 m in breadth; the relative height of the outcrops is about 90 m. The specific gravity averages 4.6.

These two ore bodies are contiguous with each other as to massive bodies, intercalated only by a thin bed of limestone. They will be mined as one ore body because they seem to be connected deep below the surface, after the occurrence of replacement. The area occupied by these two is calculated by planimeter to be 0.356 km^2. Taking 120 m as the relative height from the lowest level of ore body II to the highest level of the iron ore outcrops of ore body I, for the workable depth; assuming that the specific gravity of the iron ore as 4.5; and also, supposing that the ore body is cone shaped, then, the total reserve including $3{,}920 \times 10^3$ mt of the limestone, is $64{,}130 \times 10^3$ mt. Hence, the value becomes 60,213,550 mt, i.e., approximately $60{,}000 \times 10^3$ mt.

The computation formula is based on that of a cone formula which is represented as follows:

Iron ore reserve

(Basal area) (Height) (Sp. Gr.) (Amount of limestone to be excluded)

$$\frac{356{,}000 \times 120 \times 4.5}{3} - (550 \times 25 \times 95 \times 3) = 60{,}214{,}550 \text{ mt.}$$

VII. Some Notes in Reference to Exploitation

A. Climate

Cold and severe winter days continue for seven months, from October to April. The rest of the seasons, i.e., spring, summer and autumn are confined only five months, ranging from May to September, in Pailingmiao and its neighbourhood. The rainy season comes in July. However, which based on the amount of the rainfall, for July, 1940 as an example, was 176.3 mm; rainfall is not unusually heavy. It is said that the temperature never exceeds $-14°C$ on the average, even in the coldest season which ranges from January to March. However, as the deposit area occupies an isolated high land area, without any obstacles, it may be considered much colder than in Pailingmiao. Nevertheless, open-pit mining is done, even in the colder North Manchurian district; hence, it is possible to operate throughout the year.

B. Inhabitants and Labour Situation

Generally speaking, there is no Chinese settlement found in Inner Mongolia. A few Chinese are employed temporarily by the government offices and private organizations, or are engaged as merchants and engineers, in the vicinity of Pailingmiao. However, Chinese dwell only either in Maomingan-ch́i, a part of Ssutzŭ village, or Wuchuan Hsien. Hence, Inner Mongolians who are generally nomads, are difficult to employ as workers in the vicinity of Pailingmiao. Then, workers must be employed at Paoťou or Huhuhéto. It may be therefore impossible in addition to employ Mongolians as mine workers, without special measures for aptitude training.

C. Others

As already stated, Mongolians are generally nomads, and there are no cultivated lands within the unmixed Mongolian zone. Consequently, it is necessary to maintain food supplies in the beginning; both cultivation and forestration should be dealt with parallel to the construction of houses, when the time comes for exploitation.

VIII. Conclusion

In conclusion, the Bain-Bokto iron deposit is excellent, both in quality and in ore reserve, and can be mined easily, but the following will be obstacles to exploitation:

a. Construction of roads for haulage

b. Securing of labour

c. Securing of food

It seems to be nearly impossible to exploit the ore deposit at present. However, if the mine would be exploited, an iron foundry and other accessory works should be constructed in the vicinity, in consideration of the Tach́ingshan Coal as a coking coal.