# The Manganese Ore Resources in China and their Prospecting

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## 1 Basic Characteristic of Manganese Ore Resources in China

### 1.1 The Geographical Distribution is Uneven

The manganese ore resources in China are mainly distributed in three provinces: Guangxi, Hunan and Guizhou. The manganese ore resources are scarce in Northwest China and also insufficient in North China.

### 1.2 The Deposit Scale is small

Among all manganese ore deposits that have been prospected, only 1 (Guangxi Xialei Manganese Ore Mine) has a reserve exceeding 100 million tones, with 6 large scale deposits exceeding 20 million tones, 54 medium scale deposits 2 – 20 million tones, and the rest are all small scale deposits. The reserves of large and medium scale manganese ore deposits account for 88% of all reserves in China.

### 1.3 More lean ores and less rich ores

The average grade of manganese ores in China is approximately 22%. There are almost no rich ores (Mn 48%) that reach the internation commodity level. The rich manganese ores (Manganese Oxide Ores reserve 30%, Manganese Carbonate Ores ~ 25%) in China only accounts for 6.7% of the total reserve.

### 1.4 High levels of impurities and less high-grade ores

The manganese ores in China contain high levels of phosphorus and iron. Among all ore mines prospected, ore mines with phosphorus exceeding standard account for 49.6%, those with iron exceeding standard account for 73%, and those reach the high-grade manganese standard account for only 6%.

### 1.5 Paragenesis and Satellite Ores

Among all manganese ore deposits prospected, there are 42 paragenesis or satellite ore deposits, with main paragenesis or satellite components being silver, lead, zinc and cobalt, etc.

## 2 Excavation and Utilization of Manganese Ore Resources in China

## 2.1 Basic Situtation of Manganese Mines

Major manganese mines in China include:

- Open excavation: Liancheng, Bayi, Xialei and Jianshui;
- Open and underground excavation: Mugui, Dongping and Longtou;
- Underground excavation: Wafangzi, Taojiang, Xiangtan and Zunyi.

Due to the manganese ore deposits in China are mostly medium and small scales, the construction scale of manganese mines are limited and the current production capacity is generally low. The statistics indicated that there were 467 manganese mines with 26,700 employees in China in 2000, including 4 large-scale mines and 9 medium-scale mines, accounting for 2.8% of the total. The yield of major national mines in 1999 was 154,000 tonnes, accounting for 6% of the total; the yield of local mines was 1,027,000 tonnes, accounting for 41.2%; and the yield of township and private mines was 1,300,000 tonnes, accounting for 52.8%.

The recovery rates of excavation and segregation are not high. The average recovery rate of excavation is 84%, the average recovery rate of segregation is 74% and the combined average recovery rate of excavation and segregation is 62%.

## 2.2 Processing technology of manganese ores

Gravimetric concentration process is generally applied to Manganese Oxide ores, especially for chemical engineering, battery and high manganese content Manganese Oxide ores. The segregation efficiency is very good due to that the densities of different ore minerals vary a lot.

Strong magnetic process and strong magnetic – flotation process are mainly applied to Manganese Carbonate ores. 21 strong magnetic segregation plants and gravimetric – magnetic segregation plants have been built in China, with an annual treatment capacity of 1,200,000 tonnes. In recent years, electrolytic technology has been applied to the processing of Manganese Carbonate for manganese metal. A plant using this new technology has been built and put into production in Guangxi Daxin Manganese Mine and generates considerable profits. Electrolytic technology provided a new approach for the utilization of Manganese Carbonate ores.

Dry method is mainly applied to the processing of Manganese – Silver (Lead – Zinc) and Iron – Manganese minerals. This *Rich Manganese Residue Method* is an effective method

for the treatment of manganese ores, which are rich in iron and phosphorus and difficult to segregate. The dry concentration method has been continuously improved and developed for the processing and segregation of Manganese-Silver (Lead-Zinc) ores. These ores are applied with blast furnace smelting method to generate rich manganese residues. Lead, silver and pig iron containing manganese can be recovered at the furnace bottom, and zinc and indium can be recovered from the chimney top using bag catcher. The successful application of this method provided a new approach for the exploitation of Manganese-Silver (Lead-Zinc) ores and also provided useful information for relating geological prospecting.

Due to that the manganese ore deposits in China are mainly medium and small scales with very little large scales, the production concentration is poor. 93.6% of the manganese mine reserves are low-grade with an average grade of 21.4%, lower than the world average grade; the supply of high-grade, good quality manganese mineral ores is very insufficient. The manganese carbonate deposits are mainly obtained through underground excavation. Due to the low grade, high content of impurities, fine grains and poor quality for processing, most mineral ores need to be sintered for segregation, thus the cost of product ores as well as their market price is high. So China lacks competitive comparing to other major manganese ore production countries.

**3 Supply and demand of manganese ores in China**

Currently, the steel production of China ranks top 1 in the world, and the production of manganese metal and manganese alloys have also ranked top 1 in the world continuously. The export of manganese metal and manganese alloy products has become a priority business of China. After joining WTO, manganese industry will be an important component in the economic development of China. Thus a strong support of abundant manganese ore resources is necessary.

The yield of manganese ores amount to 7.66 million tones in 1996. From 1997, the ore yield decreased sharply. Although the manganese ore yield rose back in 2000, it could still not meet the demand of the Chinese domestic market. In China, 90% of manganese ores are used in iron and steel industry, and then chemical engineering and dry battery industry. In 2000, the steel yield of China reached 127 million tones, for which 6.35 million tonnes of manganese products were used. The gap between supply and demand was nearly 2.84

million tonnes and could only be solved by import. China has been importing good-quality, manganese-rich ores since 1983, and the import increased each year (See Table 1). The preliminary statistics indicated that altogether 9.526 million tonnes of manganese ores were imported from 1990 to 1999, with the annual import of 0.953 million tonnes. The import in 1996 amounted to 1.5853 million tonnes. The grades of imported manganese ores are mostly 40%, and some are more than 48%. The import of manganese ores to China was 1.2037 million tonnes in 2000, the import cost being 95.4 million US dollars and an average price being 658 RMB per tonne. The imports of manganese in 2001 and 2002 were 1.71 and 2.08 million tonnes. The manganese ores are mainly imported from Australia, Gabon, Ghana, and Burma, etc.

**Table 1 Supply and Demand of Manganese Ores in China**

| Year | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|
| Ore Yield | 5.85 | 5.82 | 6.89 | 7.66 | 5.97 | 5.28 |
| Consumption for Steel | 4.47 | 4.63 | 4.76 | 5.06 | 5.44 | 5.70 |
| Gap | 0.80 | 1.07 | 0.41 | 0.95 | 1.75 | — |
| Import | 0.56 | 0.96 | 1.28 | 1.58 | 1.31 | 1.18 |

Unit：Million Tonnes

According to the new standard of Classification of Solid Mineral Resources/Reserves (GB/T 17766-1999), the resource/reserve of 204 manganese mines that had been prospected were re-assessed. Ending in 1998, the retained resources/reserves of manganese mines in China was 665 million tonnes, only accounting for 2.3% of the world reserve. The proven retained reserve in Chongqing was 24.91 million tonnes, mainly distributed in Chengkou and Xiushan areas.

According to the preliminary assessment, there are 116 manganese mines available for utilization in China. The available reserves for utilization only account for 18% of all prospected reserves and they are mainly distributed in Guangxi, Hunan, Guizhou, Yunnan, Liaoning, Shaanxi, Xinjiang. The other 102 mines are very difficult to exploit due to their

poor quality, richness in phosphorus, fine grains, complex components, thin and scattered distribution, orebody slope, unstable top and bottom, complicated deposit occurances and other economic and geographical factors.

Due to the natural attenuation and resource depletion of the manganese mine production in China, the yield of manganese ores will decrease in the future. However, the demand for manganese ores is increasing with the increase of steel production. In the process of speeding industrialization, the supply of manganese ores from domestic mines will further decrease in China.

To solve the problem, it is necessary to provide resource supply for the expansion and new establishment of manganese mines by speed the prospecting strength and improving the prospection degree. It is also necessary to upgrade the process technology of manganese ores in China to improve the unsecure situation of manganese resource supply.

## 4 Main types of Manganese Deposits in China

### 4.1 Marine deposits

This is the most important type of manganese deposits in China, mainly distributed in the Yangtze platform and surrounding areas, in which the manganese reserve accounts for over 80% of the total in China. The marine deposit can be divided into 5 sub-types according to mine rock formation and the characteristic of manganese mine stratums:

- Manganese Carbonate deposit in silicon (silicon mudstone) formation: typical deposits include Guangxi Xialei Manganese Mine.
- Manganese Carbonate deposit in black rock formation: typical deposits include Xiangtan mine, Minle mine and Xiangtaoyuan mine in Hunan, Songtao mine in Guizhou, Gaoyan mine in Chongqing.
- Manganese Carbonate deposit in mudstone formation: typical deposits include Zunyi mine in Guizhou, Dounan mine in Yunnan
- Manganese Carbonate deposit in carbonate rock formations: typical deposits include Longtou mine in Guangxi and Baixian mine in Yunnan.
- Manganese deposit in volcanic rock formations: typical deposits include Motuoshala mine in Xinjiang and Bingzhuang mine in Yunnan. The scales of this sub-type of deposits are not large, but they are very promising in prospection.

### 4.2 Stratum-specific Mn-Fe-Pb-Zn Deposits

This type of deposits were often formed in specific stratums and obviously reconstructed in later periods. They are mainly distributed in the eastern and western parts of the fold belt in South China, the platform fold belt along the middle and downstream of Yangtze River and the northern boundary of North China platform. The components in the ores are complex, including Fe, Ag, Pb and Zn, forming Fe-Mn deposits, Mn-Ag deposits and Mn-Ag (Pb-Zn) deposits. Typical deposits include Houjiangqiao Manganese Mine, Manaoshan Manganese Mine, Lanshan Manganese Mine in Hunan, Xinrong Mn-Ag-Pb-Zn Mine in Guangdong, De'an Mn-Ag Mine in Guangxi, and Tonggou Mn-Ag-Pb-Zn Mine in Shanxi.

### 4.3 Weathered Manganese Deposits

They are mainly distributed in the area near 23 N, accounting for over 70% of the total reserves in China. They are mainly divided into three sub-types:

- Manganese Cap deposits: typical deposits are Baye Manganese Mine in Yunnan, Mugui Manganese Mine in Guangxi.
- Leaching deposition type deposits: typical deposits are Gongping Manganese Mine, Bayi Manganese Mine in Guangxi, and Lanqiao Manganese Mine in Fujian.
- Piling deposition/slope deposition type deposits: typical deposits are Tongde Manganese Mine and Pingle Manganese Mine in Guangxi.

## 5 Prospecting of Manganese Resources in China

Before 1990, China aimed at prospecting original manganese deposits and weathered manganese deposits, and the proven reserves were focused in Guangxi, Guizhou and Hunan.

From 1991, China Metallurgy and Geology Bureau raised a new prospecting plan for good-quality manganese mines. The grades and impurity contents of good-quality manganese mine and good-quality rich manganese mine are described in detail in the *Geological Prospecting Standard for Iron, Manganese and Chromium Deposits* issued by China Land Resources Department (See Table 2).

**Table 2 Index of Grade and Impurity content in Good-quality Manganese Deposits and Good-quality Rich Manganese Deposits**

| Natural type | Industrial Classification | Grade | Mn (%) | Mn/Fe | P/Mn | Burnt Loss (%) |
|---|---|---|---|---|---|---|
| Manganese Oxide Ore | Good-Quality Manganese Deposit | | ≥18 | ≥6 | ≤0.003 | |
| | Good-Quality Rich Manganese Deposit | Ⅰ | ≥35 | ≥6 | ≤0.003 | |
| | | Ⅱ | ≥30 | ≥4 | ≤0.005 | |
| Manganese Carbonate Ore | Good-Quality Manganese Deposit | | ≥15 | ≥6 | ≤0.003 | ≥20 |
| | Good-Quality Rich Manganese Deposit | Ⅰ | ≥28 | ≥6 | ≤0.003 | ≥20 |
| | | Ⅱ | ≥25 | ≥4 | ≤0.005 | ≥20 |

From 1991 to 1998, the newly prospected manganese deposit resource/reserve is 68 million tonnes, in which good-quality manganese deposits and rich manganese deposits accounted for 70%. A number of good-quality manganese ore producing areas with promising resource potential were also discovered.

From 1999 to 2000, the prospection of good-quality manganese deposits was included in the new round of land resource investigation organized by National Land Resource Department. 14 good-quality manganese mine assessment projects were conducted. It was anticipated that the preliminary prospected manganese reserve was 80 million tonnes and a number of major investigation and assessment area including Southwest Guangxi, Southeast Yunnan, Middle Hunan and Chongqing were confirmed.

Due to that good-quality manganese deposits are formed by manganese-phosphorus diversification and manganese-iron diversification in direction and stratum, the general sampling method according to manganese deposit stratum in the prospection and assessment of manganese deposits is generally not applicable to the assessment of good-quality manganese deposits. Systematical sampling in different stratums was adopted to understand the deposit direction and assess the deposit reserve. Proper geophysical prospecting methods can also be applied to some manganese oxide deposits

and iron-manganese deposits when certain physical data are available.

It is indicated by recent prospection that there were quite a number of good-quality manganese deposits in the normal manganese deposits prospected before 1990. By re-assessing prospected normal manganese mines, the good-quality manganese mine reserves will exceed 300 million tonnes.

**6 Planning Framework of Manganese Resource Prosepction in China**

Aiming mainly at good-quality manganese deposits, define future prospecting areas according to the formation type and geological characteristics. Arrange prospection and assessment for the future prospecting area and conduct preliminary prospection of the reserve of good-quality and normal manganese deposits.

Assess the marine depositing type good-quality manganese carbonate deposits based on understanding of basin-rock formation-manganese stratum-good quality manganese.

Assess the manganese oxide deposits in the area near 23 N in China.

Assess the Mn-Ag multi-metal deposits in conformation-magma reconstructed manganese deposits.

Re-assess the good-quality manganese deposit in normal manganese deposits that reserve has been prospected. Determine the orebody and segment of good-quality manganese deposit, estimate the reserve and increase the utilization efficiency of available reserves.

Based on the geological conditions, prospection degree, resource potential of good-quality manganese deposits, 9 future prospecting areas were selected:

Southwest Guangxi

Southwest Yunnan

Southeast Yunnan

Bordering areas of Sichuan, Chongqing and Shaanxi

Middle Hunan

South Hunan – Northwest Guangdong

Shanxi-Hebei-Inner Mongolia-Liaoning

Northeast Yunnan

Bordering areas of Hunan-Chongqing-Guizhou