Magnetite Quartzite-Type Iron Ores – China’s Most Important Current Iron Ore Source

HAO Ziguol,2, FEI Hongcail,2, HAO Qingqing3 and Susan TURNER2

1 Chinese Academy of Geological Sciences, Beijing 100037, China
2 Editorial Office of Acta Geologica Sinica (English edition), Geological Society of China, Beijing 100037, China
3 Editorial Office of Geology and Exploration, Institute of Mineral Resources Research, China Metallurgical Geology Bureau, Beijing 100025, China

China is abundant in iron-ore resources, with proven ore reserves of $576.62\times10^8$ t and proven reserves of $210\times10^8$ t, containing an average iron content of 33%. However, the rich iron-ore reserves of $10.85\times10^8$ t only account for 1.9% of all proven reserves. China’s iron-ore resources are characterized by many lean ores and a few rich ones.

In recent years, with the development of mineral processing technologies and the increasing rising iron-ore prices, producers have tended to develop low-grade and easily milled magnetite-type iron ores, and of these magnetite quartzite-type iron ores are the preferred ones. Some mines have developed iron-bearing rocks with 8% of iron content, and have profited thereby. This stimulates the exploration of low-grade and large reserves of magnetite quartzite-type iron deposits.

Previous researches have suggested that the ancient Precambrian metamorphic rocks in the world host many magnetite quartzite-type rocks, also called metamorphic-type (iron-bearing quartzite-type) iron deposits. This type of deposit is widely distributed in the North American Lake Superior region, the Canadian Labrador region, the Russian Kursk, the Ukrainian Krivoy Rog, the South African Transvaal, the Brazilian Minas Gallas and Karagas, the West Australian Hamersley, and the Anshan-Benxi area of Liaoning Province and Tai Shan in Shandong Province of China. In 2013, geologists in China discovered three super-large magnetite quartzite-type iron ore deposits. We illustrate them as follows:

1 The Chentaigou super-large iron deposit—$12.28\times10^8$ t reserves

This deposit is located 11 km northeast of Anshan city in Liaoning Province. The Anshan area is part of the basement of the North China block, and is developed within the Archean Yingtaoyuan Formation, Anshan Group, and metamorphic rocks of the Lower Proterozoic Langzishan Formation, Liaohe Group, with a minimum metamorphic age of $\geq$3 billion years. The Chentaigou iron deposit exhibits complicated and weak magnetic anomalies in the Precambrian strata. Magnetic continuation and forward and inverse analysis of these ground magnetic anomalies in 2013 suggested that iron deposits may be buried at depth, with a shallow depth of 623 m and a horizontal width of 400 m (composed of multi-layer iron ores), indicating a large-scale find. Drilling in the same year indicated that, until 2013, the cumulative $(332)+(333)$ class of magnetite resources were $11.57\times10^8$ t, with an average TFe content of 34.91% and an average mFe content of 27.93%; $(333)$ class low-grade ore resources are $0.46\times10^8$ t, with an average TFe content of 22.675 and an average mFe content of 11.52%. In addition, the $(332)+(333)$ classes of iron-ore resources in the periphery areas are $12.28\times10^8$ t. Thus this is a super-large hidden iron-ore deposit, belonging to a typical Anshan-type sedimentary metamorphic iron deposit (Fig. 1).

The drilling results suggest that the Yingtaoyuan Formation is ore bearing, and is dominated by chlorite-quartz schist (in the hanging and foot walls of the orebody), magnetite quartzite, tremolite-magnetite quartzite and actinolite-magnetite quartzite, with locally tremolite-biotite quartzite, chlorite-biotite quartzite, chlorite quartzite and biotite-quartz schist. This deposit contains five orebodies, of which Fe1 is the main orebody. Fe1 extends 240–970 m, with a thick layered shape, and has a true thickness of 76.02–273.15 m, averaging 170.00 m; it is composed of lean magnetite ores, with an average TFe content of 35.26 and a mean mFe content of 28.43%. The ores are dominated by magnetite quartzite, followed by tremolite-magnetite quartzite type, actinolite-magnetite quartzite type and biotite-magnetite quartzite type, and the industrial ore type is lean magnetite.

With a 2013–2015 strategy, the Minmetals Group Chentaigou Mining Co. Ltd in Anshan city will continue investment in this project, to develop and utilize the Chentaigou iron deposit at the appropriate time.
2 The super-large Zhaicun magnetite deposit—16.81×10^8 t reserves

Yanzhou city in Shandong Province is located in the west of the Luxi uplift, north of the Yanzhou uplift and the Jining sag. It lies in the northern peak area of the Jining magentic anomaly, and to the south of the Hongfusi iron deposit in the Yandian ore district. The bedrocks in the deposit are the Neoarchean Jining Group, Paleozoic Zhushadong and Mantou formations, Changqing Group, the Zhangxia, Gushan, Chaomidian, Sanshanzi and Majiagou formations, Jiulong Group, and Cenozoic strata; fault structures and magmatic rocks are not well developed.

The Jining magnetic anomaly is large-scale, with high amplitude, and is known as the largest magnetic anomaly in Shandong Province. It trends NE to NW from the south to the north, and is 15 km along strike, with an average width of 8 km and covering an area of 120 km². The positive magnetic anomaly has two peak values: 3800 nT in the north and 2900 nT in the south. These values represented two superposed magnetic anomalies, and the drilling has confirmed that they are the Zhaicun and Yandian iron-ore districts.

The Hongfusi iron deposit in the Yandian ore district north of the Jining magnetic anomaly is hidden, and the orefields occur in metamorphic rocks of the Archean Jining Group, with an upper burial depth of 899~1377 m. The iron orefields are stratiform or stratoid in shape, and present an overall strike of 333°~355°, trending WSW, with dips of 56°~65°; the iron ore resources are 6.22 ×10^8 t, with a mean TFe grade of 28.42% and an average mFe content of 20.96%.
The super-large Zhaiqun deep iron deposit south of the Jining magnetic anomaly occurs in metamorphic rocks of the Neoarchean Jining Group, and the orebodies have a burial depth of 600–2000 m. Exploration suggests that the (332+333) classes of iron ore resources are $10.59 \times 10^8$ t, with an average TFe grade of 31.09% and an mFe grade of 22.44%, and that low-grade (332d+333d) ore resources are $1.64 \times 10^8$ t, with a mean TFe grade of 25.45% and an mFe grade of 16.63%. These two deposits are both magnetite-quartzite type; the dominate ore minerals are magnetite, limonite and hematite, and the main gangue minerals are quartz, sericite and chlorite. The industrial type is weakly magnetic ores, and the genetic type is metamorphic sedimentary iron deposit.

3 The super-large Lanling iron ore deposit—$6.23 \times 10^8$ t reserves

This iron-ore deposit in the Lanling area of Cangshan county in Shandong Province is located in the Luxi paleo-uplift area of the North China block. The outcropping strata are within the Neoarchean Caoyu Formation, Taishan Group, the Neoproterozoic Tumen Group, and other Precambrian strata, which have a scattered distribution on the surface and are mostly covered by the Quaternary loose sediments. The regional magnetics is a negative field of -50nT~50nT. The WNW-trending banded magnetic anomaly superposed in the regional negative field is composed of three belts: (1) the Nihe-Dongshimen magnetic belt, which is about 30 km long by 2.5 km wide, with a magnetic peak of 500 nT; (2) the east Xingxing magnetic anomaly belt, which is about 5 km long by 2 km wide, and has a magnetic peak of 300nT; and (3) the Lanling-Changcheng magnetic belt, which is about 15 km long by 2–3 km wide, has a magnetic peak of 500 nT. The orebodies have a burial depth of 550–800 m. Earlier geological exploration indicated that the Nihe-Dongshimen magnetic anomaly hosts the large sedimentary-metamorphic Cangyi iron deposit, and that the east Xinxing magnetic anomaly also hosts the same type of iron deposit; both have been put into operation.

The Lanling-Changcheng magnetic anomaly has a high intensity, large width and a regular shape, indicative of a super-large scale of iron deposit. The drilling and geophysical surveys suggest that there are overall 5 magnetic anomaly sections, 3 ore blocks and 12 hidden iron orebodies, and that these orebodies occur in the Caoyu Formation, Taishan Group, quartz-magnetite rocks, belonging to a sedimentary metamorphic type. Resource estimation of the 12 orebodies shows that the newly increased iron-ore resources are $6.23 \times 10^8$ t, with a mean TFe grade of 32.91% and an mFe grade of 23.34%, and that the ores are all primary ores. This deposit offers good mining conditions, and has yielded significant economic benefits through development and utilization. The total profit has reached 234.34 ×10^8 yuan; the annual total benefits after tax are $3.05 \times 10^8$ yuan; the annual investment rate is 12%; and the investment recovery period is 8.2 years.

Fig. 2. Field photograph of the Lanling ore district in Cangshan county, Shandong Province.

E-mail: haoziguo@126.com
The Newly Discovered Super-Large Wulashan-Hademengou Gold Metallogenic Belt in Inner Mongolia, China Has Gold Reserves of Over 100 Tons

HAO Ziguō1,2, FEI Hongcai1,2, HAO Qingqing3 and Susan TURNER 2

1 Chinese Academy of Geological Sciences, Beijing 100037, China
2 Editorial Office of Acta Geologica Sinica (English edition), Geological Society of China, Beijing 100037, China
3 Editorial Office of Geology and Exploration, Institute of Mineral Resources Research, China Metallurgical Geology Bureau, Beijing 100025, China

The Wulashan-Hademengou gold ore district in Baotou city, Inner Mongolia, is a further newly discovered super-large gold metallogenic belt in northern China. The accumulated proven gold metal amount is 84.46 t, with an average grade of 3.53 g/t and a gold metal amount of 63.16 t, with an average grade of 3.30 g/t. The potential reserves are over 100 t.

The Hademengou gold deposit is located at the junction of the Yinshan platform uplift in the Inner Mongolian axis with the Hetao fault depression, and is north of the Wulashan-Daqingshan piedmont fault zone. The outcropping strata are in the Upper Archean Wulashan Group with an isotopic date of 2.65 billion years, which is close to the age of the ore-controlling rocks in the granite greenstone belt in North China Platform.

Strong magmatic activities formed the Early Proterozoic gneissic biotite K-feldspar granite, gneissic quartz-bearing diorite, middle Hercynian quartz diorite, granodiorite, syenite, granite, microcline pegmatite, diabase and lamprophyres. The Wulashan Group metamorphic rock series is the main ore-source sequence for gold mineralization, and is dominated by marble, quartzite, gneiss, amphibolite, leucolite and granite, which have undergone widespread migmatization. This area has experienced intense tectonic activity. The ore-hosting gneiss and amphibolite type rocks contain a gold content of 7.19 ppt to 9.58 ppt, which is three times the gold abundance of continental crust. Brick to flesh red syenite, extending more than ten kilometers and 200–300 m wide, is also genetically linked to the gold mineralization; it contains 4.8 ppt gold content.

This area is dominated by two important gold deposit types: (1) a quartz-feldspar vein type that underwent varying degrees of gold mineralization, with gold-bearing veins that show a clear boundary with the wall rocks. Potassium feldspar

Fig. 1 Geological sketch map showing the geological characteristics of the Hademengou gold ore district, Inner Mongolia (after Li Qiangzhi, et al., 1999).

1-Quaternary; 2-Precambrian Wulashan Group; 3-K-feldspar alteration zone; 4-gold-bearing ore vein; 5-serial number of ore vein group; 6-regional faulted structure; 7-inferred fault in the ore district; 8-lithological boundary; 9-Archeozoic–Early Proterozoic; 10-Middle and Late Proterozoic; 11-Early Paleozoic; 12-Late Paleozoic; 13-Paleozoic suture zone; 14-study area; 15-medium-size gold deposit; 16-super-large rare earth deposit.
is xenomorphic granular, and contains brown red muddy and iron mixtures. The feldspar is dominated by orthoclase and microcline, with small amounts of perthite. Quartz is dark gray, with clear wavy extinction, and contains a large number of fine gas-liquid inclusions. The quartz veins also include small amounts of metal sulfides. The ore types are simple, and are mainly gold-quartz-K-feldspar ores. The gold minerals are principally natural gold, silver gold and gold silver, and the main gold-bearing minerals are quartz, potassium feldspar, limonite and pyrite. Wall-rock alteration is dominated by potassium feldspathization, silicification, sericitization, carbonation and pyritization. (2) Potassium feldspathization altered ones, which are distinct from type (1) in that they have wide mineralization belts, and also have no clear boundary with the wall rocks. The ores are disseminated pyrite sericite quartz K-feldspar cataclastic rocks or pyrite sericite quartz K-feldspar and pyrite sericite quartz K-feldspar mylonite. The ores have a poor and stable grade, and contain a large number of metal sulfides. These ores can form orebodies independently, and also occur in the hanging wall and footwall of the quartz-feldspar veins and quartz vein orebodies, or in the discontinuity of the quartz-feldspar veins. They transit in strike and trend, and are mainly K-feldspar altered gold deposits at depth.

There have been 15 gold ore bodies discovered, and numbers 32, 13, 2, 113 and 14 are large-scale. Gold ore body No. 32 is 1750 m long, extending 1100 m at depth, 1.00–5.91 m thick, and has an average thickness of 1.82 m; the gold grade is 0.5 g/t–79.50 g/t, and the greatest grade of a single project is 12.80 g/t; the average gold grade is 3.41 g/t, and the variation coefficient of the gold grade is 121.10%; the useful components are uniform. The other orebodies are generally similar.

The ore types are quartz veins, quartz K-feldspar veins and altered rocks. The metal minerals in the ores are uniform. The gold minerals have a high fitness, and include large numbers of natural gold, with minor amounts of silver gold. The gold size is medium and fine. Gold mainly occurs as intergranular and fissures. This mine adopted all slime cyanidation CIP adsorption and high-voltage electrolysis processes to carry out gold smelting, and the smelting recovery rate was 86.10%, indicating that it is easy to mine. The mine is being successfully mined has processed $5 \times 10^7$–$6 \times 10^5$ t, with an annual gold production of 1100 kg and an annual profit of $1.2 \times 10^8$ t.

E-mail: haozigue@126.com