Cobalt Deposits of China: Classification, Distribution and Major Advances

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Abstract The important strategic metal cobalt has diverse uses and the majority of world cobalt deposits have been found in China. The deposits can be classified into four types, i.e., magmatic Ni-Cu-Co sulfide deposits, hydrothermal and volcanogenic cobalt polymetallic deposits, strata-bound Cu-Co deposits hosted by sedimentary rocks and lateritic Ni-Co deposits, of which the former two types are the most important. There are six principal metallogenic epochs and seven important metallogenic belts according to their distribution and tectonic position. Although cobalt generally occurs in nickel-copper, copper and iron deposits as an associated metal, great developments in exploration for independent cobalt deposits have happened in China, and, in recent years, many independent deposits with different elementary assemblages and different genetic types have been discovered in the eastern part of the northern margin of the North China platform, the Central Orogenic Belt of China, western Jiangxi and northeastern Hunan. In addition, it is inferred that the Kunlun-Qinling Orogenic Belt has great potential for further exploration of new types of independent cobalt deposits.

Key words: cobalt deposit, classification, temporal and spatial distribution, major advances

1 Introduction

Cobalt is a very important strategic metal used in many diverse fields. It is also in short supply in China because of rapidly increasing demands caused by the development of alloy, pottery and china (porcelain), magnetic materials and rechargeable battery industries. In the past, cobalt found often occurred as an associated metal in Cu-Ni, Cu and Fe deposits, but many independent cobalt deposits with different elementary assemblages and different genetic types have recently been discovered in China. As a result, these finds have been attracting more attentions and emphases than before.

2 Main Genetic Types of Cobalt Deposits in China

Compared with other countries, China has most types of cobalt deposits. They can be classified into four types based upon ore-bearing formations and current world classification based on Smith (2001). Unlike other countries, however, magmatic Ni-Cu-Co sulfide deposits and hydrothermal and volcanogenic cobalt poly-metallic deposits are the most important in China.

2.1 Magmatic Ni-Cu-Co sulfide deposits

This type of deposit has the largest production of cobalt, constituting over 75% of the total. They are mainly distributed in northern Gansu, northeastern Xinjiang, and the southern part of Jilin and Sichuan formed during the Middle Proterozoic and Upper Paleozoic metallogenic epochs. The deposit type can be divided into two subtypes. One is a kind of Ni-Cu-Co deposits, which occurs in the continental margin and Phanerozoic orogens, and is related spatially and genetically to small mafic or ultramafic intrusions. Typical examples include Jinchuan, Gansu; Hongqiling, Jilin; Kalatongke and Huangshan, Xingjiang; and Baimazhai, Yunnan (Qin, 1995; Tang, 1996; Wang et al., 2000; Tang et al., 2002). In this case ore-forming magma is generally considered to inject after deep melting. The ores had then undergone tectonic deformation and remobilization with nickel as the main ore-forming element in these deposits. Copper can be either a co-product or by-product, and cobalt is a typical by-product. The main ore minerals consist of pyrrhotite, pentlandite and chalcopyrite. The second subtype is a type of vanadium-titanium magnetite deposit such as Panzhihua, Hongge, Baima and Taihe in Sichuan (Chen and Qi, 1986).

2.2 Hydrothermal and volcanogenic cobalt polymetallic deposits

This is the second most important type of cobalt deposit widespread in many provinces of China. Especially, some large- and medium-scale deposits of this type were discovered in the past few years. They mostly occur in orogens and depression belts, and are hosted by microclastic rocks, carbonate rocks and marine volcanosedimentary rocks. The deposits are apparently controlled by stratum, lithological interfaces and faults, and the shapes of orebodies include layer and lens. The main metallogenic epochs are Proterozoic, Late Paleozoic and Late Mesozoic. Actually, hydrothermal and volcanogenic
cobalt poly-metallic deposits show a wide range of styles and associated metals although they can be grouped together under the one heading, including skarn deposits such as Daye in Hubei (Zhao and Lin, 1990) and many other medium- and small-scale Fe-Co deposits located in southern Hebei and Laiwu district in Shandong; sedimentary exhalative (SEDEX) type deposits such as Tuolougou and Kendeskeke in Qinghai (Zhang et al., 2002; Pan and Sun, 2003), Hujiayu-Bizigou in Zhongtiaoashan, Shanxi (Sun and Ge, 1990) and Yindongzi in Shaanxi; volcanic-hosted massive sulphide (VHMS) type deposits such as Lalachang in Sichuan (Chen and Xia, 2001), De'ermi in Qinghai (Wang and Qin, 1997) and Dahongshan in Yunnan; hydrothermal superimposed strata-bound deposits such as Wubaoshan and Qibaoshan in western Jiangxi (Fu, 1998; Zhou and Zeng, 2000), and Pule and Hengdong in northeastern Hunan (Ning, 2002); volcanogenic hydrothermal and sedimentary deposits such as Shiliu in Hainan (Liu, 1981) and Cihai in Xinjiang (Xue et al., 2000); epithermal deposits such as Ku'erzhenkuo in Xinjiang (Yin et al., 2003); and porphyry deposits such as Yulong in Tibet (Wang et al., 2001).

2.3 Strata-bound Cu-Co deposits hosted by sedimentary rocks

It is well known that this type of deposit is the most important outside China, particularly in the Central African Copper Belt. However, only a few deposits of this type have been found in China, at Changjipe, central Yunnan (Xue, 2001), Dahenglu, southern Jilin, and located at the bottom of Liaodong rift, eastern Liaoning (Chen, 1999; Guo and Liu, 2002). The sediment-hosted deposits occur generally in a rift or sag on the margin of an old landmass largely in the Paleoproterozoic metallogenic epochs. It is generally believed that this type of deposit is of diagenesis to early metamorphism in origin and possible sources of the cobalt were either red beds and/or ultramafic rocks (Smith, 2001).

2.4 Lateritic Ni-Co deposits

Lateritic deposits are distributed mostly in the south of China, especially in Hainan and Yunnan. They were formed by the weathering of olivine basalt and ultrabasic intrusions in hot, humid and monsoonal or high rainfall climates. Such deposits include Penglai and Juding in Hainan and Yuanjiang-Mojiang in Yunnan. The olivine basalt and peridotite underwent intensive leaching in this climatic setting, which caused the loss of large amounts of silicon and magnesium leaving behind insoluble components. During the course of this laterization, nickel, cobalt and iron were enriched in the weathering crust, forming typical lateritic deposits.

3 Temporal and Spatial Distribution of Cobalt Deposits in China

3.1 Characteristics of temporal distribution

Cobalt deposits in China formed in a wide time range from the Proterozoic to Cenozoic. Based upon the tectonic evolution and metallogenic settings, six metallogenic epochs are recognized; Paleoproterozoic, Mesoproterozoic, Caledonian, Variscan, Yanshanian and Himalayan. Of these the most important are Mesoproterozoic, Variscan and Yanshanian, but, various types of cobalt deposit were formed in each metallogenic epoch. The Paleoproterozoic cobalt deposits are mainly SEDEX and sediment-hosted deposits. The Mesoproterozoic deposits are chiefly magmatic sulfide and VMS deposits. The Caledonian and Variscan deposits are magmatic sulfide, SEDEX, VMS, volcanogenic hydrothermal and sedimentary, and epithermal deposits. The Yanshanian deposits mainly include skarn, hydrothermal superimposed strata-bound and sediment-hosted types of deposits. The Himalayan deposits are predominately lateritic Ni-Co deposits.

3.2 Characteristics of spatial distribution

Cobalt deposits are widespread in most provinces of China, including mainly Gansu, Xinjiang, Qinghai, Shanxi, Sichuan, Jilin, Yunnan, Hainan, Hebei, Shandong, Hubei, Jiangxi, Anhui, Shaanxi, Guangxi and Hunan. According to the tectonic position and concentration of distribution, seven metallogenic belts are defined (Fig. 1).

Altay-northern Tianshan metallogenic belt

This metallogenic belt is located in the northeastern Xinjiang, in which there are mainly magmatic sulfide deposits related closely to mafic or ultramafic intrusions such as Kalatongke, Huangshan, Tudun and so on. Cobalt is produced as an associated constituent, but reserves are large. It is generally considered that magma intruded during the relaxing stage after the Paleozoic collision orogenic period (Tang, 1996; Tang et al., 2002) and ore-bearing rock bodies occur disjointedly along deep faults and their secondary faults. In addition, the Hami subvolcanic hydrothermal Fe-Co-deposits are also found in this belt.

Middle part of the North China Platform metallogenic belt

The range of this belt is from Jinchang, Gansu in the west to the Laiwu district, Shandong in the east. During the Paleoproterozoic to Mesoproterozoic, a series of volcano-sedimentary rocks were formed and many small basic-ultrabasic rock bodies also intruded as well, forming correspondingly the Zhongtiaoashan SEDEX Cu-Co deposit, which is the oldest, and the Jinchuan magmatic
sulfide deposit. After extensive tectonic activity in the Mesozoic, magmatism and mineralization took place due to a further epicontinental tectonic phase. Some medium- and small-scale skarn Fe-Co-deposits were formed in southern Hebei and Laiwu district, Shandong.

**Eastern part of the northern margin of the North China Platform metallogenic belt**

There are two main types of deposits. One is a strata-bound Cu-Co deposit with a typical example at Dahenglu, which occurs in the fault basin of a Paleoproterozoic rift and was hosted by carbon-bearing microclastic and carbonate rocks. The other is a magmatic sulfide deposit such as Hongqiling, which is located in an epicontinental fault belt and related to mafic and ultramafic rocks.

**Kunlun-West Qinling metallogenic belt**

This is another important metallogenic belt found recently, which is composed of a Precambrian basement of metamorphic rocks and Paleozoic marine volcano-sedimentary formations, that underwent a multiple orogenic process. With the exception of the large-scale De’erlin massive sulfide deposit hosted by ophiolite, a few of the recently discovered deposits are SEDEX-type
deposits at Tuolugou and Kendekke in Qinghai and Yindongzi in Shaanxi, VMS-type deposits of Dulenggou in Qinghai and Yangba in Gansu, and hydrothermal vein and magmatic cobalt poly-metallic deposits in the triangle region of Mianxian, Lueyang and Yangpinguan, Shaanxi (Yao et al., 2002; Qiu and Liu, 1993; Han et al., 2000). In addition, to the west of this metallogenic belt, the Tumukalangu epithermal deposit was discovered in recent years (Xu and Zhu, 2000). All deposits in the belt were formed during the Early to Late Paleozoic.

**Middle-lower reaches of the Yangtze metallogenic belt**

Located in the northeastern Yangtze Platform and close to the southeastern part of the North China Platform, this is an important metallogenic belt for iron, copper, gold and cobalt deposits in China. Yanshanian intermediate-acidic magmatism is intensive. Up to now, cobalt in the belt occurred mostly in skarn Fe-Cu-Au deposits as an associated component. The main deposits are Daye in Hubei, Ma’anshan and Yaoyuanshan in Anhui, and Yeshan and Weigang in Jiangsu. In addition, some massive sulphide deposits in the Lower Yangtze region such as Mashan, Dongguashan, Tongguanshan and Qixiaoshan have recoverable contents of cobalt (Gu et al., 2000).

**Western margin of the Yangtze Platform metallogenic belt**

The deposits here occur from southwestern Sichuan to the middle of Yunnan and correspond to the Kangdian Axis in the past. The basement was composed of Mesoproterozoic marine meta-sedimentary rocks and was later changed into an inland fault basin by the Indo-Australian movement. There are mainly Paleoproterozoic and Neoproterozoic VMS-type deposits which occurred in a rift near to an ancient landmass, such as Lalachang in Sichuan, Dahongshan and Yimen in Yunnan, Upper Paleozoic magmatic sulphide deposits such as Panzhihua and Baimazhai, and Mesozoic continental sandstone-hosted copper-cobalt deposits.

**South China metallogenic belt**

This was a late Caledonian fold system that became an epicontinental active belt since the Indosinian. Yanshanian magmatic intrusions were very intensive. Some important deposits include volcano-sedimentary deposits transformed by metamorphic fluid such as Shilu in Hainan, and hydrothermal superimposed strata-bound deposits such as Wubaoshan and Qibaoshan in western Jiangxi, and Pule and Hengdong in northeastern Hunan.

4 **Major Advances in Exploration and Researches on Cobalt Deposits**

(1) Some independent cobalt deposits have been discovered in recent years. In the past, cobalt was generally considered as an associated metal in nickel-copper, copper and iron deposits, and it was very difficult to form independent economic deposits. Many large- and medium-scale independent cobalt deposits, however, have now been discovered in the eastern part of the northern margin of the North China Platform, Central Orogenic Belt of China, western Jiangxi and northeastern Hunan. The great developments of exploration for independent cobalt deposits are very important for opening up researches on mineralization and in the long-term making up the short supply of cobalt resources in China.

(2) Based on comprehensive studies, we have found that the recently discovered cobalt deposits not only have different elementary assemblages but also have various and typical genetic types. The elementary assemblages include Co-Au, Co-Bi-Au, Cu-Co, Co-Pb-Zn and Au-Co. The chief genetic types are SEDEX- such as Tuolugou and Kendekke, VMS- such as Dulenggou, sediment-hosted deposits such as Dahenglu, hydrothermal superimposed strata-bound deposits such as Wubaoshan, Qibaoshan, Pule and Hengdong, and epithermal deposits such as Kuo’erzhenkuo. The newly found cobalt deposits have some typical geological characteristics, which differ from other deposits. For instance, the large-scale Dahenglu Cu-Co deposit in Jilin occurs in Paleoproterozoic epimetamorphic microclastic and carbonate rocks in the middle of the Liao-Ji Proterozoic Rift. Three layers of orebodies have been found; each orebody is either in stratiform, stratiform-like or diverging form with lengths of 360 to 1400 m and average thickness of 8.68 to 35 m controlled by multiple folds. The average cobalt grades range from 0.035%~0.080%. The Tuolugou Co-Au deposit is a typical SEDEX-type deposit (Zhang et al., 2002), which was found only in the past five years in the central part of the East Kunlun Orogen. It is hosted by Sinian to Cambrian volcano-sedimentary rocks. Quartz albite is a very important exhalite and ore-bearing bed, and is interbeded in the metamorphosed pelitic siltstone. Co-Au orebodies are in stratiform and lenticular forms. They extend conformably in strata, forming an over 7 km-long mineralization zone. Individual orebodies are 100 to 1000 m long and 0.86 to 4.45 m thick, with average grades of 0.024%~0.108% Co and 0.3~0.78 g/t Au. The ores display laminar, banded, disseminated and massive textures. Cobalt is mostly contained in pyrite in the ore. The Wubaoshan Co-Pb-Zn deposit is a medium-scale hydrothermal superimposed strata-bound deposit (Fu, 1998), which is located in the western Jiangxi. It occurs in Upper Triassic quartz sandy gravel. Orebodies are in stratiform and lenticular form with an average cobalt grade of 0.403%.

(3) From west to east of the Kunlun-Qinling Orogenic
Belt, not only were many different types of independent cobalt deposits found recently, but also they are distributed disjointedly near 1000-kilometer drainage anomalies of cobalt. We are eager to explore for more independent deposits according to the most advantageous ore-forming geological setting. As a result, attention should be paid to it.

5 Conclusions

(1) Most major types of cobalt deposits in the world have been found in China. These can be classified into four types, of these magmatic Ni-Cu-Co sulfide deposits and hydrothermal and volcaogenetic cobalt poly-metalliferous deposits are the most important. Unlike other countries, especially Africa, only a few sediment-hosted cobalt deposits have been found in China. Lateritic deposits are mostly distributed in Hainan and Yunnan, and were formed by weathering in hot, humid and high-rainfall climates.

(2) There are six principal metallogenic epochs: Paleoproterozoic, Meso-Neoproterozoic, Caledonian, Variscan, Yanshanian and Himalayan. Of these the Meso-Neoproterozoic, Variscan and Yanshanian are the major deposits. Seven important metallogenic belts are defined according to tectonic position and concentrated distribution.

(3) Great development of exploration for independent cobalt deposits has taken place in China in recent years, and the newly discovered deposits not only have different elementary assemblages but also have various and typical genetic types. As a result, it is inferred that the Kunlun-Qinling orogenic belt has potential for exploration of new-type independent cobalt deposits, and consequently attention should be paid to this region.

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References


