http://www.geojournals.cn/dzxbcn/ch/index.aspx

Cobalt Deposits in the Central China Orogenic Belt

XU Yong
Bureau of Geology and Exploration, 12B Fuxing Rd. Beijing, 100814
and ZHU Xinyou
Beijing Institute of Geology for Mineral Resources, Anwai Beiyuan, Beijing 100012

Abstract Cobalt mostly occurs as an associated metal in Cu-Ni sulphide deposits, skarn Fe-Cu-Pb-Zn deposits and volcanic-hosted massive sulphide (VHMS) or sedex deposits. There are different types of cobalt deposits in the Central China orogenic belt. In the Tamu-Kalangu Mississippi-valley type Pb-Zn deposits, many cobalt-nickel sulphide minerals were found. The cobalt content of the ore is 0.064%–0.46% in sedex-type Kendekeke Fe-Pb-Zn-Au deposits, and cobalt sulphide veins with Co contents of 4%–9% have also been found. About 28000 tons of cobalt reserves were delineated in the Dur'ngoi Cu-Co-Zn deposit of VHMS type in the A'nyemaqên Mountains. It is considered that the exploration potential for cobalt is attractive in this district, especially in sedex-type deposits and Co-rich sulphide veins in sedex-type Fe, Cu and Pb-Zn deposits and their surroundings.

Key words: cobalt deposit, central China orogenic belt, metallogenic prognosis

Cobalt has long been considered as an associated metal in copper-nickel sulphide deposits and shale-type copper deposits, and cobalt deposits that are mined exclusively for cobalt are rare. In recent years, some large but low-grade cobalt deposits that yield only cobalt have been discovered in Jilin and Hainan provinces, China. Those cobalt deposits become more and more important with the rapid rise of the cobalt metal price.

1 Geological Setting of Cobalt Deposits in the Central China Orogen

The Central China orogenic belt (Fig. 1), consisting of the Kunlun and Qinling orogenic belts, was the boundary or suture between the northern China and Yangtze palaeo-continents. Many ophiolite suites occur along the belt (Xiao et al., 1978; Feng et al., 1994; Zhang et al., 1998; Lai, 1999). This belt is also called the gold girdle of China because a lot of gold and other metal deposits occur therein. In recent years, cobalt has been found in many Fe-Cu, Cu-Zn and Pb-Zn deposits, especially in the A'nyemaqên Mountains and on the southwestern margins of the Qaidam basin and Tarim basin (Yan, 1995; Jiang et al., 1999).

1.1 Dur'ngoi

The Dur'ngoi copper-zinc-cobalt deposit occurs in early Palaeozoic ophiolite (Jiang, 1995). Banded massive sulphide orebodies are hosted in ophiolite (Zhang, 1981), and concordant with fine-clastic sandy shale of the hanging wall. The reserves of the deposit are copper 555,800 tons, zinc 162,200 tons and cobalt 28,400 tons with a Co grade of 0.089% and no nickel. It is considered as a Cyprus-type volcanic-hosted massive sulphide (VHMS) deposit (Zhu and Jiang, 1994) associated with tholeiite.

1.2 Kendekeke

The Kendekeke iron deposit was found at the end of the 1950s. In the 1980s, it was found that it also contained 45000 tons of lead, 125000 tons of zinc and 2 tons of gold besides iron. In 1995, widespread cobalt mineralization was found in the iron orebodies and their vicinity.

The deposit occurs in volcanic rocks of the Late Ordovicain Tieshidasi Group in a Late Palaeozoic continental-margin WNW-trending depression on the southwestern margin of the Qaidam basin. Bimodal volcanic rocks consisting of basalt with minor acid tuff are developed in the depression. The deposit is

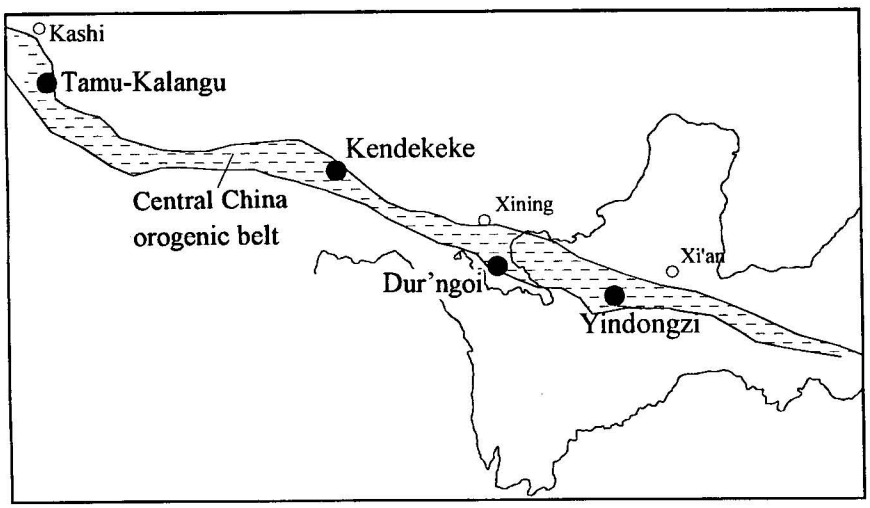

Fig. 1. Distribution of cobalt deposits in the Central China orogenic belt.

considered to be of metamorphosed sedimentary exhalative (sedex) type.

Cobalt mineralization is mostly associated with gold mineralization with a Co grade of 0.064%–0.46%. Besides, several ca. 10-cm-thick, high-grade Co ore veins with a Co grade of 4% to 9% have been found in the ore district. The ore minerals in the veins are skutterudite (40%–55%), arsenopyrite (30–40%), bismuth or bismite (5%) and minor fluorite, K-feldspar and erythrite.

1.3 Tamu-Kalangu lead-zinc district in western Kunlun

The Tamu-Kalangu lead-zinc deposits are located in the carbonate platform of the passive margin of the Tarim plate. Lead-zinc-copper orebodies occur in brecciated rocks in several rock sequences which consist of Devonian-Carboniferous sandstone and overlying carbonate rocks. The ore minerals are galena and sphalerite with minor pyrite, arsenopyrite, marcasite, hematite, magnetite etc. Sparry dolomite alteration occurs in the brecciated rocks, associated with lead- zinc mineralization. The ore-forming temperature is about 120°–180°C, and the salinity of fluid inclusions is 15 wt% NaCl equi. The deposits are similar to the Mississippi Valley-type (MVT) lead-zinc deposits in North America (Zhu et al., 1998).

In the early stage of exploration (at the end of the fifties), cobalt was found in the Kalangu lead deposit. Many Co and Ni sulphide minerals, e.g. cobaltite, gersdorffite, siegenite, modderite and erythrite have been discovered in the lead-zinc deposits in recent years. The cobalt content is up to 0.03% in some lead-zinc ores.

2 Discussion

Cobalt is rich in basic or ultrabasic igneous rocks. The cobalt content in the crust is much lower than that in the mantle. Most of large cobalt deposits or cobalt-rich deposits occur in large-scale faults or depressions at the margins of palaeo-continents. In the Kunlun-Qinling belt, there is a giant fault system including the Kunzhong, A'nyemaqên, Luoyang-Baohe faults etc., which may provide passageways for cobalt and nickel in the deep levels of the earth to rise to the surface. The basic volcanic rocks are widely distributed in this area, especially in the Dur'ngoi and Kendekeke districts, and perhaps is one of the most important ore of sources of cobalt.

(1) As a thiophile element, cobalt occurs in various sulphide deposits, such as copper-nickel, copper, lead-zinc, and some iron deposits. The statistics of the total cobalt reserves in China shows that almost all cobalt occurs as an associated element in other metal depos-

Table 1 Electron microprobe analysis of sulphide minerals of Co-rich veins in the Kendekeke deposit, Qinghai (%)

	Skutterudite	Arsenopyrite	Bismuth	Bismite	Bismite
S	0.908	18.840	0.005	0.154	0.028
Fe	1.782	30.797	0.012	0.288	0.359
Co	17.480	2.163	0.145	2.784	0.181
Ni	1.382	1.265	0.066	0.180	0.051
As	79.533	46.803	0.000	12.501	0.000
Cu	0.000	0.006			
Bi			98.044	84.982	87.796
Total	101.085	99.873	98.272	100.890	88.415

Note: Analized by China Mineral Exploration Center; analysis instrument: SHIMADZU EPMA-1500.

Table 2 Electron microprobe analysis of Co and Ni sulphide minerals from the Tamu-Kalangu Pb-Zn district (%)

	KB226	KB453	KB453	KB604
	Gersdorffite	Cobaltite(?)	Cobaltite (?)	Siegenite (?)
S	21.294	25.654	22.599	46.630
Fe	0.606	4.570	3.452	5.134
Co	4.013	26.666	28.697	12.541
Ni	22.760	2.420	2.377	37.537
As	41.935	36.094	38.215	0.061
Cu	0.000	5.903	5.569	0.034
Total	90.608	101.308	100.908	101.937

Note: Analyzed by China Mineral Exploration Center; instrument: SHIMADZU EPMA-1500.

its except asbalite in southern China. About 36.89% of the total cobalt reserves of 550000 tons are contained in the copper-nickel deposits, 32.22% in skarn copper-iron, 15.69% in volcanic-hosted massive sulphide (VHMS)-type copper, 7.31% in asbalite, 4.55% in the sedex-type copper, 0.12% in sedex-type lead-zinc deposits, and 0.07% in the epithermal lead-zinc veins. Only two sedex-type lead-zinc deposits are associated with cobalt mineralization, which are Yindongzi in Shaanxi and Huoshibulak in Xinjiang, both located in the Central China orogenic belt or in their vicinity.

sedex-type deposits are the most important source of cobalt around the world, e.g. the Zaire copper belt and Idaho cobalt mineralization belt. Many cobalt deposits (mined exclusively for cobalt) are located in districts where sedex-type mineralization occurs. Several large but low-grade cobalt deposits were discovered in the 1990s in Jilin province, China, which occur in marine fine-clastic rocks and are considered to be of sedex type. So, it is suggested that attention should be paid to sedex deposits hosted in marine fine-clastic rocks in cobalt exploration, especially in the Kunlun-Qinling belt in China.

(2) A large amount of cobalt mineralization and Co geochemical anomalies were discovered along the Central China orogenic belt in the 1990s, e.g. in the West Kunlun, southeast Dulan of Qinghai and southern Shaanxi in addition to the cobalt deposits mentioned above.

(3) The discovery of high-grade cobalt lodes in Kendekeke implies that cobalt can be also accumulated to form high-grade hypothermal deposits, besides large low-grade ones in the belt.

(4) Cobalt is contained in different types of deposit in the belt. It is found in the Dur'ngoi Cyprus-type copper-zinc-cobalt deposit, the Kendekeke sedex-type iron-lead-zinc-gold deposit, the Tamu-Kalangu MVT lead-zinc deposit and the Yindongzi sedex-type lead-zinc deposit, which suggests that there is favourable environments for cobalt mineralization in the belt, and cobalt minerals can accumulate in different geological settings. Most of MVT deposits in North America contain cobalt minerals (Hangi, 1983).

3 Conclusions

(1) Cobalt mineralization occurs in different types of deposit, e.g. igneous copper-nickel, sedex-type and hydrothermal deposits; in addition, it can occur as hypothermal lodes.

(2) The Central China orogenic belt is a very prospective cobalt metallogenic province, where not only there occurs cobalt accompanying copper and zinc in large copper-zinc deposits, but also there are cobalt deposits and hypothermal high-grade cobalt sulphide lodes that can be mined exclusively for cobalt. The hypothermal high-grade cobalt lodes are a new type of cobalt deposit.

(3) The important districts for exploration of large cobalt deposits are those in which sedex-type copper and zinc mineralizations occur in or near the belt.

Manuscript received Jan. 2000
edited by Ren Xifei and Fei Zhenbi

References

Feng Yimin, He Shiping and Yan Jun, 1994. The discovery and geological significance of sheeted dyke complex in the Early-Middle Ordovician ophiolite in the central section of the north Qinling Mountains, China. *Geological Review*, 40(3): 252–264 (in Chinese with English abstract).

Hangi, R.D., 1983. Ore microscopy, paragenetic sequence, trace element content and fluid inclusion studies of the copper-lead-zinc deposits of the southeast Missouri lead district. In: Kisvarsanyi, G., Grant, S.K., Pratt, W.P., and Koenig, J.W. (eds.), *Proceedings of International Conference on Mississippi Valley-type Lead-Zinc Deposits*. Rolla: Univ. Missouri-Rolla Press, 243–256.

Jiang Fuzhi and Wang Yuwang, 1999. Geological features and ore potentiality of volcanic rocks around the periphery of the Qaidam Basin. *Geological Review,* 45 (Sup): 1019–1027 (in Chinese with English abstract).

Lai Shaocong, 1999. Ophiolites and their tectonic significance in the Mianlue suture zone, Qinling-Dabie orogenic belt. *Geological Review,* 45 (Sup): 1062–1071 (in Chinese with English abstract).

Nold, J.L., 1990. The Idaho cobalt belt, northwestern United States— A metamorphosed Proterozoic exhalative ore district. *Precambrian Research,* 25(3): 163–168.

Xiao Xuchang, Cheng Guoming and Zhu Zhizhi, 1978. A preliminary study on the tectonics of ancient ophiolites in the Qinling Mountain, Northwest China. *Acta Geologica Sinica,* 52(4): 281–295 (in Chinese with English abstract).

Yan Jincai, 1995. Discovery and geological significance of slump structure in the Daxigou-Yindongzi orefield. *Geological Review,* 41(4): 293–300 (in Chinese with English abstract).

Zhang Wusheng, 1981. Derni Copper Deposits Geology. Beijing: Geological Publishing House (in Chinese).

Zhang Zhaochong, Mao Jingwen, Yang Jianmin, Wu Maobing and Zuo Guochao, 1998. Geochemical evidences on the Petrogenesis of the Aoyougou ophiolite in North Qinling Mountains. *Acta Geologica Sinica,* 72(1): 42–51 (in Chinese with English abstract).

Zhu Xinyou and Jiang Fuzhi, 1994. Derni large-scale copper-cobalt massive sulfide deposit, Qinghai, a Cyprus type in China: geological characteristics and genesis. *Abstracts of Papters Submitted to the the 9th Symposium of IAGOD,* Beijing.

Zhu Xinyou, Wang Dongpo and Wang Shulai, 1998, Tarm-Kalangu Mississippi Valley-type lead-zinc deposits, Arketao County, Xinjing: Geology and sulfur isotope geochemistry. *Deposit Geology,* 18(13) (in Chinese).

About the first author

Xu Yong Born in January 1965; graduated from China University of Geosciences in 1989; obtained a Ph. D degree in geochemistry in 1995; now engaged in mineral exploration and management. Tel: 0086-010-63971547; E-mail: xuy@earthling.net