The Zhaotong Maoping Zn-Pb-(Ge-Ag) deposit is located in the well-known Sichuan-Yunnan-Guizhou Zn-Pb Poly-metallic Mineralization Province. Though geological experts have studied the deposit (Liu and Lin, 1999; Han et al., 2007), prior to this breakthrough exploration project, the Pb-Zn resources in the deposit were virtually exhausted. The question of how to explore the concealed ore-bodies in the depths has become a crucial issue requiring a solution.

In order that the concealed ore-bodies could be targeted deep in the mine, Tectono-geochemical exploration technique, which combines the studies of ore-controlling structures and the geochemical studies of multi-ore-forming element groups within fault zones, has been proven to be effective in the exploration of concealed ore-bodies (Han et al., 2013). Tectono-chemistry has provided geologists with a better understanding of the ore-induced anomalies and metallogenic information in the depth. Thus allowing them to extract the essential information needed to explore the concealed ore-bodies. The case study of the Zhaotong deposit is a successful example of the application of Tectono-geochemistry.

2 Geological Structural Characteristics

The Zhaotong Maoping mining district is tectonically controlled by the NE-trending thrust-fold structure which resulted from the sinistral shear of the Xiaojiang deep fault and Zhaotong-Qujing concealed fault (Han et al., 2007). The main ore-hosted strata in the late Devonian and early Carboniferous are largely composed of grayish-white and cream-colored coarse-crystalline dolomite, compact massive light gray limestone making them lithologically similar to the host rocks in MVT-type deposits. Yet, ore-hosted coarse-crystalline dolomite in the deposit is the result of hydrothermal alteration, and the ore-bodies can be distinguished from those in the MVT deposits as they are noticeably controlled by thrust-fold structures and occur within fault zones.

Detailed studies of ore-controlling structures showed the NE-trending sinisterly transpressional Maoping fault is the main conduit structure for ore-bearing fluid migration while the NW-trending tensile faults and fold serve as coordinating structures, and the lower-ordered NE-trending compressive-shear faults for mainly the ore-allocation or ore-hosting (Han et al., 2007).

3 Studying Method and Discussion

Tectonic deformation synchronizes with the changes of the composition of materials. In addition, the migration of ore-bearing fluids always takes place simultaneously, resulting in geochemical anomalies within mineralization-relating fault zones (Qian, 1994; Han et al., 2001). Therefore, it is important and essential to investigate the characteristics of ore-controlling structures and the migration of ore-bearing fluids. The issue at present is how to obtain the information of concealed ore-bodies at depth? Research and analysis of the Zhaotong deposit have scrutinized multi-ore-forming element associations in fault zones and revealed valuable information in their anomalies,
which cannot be interpreted merely by single-ore-forming element.

In many cases, fault-related primary halos from tectonite samples are often clearly recognizable when no halo anomaly is visible in the intact rock samples. Consequently, all samples were taken from the tectonite. On the basis of ore-controlling structure analysis and fault tectono-geochemical mapping, 259 typical samples of different orientations and characters were collected from fault zone at the earth's surface in the mine. Each of the samples weighs 1000~2000 g. All the samples were grounded to as fine as 200 mesh, prepared as test specimens through quartering, and underwent quantitative analyses for the contents of 52 trace elements by ICP-MS.

The focus is placed on the analysis of element associations in these samples. When the value of accumulative variance contribution is more than 77%, four main factors will be acquired: F1: Ti, Th, Cs, LREE, Nb, Rb, Zr, Hf, Ga, HREE, Sc, Co, Ta, W, Ni, U, V; F2: Zn, Pb, Cd, Mn, Ge, Ba; F3: In, Bi, Ta, Sn, V, Cr, Tl, Mo, Hf, Ge, Ga; F4: Mo, U, W. Of these factors, F2, F3 and F4 represent the mineralizing element associations.

The factor scores corresponding to the anomalies of ore element association halos are shown in Figure 1. The distribution of anomalies of the metal element association halos (MEAH) showcases the interesting characteristics as follows:

1) The anomaly zones are controlled by NE-trending faults, demonstrating the clear controls of ore-controlling structures. Generally, the NE-trending faults favor the injection of ore fluid and ore deposition.

2) The MEAH distribution is indicative of the zoning features of the mineralization. The intensity of the mineralization diminishes from a SW to NE direction, depicting the flow path of ore fluids.

3) The anomaly zone of MEAH and structurally ore-controlling features indicate that concealed ore-bodies are inclined in the SW direction and the ore-bodies extend vertically in the SE direction.

4 Targeting of Concealed Orebodies

The key indicators are summarized as: ore-controlling structures, metal element association anomalies, host-rock alteration and TEM anomalies in the mine.

The prognosis indicators suggest that the important target areas are located at the depth of E-1, F-1, A-1, A-2, A-3, D-1, D-2 anomaly zones, especially E-1 and F-1. Tunnel and engineering drilling exploration tests were carried out in the target areas. The No.1-6 ore-body has been discovered. The average grade of the ore is approximately 30% Pb and Zn. The discovery has resulted in the weight of Pb-Zn metal reserves elevating to almost one million tonnes, and this exploration technique has resulted in the deposit being recognized as a large-size Pb-Zn-(Ge-Ag) deposit.

5 Conclusions

1) MEAH within fault zone is an important indicator for the exploration of concealed ore-bodies. Variations in the gradient of primary anomalies are indicative of the dipping direction and extension of concealed ore-bodies.

2) The successful discovery of the No.1-6 ore-body indicates that Tectono-geochemical Exploration Technique is very effective in locating and exploring deep-seated ore-bodies. No doubt, it is of great significance in locating and exploring concealed ore-bodies, as well as in increasing the metal reserves in the Sichuan—Yunnan—Guizhou Zn-Pb Poly-metallic Mineralization Province and the world.
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References