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Analysis of metal–element association halos within fault zones for the exploration of concealed ore-bodies — A case study of the Qilinchang Zn–Pb–(Ag–Ge) deposit in the Huize mine district, northeastern Yunnan, China

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ABSTRACT

Metal–element association halos within mineralization-related fault zones (MEAHFZ) and their geochemical characteristics are examined as prospective targets to explore for concealed ore-bodies at the Qilinchang deposit, Huize Zn–Pb–(Ag–Ge) district, located in the Sichuan–Yunnan–Guizhou Triangular area of poly-metallic Zn–Pb deposits in southwestern China. By detailed study of the geochemical anomalies, concealed ore-bodies have been successfully found within the MEAHFZ, leading to a 2 million ton (Mt) increase in the Zn–Pb metal reserves. The successful exploration in the Huize district demonstrates that the MEAHFZ prospecting method has the potential to increase metal reserves in the brown field and to find new deposits in green field or new ore-bodies surrounding areas of the mine area. Variations of gradient value for primary anomalies, controlled by structures, may predict the dipping direction and the extension of the concealed ore-bodies. Also, the shifting direction of anomalies at different levels reflects the dip direction of concealed ore-bodies at depth. Thus, this method can not only find concealed ore-bodies, but also provide important information about deposit genesis. The method is low cost and its operation is simple, and can be used in exploration for concealed ore-bodies at depth in areas such as the Zn–Pb deposits in Northeastern Yunnan, the Sichuan–Yunnan–Guizhou Triangular area of poly-metallic Zn–Pb mineralization and the other similar areas over the world where the ores are obviously controlled by structures.

1. Introduction

The Huize Zn–Pb–(Ag–Ge) district is located in Northeastern Yunnan of southwestern China where it is the central part of the Sichuan–Yunnan–Guizhou Triangular area (SYGT) of poly-metallic Zn–Pb mineralization. This district consists of two large-sized deposits including the Qilinchang and the Kuangshanchang deposits and a medium- to small-scale Yinchangpo deposit (Fig. 1). There are 255 deposits and mineralization occurrences, including 80 medium-sized deposits and seven large-sized deposits in the Northeastern Yunnan Deposit Concentration Area (NEYDCA), the major part of the SYGT. Thus, the district has become one of the major producers for Zn–Pb and Ge–Ag resources in China (Zaw et al., 2006; Zhang et al., 2015) (Fig. 2).

Since the discovery of the Pb–Zn ore occurrence of the Kuangshanchang in the 1950s and a port of the Qilinchang mine in 1980s, the Southwest Non-ferrous Geological Exploration Bureau started to carry out the prospecting and subsequent exploration programs and Zn and Pb reserves of about 0.68 Mt have been obtained. After several stages of exploration in the area, total reserve of 2 Mt. Pb–Zn metal with average grade of 16% was obtained until 1993 (The Compiling Committee of the Discovery History of Ore Deposits in China, 1998). As far as the ore genesis, several hypotheses have been debated for a long time, such as the 'Sedimentary–reworking origin' (Tu, 1984, 1987, 1989), the 'Hot water sedimentary origin' (Zhang, 1984; Liao, 1984) and the 'Sedimentary–reworking closely associated with micro-facies carbonate' (Chen, 1984), 'Emeishan basalt magmatic hydrothermal mobilization and enrichment during Indosinian–Yanshanian tectonic event' (Shen, 1988), 'Rift-related tectonic and rift transformation–reworking' (Zhang and Yuan, 1988), 'Sedimentation–reworking' (Zhao, 1995), 'Sedimentation, reworking and epigenesis" (Liu, 1996; Liu and Lin, 1999), "Deeply circulating geothermal water filling and epigenetic stratabound' genesis (Shao, 1995), 'Convection–circulation metallogenesis and hydrothermal cave' (Zhen, 1997) and 'Strata-bound, epigenetic and hydrothermal deposit in the magnesia carbonate of neritic platform facies' genesis (Zhang, 1989).

The traditional viewpoints about sedimentary strata controlling the ore formation limited the exploration to the ore-hosting strata. Similarly, geophysical exploration techniques (e.g. Transient Electromagnetic Method) and some general drilling methods could not satisfactorily be used to explore for Pb–Zn resources at the deposit in the Huize district

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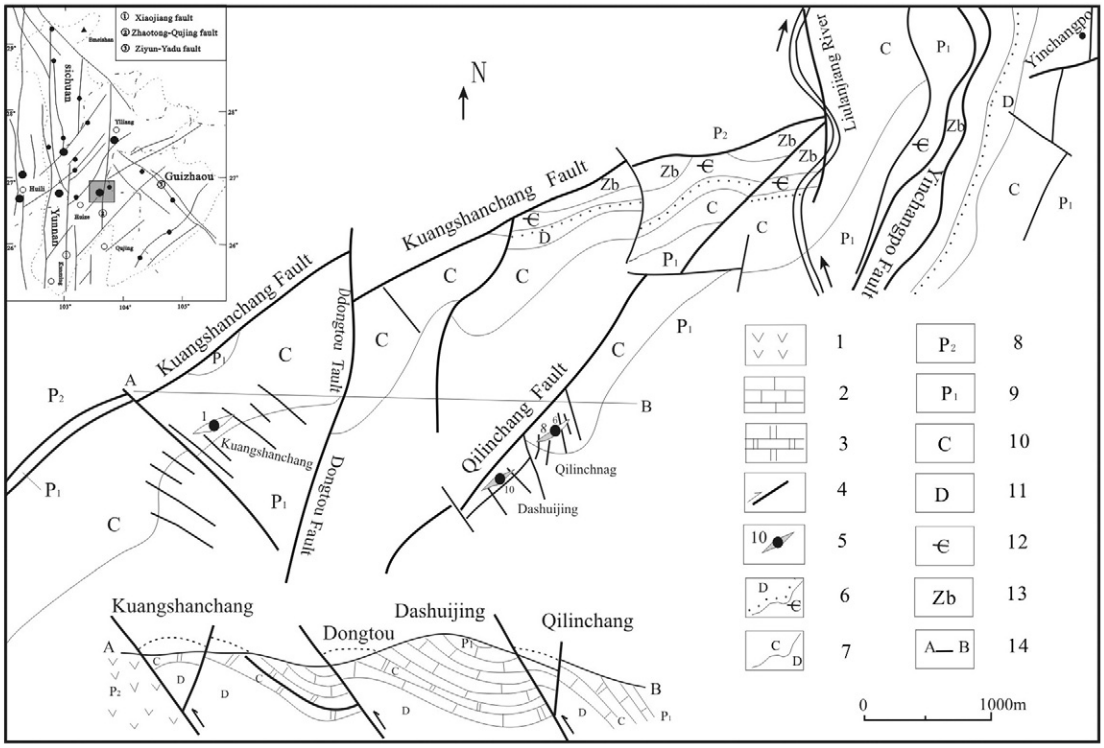

Fig. 1. Geological sketch map of the Huize Zn–Pb–(Ag–Ge) mine district. 1-Basalt, 2-Limestone, 3-Dolomite, 4-Fault, 5-Deposit and orebody number, 6-Pseudo-conformability, 7-Geological boundary, 8-Upper Permian Emeishan Fm. basalt, 9-Lower Pernian Qixia-Maokou Fm. limestone , 10-Carboniferous dolomite with limestone of Datang Fm. Baozuo Fm. Weining Fm. and Maping Fm., 11-Middle-Upper Devonian Haikou Fm. and Zaige Fm. limestone with sandy shale, 12-Low Cambrian Qingzhushi Fm. shale, 13-Upper Sinian Dengying Fm. limestone, 14-Section line.

because of the serious electromagnetic interference of Permian basalt in the mining area (Chen et al., 2001). Hence identifying a technique for exploring the concealed ore-bodies at depth becomes a crucial point. Zhou et al. (2001) proposed that the Qilinchang deposit belongs to MVT-type Pb–Zn deposit. Since 1998, the Huize deposits have extensively been studied by our team (Han et al., 2000, 2001, 2006; Huang et al., 2003; Zhang et al., 2006). Han et al. (2001) stressed that the Huize district should be recognized as an epigenetic deposit, formed by hydrothermal solutions. Han et al. (2012a, 2012b, 2015) further proposed that the formation of such deposits generally had three stages: 1) formation of thrust-fold structures and extensive fluid flow; 2) injection of fluid into fault zones and differentiation of gas–liquid; and 3) unloading of ore-forming fluid and coupled mineralization of structures and fluid. It is proven that applying metal–element association halos along fault zone (MEAHFZ) is a significant method to successfully explore for concealed orebodies.

Exploration projects had achieved a great breakthrough when high-grade ore bodies (Noes. 8 and 10) were found at depth in Qilinchang from 1999 to 2002. The exploration achievement also was a milestone in the historical development of Yunnan Chihong Zn & Ge Company Ltd., China. In addition, Han et al. (2007, 2012a) applied the MEAHFZ method to find a high-grade ore body at depth in the Kuangshanchang mine with the deposit model of tectonic-fluid injection. Till now, the total metal reserves of the Huize district have been defined to be more than 6 Mt. with combined Zn + Pb grading ≥30 wt.%. The Huize district is one of the highest grade and super-large-sized Zn–Pb deposits in the world.

The methodology combining the ore-controlling structural analysis with the geochemical studies has been developed in recent years and has been effectively applied to the deposits of similar geological setting (Yunnan Chihong Zn & Pb Co. Ltd., 2014); for instance, the Maoping Zn–Pb deposit in Northeastern Yunnan (Han et al., 2010a). The MEAHFZ method can be widely adopted in the geological exploration for deposits which are controlled by structure, and it provides meaningful exploration information about the ore-induced anomalies and metallogenic characteristics at depth.

This paper first introduces the metallogenic setting and geological characteristics of the area. Then, the basic principles and the methodology, metallotectonic analysis and MEAHFZ field mapping are discussed. Next, the typical features and distribution of MEAHFZ anomalies and the targeting of concealed ore-bodies are discussed. Finally, the paper comprehensively emphasizes and concludes that the method can be successfully applied in geological exploration to predict the targets of concealed ore-bodies. On the one hand, the new exploration method is a successful example for geological exploration to increase Pb–Zn metal reserves. On the other hand, the method is useful to explore concealed ore-bodies at certain depth in the Huize district, its adjacent areas as well as the other geologically similar regions, such as Pb–Zn deposits in the NE-YDCA and the SYGT of poly-metallic Zn–Pb mineralization and other similar type of deposits which are distinctly controlled by structure.

2. Regional and deposit geology

2.1. Regional geological background

The Huize district is situated in the southwestern margin of Yangtze Block, the southern part of Northeastern Yunnan basin. It is the main location of poly-metallic Zn–Pb mineralization in SYGT. The district is located in a triangular area which is surrounded by the NS-trending crustal-scale Xiaojiang fault at the Western region, the NE-trending crustal-scale Mile-Shizhong fault at the Southeastern region and the NW-trending Ziyun–Yadu fault at the Northeastern region. Also, the district is tectonically controlled by the NE-trending Dongchuan–Zhenxiong thrust-fold structural zone which has resulted from the sinistral shearing of the Xiaojiang fault and Zhaotong–Qujing concealed fault (Fig. 2).