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Petrogenesis of bismuth minerals in the Dabaoshan Pb–Zn polymetallic massive sulfide deposit, northern Guangdong Province, China

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ABSTRACT

Located in the northern Guangdong Province, the Dabaoshan Pb–Zn polymetallic massive sulfide deposit is one of the most important regions to have produced Fe, Cu, Pb, Zn and S in southern China. While much progress has been made with respect to the geology and geochemistry of the deposit, a better understanding of ore genesis is warranted. This ore body contains abundant bismuth element, only few studies exist on the distribution characteristics and existing states of bismuth. Electron microprobe study yields that native bismuth, tellurides (e.g. hedleyite) and sulfide minerals, are the main forms in which this element is found. The occurrence and characteristics of native bismuth and its mineral assemblages are different with high-T gold-bearing deposits, but are more similar to those of mid-low temperature hydrothermal deposits. Our research shows that the Bi(Te) at Dabaoshan derived from the Late Yanshanian dacite porphyry. The Bi(Te)-rich ore-forming fluid developed during intrusion of the dacite and mineralized along fractures, and overprint the earlier Pb–Zn mineralization. During the early overprinting event, the ore-forming fluid was rich in Bi and Te and poor in S, under uniform mid-temperature conditions. As the hydrothermal fluids evolved, they became enriched with Ag and Pb. Sulfur was rich in the fluid during the late overprinting event; this may have been related to dissolution of sulfide. The low abundances of Bi, Te and Ag in sulfide minerals (e.g., galena and sphalerite), indicate that ore genesis and the ore-forming materials were different between the Pb–Zn and Bi–Te–Ag stages. Thus, new geological and geochemical data were used to delineate the sequence ore genesis of Dabaoshan Pb–Zn mineralization.

1. Introduction

The Dabaoshan Pb–Zn polymetallic massive sulfide deposit, northern Guangdong province, is one of the most important mineral resources for iron, copper, lead, zinc, and sulfur in southern China with a reserve of approximately 100 Mt of Fe, 0.88 Mt Cu and 1.5 Mt of Pb + Zn. The Dabaoshan deposit is characterized by varied mineral suites and multiple types of mineralization. These include centrally-located (weathering–leaching) iron deposits, volcanic–sedimentary hydrothermal superimposed siderite deposits; northern district porphyry type and skarn type Wo–Mo deposits; and southern district lead–zinc–copper deposits (Fig. 1a).

Substantial progress has been made in studies of the geology and geochemistry of the deposit (e.g. Wang, 2006). Nevertheless, there has been much debate concerning the genesis and ore-forming mechanisms. As a result, a number of different genetic models have been proposed. Interpretations include: (1) porphyry or continental subvolcanic type deposits (e.g. Gu et al., 1984; Liu et al., 1985); (2) magmatic–hydrothermal type deposits (e.g. Huang et al., 1987; Xu, 2008b); and (3) volcanic-associated massive sulfide (VHMS) (e.g. Chen, 1985; Ge and Han, 1986; Yang, 1997; Gu et al., 2007). It is nevertheless clear from the previous geological and geochemical research that ore formation was a complex, multi-stage process and the observed features cannot be explained by a single metallogenic model (e.g. Qiu, 1981; Deng et al., 2005; Song et al., 2007).

Lead, zinc, copper, and sulfur are the dominant commodities in the Dabaoshan deposit. Bismuth is an abundant minor element and its presence at significant concentrations has been documented by many previous workers. There is, however, a marked gap in understanding the mineralogical distribution and speciation of bismuth in the deposit. As an important metal, Bi is obtained mainly as a by-product in the gold deposits (e.g. Drummond and Ohmoto, 1985; Chen et al., 2001; Tuomo and Randolph, 2005) and mid-high temperature magmatic hydrothermal deposits (e.g. Newberry, 1998; Simmons, 2001; Barkov et al., 2008), and few of them come

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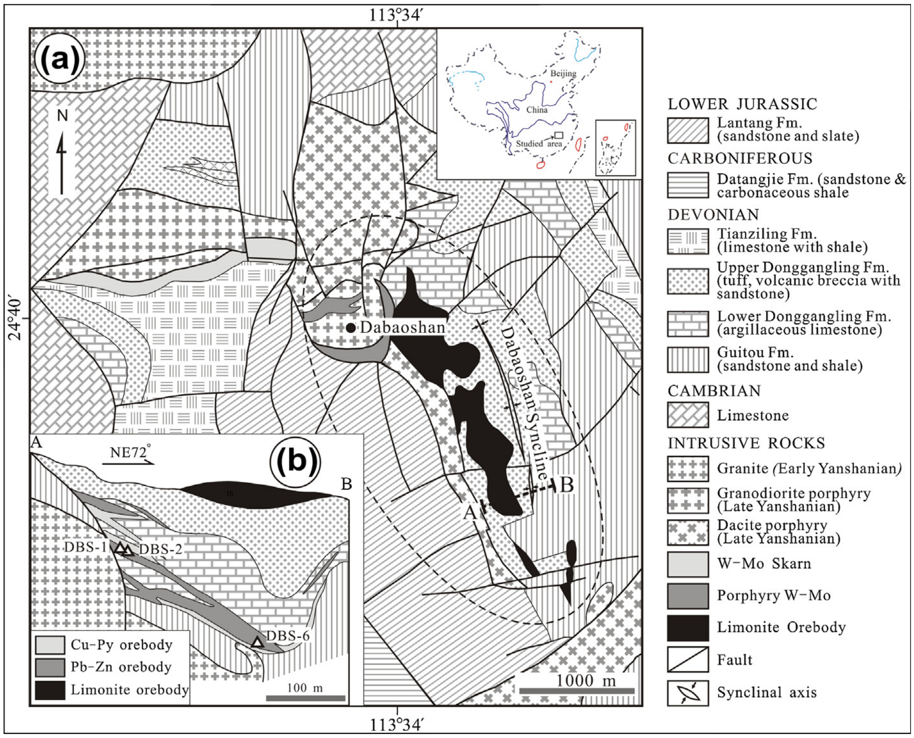

Fig. 1. Geological map (a) and profile map (b) of the Dabaoshan Pb–Zn polymetallic mine, Guangdong (after Wang, 2006).

from middle temperature sulfide deposits (Wang et al., 1982). In this paper, native bismuth and other Bi minerals are described. The occurrence of bismuth in the Dabaoshan deposit is shown to be distinct from that in high temperature hydrothermal deposits. Using the information from the detailed study of bismuth mineralogy, new ideas can be proposed regarding the genesis of the deposit. The classification standard of ore-forming temperature is based on Tu et al. (2003), and the high-, mid- and low temperature means >300 °C, 200–300 °C and <200 °C respectively in the paper.

2. Regional geological setting and mineral deposits in the Dabaoshan

The Dabaoshan deposit is located with a plunge of the northeastern Xueshangzhang anticlinorium in the Neocathaysian structural system. Structurally, the deposit lies at the intersection of the Dadongshan–Guidong E-W-trending structural belt and the Beijiang fault belt in the Shanguan–Wuchuan deep fault belt of the northern Guangdong Paleozoic depression zone (Ge and Han, 1986; Wang, 2006). The N- and NW-trending Dabaoshan syncline (~2 km in length) is the dominant regional fold in the area of the deposit. It dips at a relatively high angle to the east (60–70°), and at 40–50° to the west (Fig. 1a). Major faults include N- and NW-trending fault (F_a; Dabaoshan fault), a NE-trending fault (F_b), and an EW-trending fault. The Dabaoshan fault is closely related to the Pb–Zn mineralization; both F_1^a and F_3^a appear to confine the Dabaoshan deposit.

Exposed rocks in the mine district include terrigenous clastic sedimentary sequences and coast–shallow marine carbonates of the Upper Paleozoic (Early Devonian) epi-metamorphic rock series, and intermediate–acidic lavas and sub-volcanic clastic sedimentary rocks associated with Mid-Devonian seafloor volcanic activity. These strata account for ~70% of surface outcrop across the ore district; minor Early Paleozoic strata are exposed in the northern orearea. The Mid-Devonian Donggangling Formation is the dominant host for mineralization. It can be sub-divided into: the upper sub-formation (D_{2d}^b), which is chiefly composed of sandy shale, tuffs, and volcaniclastic breccias, and is marked by the pyritization and siderite mineralization; and the lower sub-formation (D_{2d}^a), which mainly consists of carbonaceous mudstone, mudstone, dolomite, and dolomitic and calcitic sandy shale. The Pb–Zn–Cu orebodies are hosted in the lower sub-formation.

Large volumes of intrusive rocks are closely associated with mineralization. The main intrusions are Yanshanian intermediate–acidic sub-dacite and granitic–dioritic porphyries. Based on geochemical criteria, the pluton is an intermediate–acidic, calc–alkaline, Si–Al-supersaturated intrusive rock, which is K_2O-rich, poor in Na_2O and CaO, and is spatially related to Pb–Zn mineralization (Wang, 2006). The granitic–dioritic porphyries (180–170 Ma, Wang et al., 2010) are found in the northwestern part of the Dabaoshan mine area (Fig. 1a), and are closely associated with Mo mineralization (Wang, 2006). The sub-dacite porphyries are the Dabaoshan dike, and the Jiuquling, Jimatou, and Xuwu intrusions (Fig. 1a), with K–Ar age estimates of 143 Ma (Wang, 2006). There are also minor amounts of diabase and felsite; they formed later than that of Yanshanian intrusions.

Most Cu-sulfide and Pb–Zn polymetallic orebodies occur in the northern and southern parts of the Dabaoshan mine area, respectively. The Pb–Zn segment is 3.1 km long from north to south, 400 m wide (E-W) and outcrops over an area of about 0.36 km^2. The Pb–Zn oreodies are hosted by carbonate strata of the lower sub-formation of the Donggangling Formation (D_{2d}^a), occur subparallel to host-rock bedding, and are situated within 500 m of the eastern part of a sub-dacitic porphyry dike and the hanging wall of the F_a^3 fault. The ores are overlain by the upper sub-formation of the Donggangling Formation (D_{2d}^b), which hosts a number of stratiform siderite deposits. A sizeable siderite gossan is exposed at the surface. There are more than 40 individual stratiform, stratoid, lenticular Pb–Zn orebodies. Most Pb–Zn orebodies coexisted with a copper–sulfur orebody, composed of three main polymetallic orebodies (Fig. 1b). The largest Pb–Zn orebody (no. 2/1-w) strikes N-S over a length of 810 m, is 60–210 m wide and 2–35 m in thickness. The next largest (no. 4/16) is 65–100 wide, 5–33 m thick and