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Geology and genesis of the Hehuaping magnesian skarn-type cassiterite-sulfide deposit, Hunan Province, Southern China

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ABSTRACT

Magnesian skarn-type tin deposits are relatively rare in the world. The Hehuaping cassiterite-sulfide deposit in southern China, having a total reserve of approximately 130,000 t of tin, 50,000 t of lead and 10,000 t of zinc, is identified as such type. The deposit is related to the Late Jurassic (157 Ma) Hehuaping medium- to coarse-grained biotite granite that intruded the Middle Devonian Qiziqiao dolomite Formation and the Tiaomajian sandstone Formation. Four paragenetic stages of skarn and ore formation have been recognized: I. prograde stage, II. retrograde stage, III. cassiterite-sulfide stage and IV. carbonate stage. Alteration zoning between fresh granite and unaltered country rocks can be identified. The skarn are typified by Mg-mineral assemblages of forsterite, spinel, diopside, tremolite, serpentine, talc, and phlogopite. The geochemistry of various skarn minerals shows a gradually decrease of Mg end member and, correspondingly, an increase of Fe- and especially Mn end members along the process of skarn alteration.

Tin mineralization developed during the late retrograde stage resulted in cassiterite–magnetite-diopside skarn. However, the deposition of cassiterite occurred predominantly as cassiterite-sulfide veins along fractures and interlayer fracture zones during stage III. The petrogeochemistry of Hehuaping granite, as well as S- and Pb isotopic analyses suggest that the ore-forming elements have a magmatic source originated from the upper crust. The H – O isotopic and fluid-inclusion analyses indicate that high-temperature ore-forming fluids in early anhydrous skarn stage (stage I) are also magmatic origin. In comparison, the retrograde fluids are characterized by relatively low salinity (2 to 10 wt.% NaCl equiv) and low temperature (220 to 300 °C), suggesting a mixed origin of meteoric waters with magmatic fluids. The major ore-forming stage III fluids are characterized by lower temperature (170 to 240 °C) and salinity (1 to 6 wt.% NaCl equiv), indicating fluid mixing could be an efficient tin-mineralizing mechanism. Meteoric waters are dominant in stage IV, resulting in a further lowering of temperature (130 to 200 °C) and salinity (0.4 to 1 wt.% NaCl equiv).

1. Introduction

Skarn-type tin deposits contribute a significant part to the total Sn resources in the world. Tin-bearing skarns are extremely complex, bearing a wide range of textures, mineral assemblages (often superimposed upon each other), and bulk compositions and structures (Kwak, 1987). As far as mineral assemblages are concerned, skarns can be classified as either calcic or magnesian. Magnesian skarns result from the replacement of dolomitic rocks and are characterized by minerals such as diopside, forsterite, spinel, phlogopite, serpentine, and talc (Einaudi and Burt, 1982). Magnesian skarn-type tin deposits are less common compared to calcic ones, and they were found mainly in eastern Chukotka (Russia) (Aleksandrov, 1975), Tasmania (Australia) (Kwak and Nicholson, 1988), and Alaska (USA) (Aleksandrov, 2010). Because of their relative scarcity and complexity, magnesian skarn-type tin deposits have not attracted much research attention.

South China is one of the most important tin metallogenic provinces in the world. Among the major tin deposits there, the skarn type, such as the world-class Gejiu, Dachang, and Shizhuyuan deposits, is of particular importance (Mao, 1995). All of these are characterized by calcic skarn-type mineralization (Chen et al., 1992a; Fu et al., 1991; Lu et al., 2003; Mao et al., 1996).

The recently discovered Hehuaping tin deposit is a large magnesian skarn type which was only previously reported in the Dading Sn–Fe deposit (Wang, 1984) and the Xianghualing Sn–Be deposit (Aleksandrov and Senin, 2002) in this region. The purpose of this paper is to give a detailed description of the skarn alteration, related granite, and mineral assemblages (texture, paragenesis and mineral chemistry) of the Hehuaping deposit. We will also attempt to explore the ore genesis and to constrain the physico-chemical conditions of skarn alteration and ore formation through isotopic geochemical analyses and fluid inclusion microthermometry.

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2. Geological setting

South China consists of the Yangtze Block to the northwest and the Cathaysian Block to the southeast (Fig. 1A). The Hehuaping deposit is located in the Nanling Range, which is characterized by intensive and widely distributed granitoids associated with numerous non-ferrous and rare-metal minerals of Mesozoic age (Hua et al., 2005; Mao et al., 2006; Wang et al., 2010). The Hehuaping deposit is located in the middle part of the Chenzhou–Lingwu fault zone. The NE-trending fault controls the distribution of the Mesozoic granites enriched in Sn–W–Pb–Zn mineralization (Fig. 1B). Based on the systematic geologic and geochemical variations between the Mesozoic basalts on different sides of the Chenzhou–Lingwu fault, Wang et al. (2008) suggested this fault to be a boundary between the Yangtze Block and Cathaysian Block during the Neoproterozoic collision.

2.1. Sedimentary rocks

The strata outcropping in the Hehuaping deposit include Precambrian metasandstone, Middle- and Upper Devonian clastic and carbonate rocks, and Lower Carboniferous carbonate rocks, among which the Middle Devonian rocks are dominant (Fig. 1C). Lying unconformably on the Precambrian metasedimentary rocks, the Middle Devonian strata can be divided into two formations, Tiaomajian and Qiziqiao. The Tiaomajian Formation is up to 300 m thick and consists of quartz sandstone, siltstone, and shale, with sandstone and conglomerate beds at the bottom. The sandstone is composed predominantly of quartz clasts with a matrix of finer quartz and clays and shows reddish coloration from iron oxide and hydroxide. The Qiziqiao Formation is made up mainly of dolomite, dolomitic limestone, and limestone with a total thickness of more than 500 m (Lu et al., 2003). This Formation is the host rock of most W–Sn–Pb–Zn deposits in this region. Samples of unaltered Qiziqiao Formation dolomitic carbonate rocks have average background concentrations of 53.11 wt.% CaO, 0.73 wt.% MgO, 1.41 wt.% SiO_2, 0.27 wt.% Al_2O_3, 0.20 wt.% Fe_2O_3 and 0.03 wt.% MnO (Bureau of Geology and Mineral Resources of Hunan Province, 1988). The 276 m thick Upper Devonian Shetianqiao Group comprises moderate- to thick-layered micritic limestone intercalated with thin-layered shale. The Upper Devonian Xikuangshan Group consists mainly of massive chert-bearing limestone and dolomitic limestone. The Lower Carboniferous Datang Stage and Yanguan Stage consist of sandstone and limestone, respectively.

2.2. Structure

The Hehuaping deposit is located to the east of the NE-trending Chenzhou–Lingwu deep fault and on southeastern side of the Wangxianling granite (Fig. 1B). The tectonic framework of this area is controlled mainly by three directions of faults that trend approximately

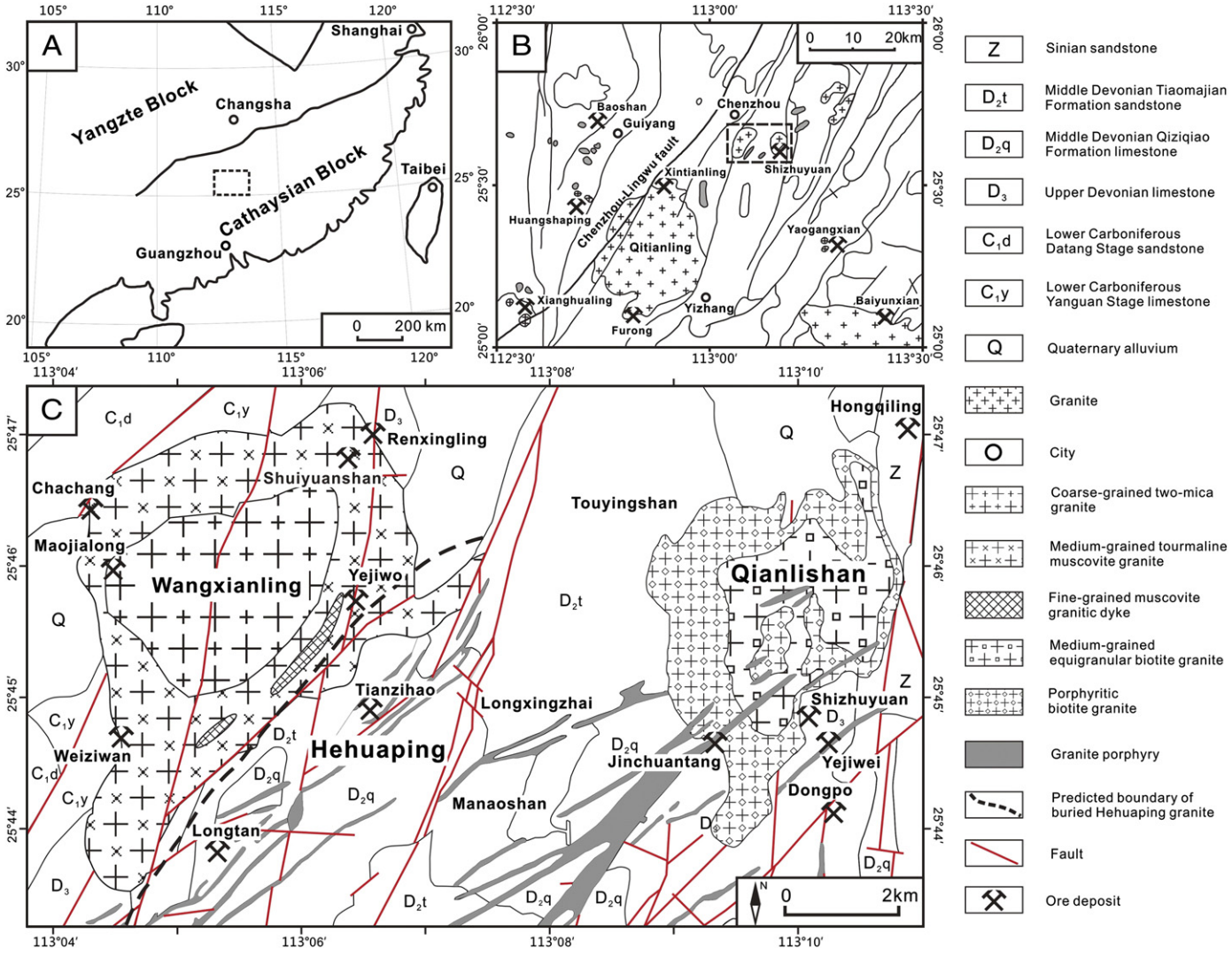

Fig. 1. Regional geological map of the Hehuaping deposit, also showing the important W, Sn, Pb and Zn deposits in the central Nanling Range, Southern China (Fig. 1B modified from Peng et al., 2006; Fig. 1C modified from Zhang et al., 2011).