Epigenetic hydrothermal features of the Emeishan basalt copper mineralization in NE Yunnan, SW China

Houmin Li, Jingwen Mao, Yuchuan Chen, Denghong Wang
Institute of Mineral Resources, Chinese Academy of Geological Sciences, 26 Baiwanzhuang Rd., Beijing 100037, China

Changqing Zhang, Hong Xu
Faculty of Geosciences and Resources, China University of Geosciences (Beijing), 29 Xueyuan Rd., Beijing 100083, China

Abstract. Native copper in basalt copper deposits in NE Yunnan, SW China, formed in fissures of basalt or in carbonaceous sedimentary interbeds of basalt together with organic matter such as bitumen. The mineral fills in fissures of bitumen and replaces plant fragments. Bitumen is of organic origin, with its $\delta^{13}C_{V\text{-}PDB}$ values ranging from –27.3 to –33.1‰. The ^{40}Ar-^{39}Ar ages of the gangue minerals zeolite and actinolite in copper ores are 226 to 238.6 Ma and 134 to 149.1 Ma respectively, indicating the occurrence of two copper mineralization stages. All these suggest that the copper mineralization is of epigenetic hydrothermal origin.

Keywords. Basalt copper deposit, epigenetic hydrothermal mineralization, organic matter, Emeishan basalt, NE Yunnan, SW China

1 Introduction

The Emeishan basalt is widely distributed in SW China. There are many traces of copper mineralization, copper mineralization occurrences and small-scale copper deposits in the basalt. Mining of this type of copper deposit goes back to ancient times and numerous old adits are left. Mining is still conducted by local people now. From 1958 to 2002 some geological and mineral departments have performed prospecting and evaluation for this type of copper in several periods and it was considered that copper mineralization was of volcanic-hydrothermal origin during the late stage of basaltic eruption and had no economic value because of disperse mineralization. No fruitful results were obtained during the mineral prospecting.

In 2002 Zhu et al. (2002a, b, 2003) reported that a copper deposit closely related to bitumen has been found in basalt on the Yunnan-Guizhou border region. This finding again attracted geologists' attention to the Emeishan basalt copper deposits. Study, prospecting and exploration of this type of basalt copper deposit have been carried out once again since then.

In this paper, we will introduce the epigenetic hydrothermal features of this type of basalt copper deposit in NE Yunnan.

2 Geological setting of the basalt copper deposits

The Emeishan basalt is widely distributed in the border region of Yunnan, Guizhou and Sichuan provinces, SW China, covering an area of more than 300,000 km^2. It formed in a rift environment on the western margin of the Yangtze craton in the early Late Permian. The rock belongs to continental flood basalt and may be related to the Emei mantle plume (Chung and Jahn 1995).

The Emeishan basalt stratigraphically belongs to the Upper Permian Basalt Formation and disconformably overlies carbonate rocks of the Lower Permian Qixia and Maokou formations. The Basalt Formation is divided in ascending order into four members: the First Member, mainly volcanic breccia; the Second Member, mainly porphyritic massive basalt; the Third Member, also mainly porphyritic massive basalt; and the Fourth Member, mostly massive basalt with some amygdaloidal basalt and local tuff and carbonaceous sedimentary interbeds (Yunnan Bureau of Geology and Mineral Resources 1989).

The Basalt Formation is disconformably overlain by coal measures of the Upper Permian Xuanwei Formation, which are in turn conformably overlain by Triassic and Jurassic red clastic rocks. Locally Cretaceous sandy conglomerate unconformably overlies old strata of different ages.

Regional faults are well developed in the basalt and mostly strike NE and ENE. The axis of folds is also mainly oriented in a NE direction. These faults and folds occurred in the Late Jurassic.

No significant magmatic activity occurred after eruption of the Emeishan basalt in the area.

3 General characteristics of the basalt copper deposits in NE Yunnan

The basalt copper mineralization in NE Yunnan is stratabound (Fig. 1). The lower part of the Fourth Member of the Basalt Formation is the main mineralization horizon, 50 to 100 m thick and composed of 3 to 5 basalt flows. Each flow consists of massive basalt in the lower part and amygdaloidal basaltic breccia or amygdaloidal basalt in the lower part, often intercalated with carbonaceous conglomeratic mudstone and tuff between the flows.

The carbonaceous conglomeratic mudstone commonly contains plant fragments. There are generally 1 to 3 layers of copper mineralization and sometimes as many as 5 layers. The copper orebodies and mineralization bodies, tens of centimetres to 2 m thick, mainly occur in schistose amygdaloidal basalt, amygdaloidal basaltic breccias

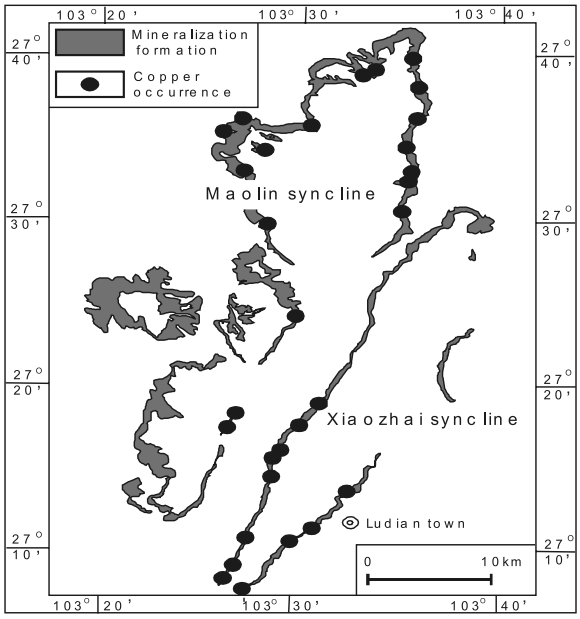

Figure 1: Distributions of the Emeishan flood basalt and basalt copper occurrences in NE Yunnan, SW China.

and carbonaceous sedimentary rocks along the contact zone of different basalt flows. The footwall and hanging wall of the orebodies are generally massive basalt. The dominant metallic minerals in the basalt are native copper and those in carbonaceous sedimentary interbeds are native copper and minor chalcocite. The dominant gangue minerals include bitumen, carbon, laumontite and quartz with subordinate calcite, pumpellyite, epidote, chlorite and prehnite (Li et al. 2004a; Zhu et al. 2002a, 2003).

4 Evidence of epigenetic hydrothermal mineralization of the basalt copper deposits in NE Yunnan

4.1 Geological evidence

Bitumen fills along fissures of basalt (Fig. 2), while native copper fills along fissures in bitumen (Fig. 3). Native copper and chalcocite have replaced the plant fragments in the conglomeratic carbonaceous mudstone (Fig. 4) and some quartz chalcocite veins penetrate the carbonaceous mudstone and gravels therein. All these features suggest that palaeo-petroleum, the precursor of the bitumen, was trapped in the fissures of the basalt after cooling of the basalt, and that native copper mineralization occurred later than the transformation of petroleum into bitumen (Li et al. 2004a).

4.2 Geochemical evidence

Figure 4: Chalcocite (bright) replaces plant fragments and the texture of the plant is preserved. Polished section; plane polarized light; 1.2 × 0.8 mm. Sample taken from the Naoyingyan

Figure 2: Bitumen (black) fills the fissures of basalt (grey). Field photo of the Sujiaqing copper deposit in NE Yunnan.

Figure 3: Native copper (white) fills the fissure of bitumen (grey). Polished section; plane polarized light; 0.6×0.4 mm. Sample taken from the Dadi copper deposit, NE Yunnan.

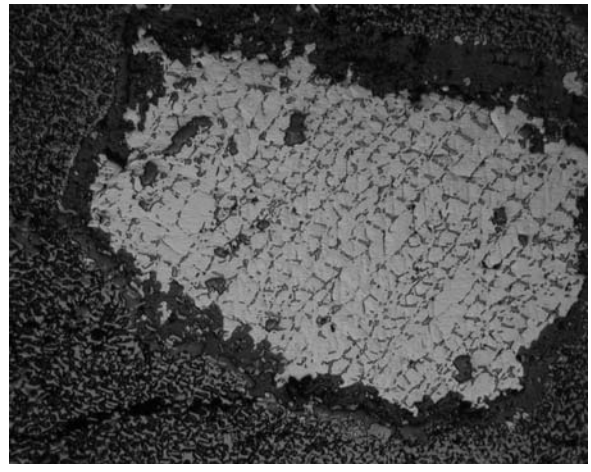

Figure 4: Chalcocite (bright) replaces plant fragments and the texture of the plant is preserved. Polished section; plane polarized light; 1.2×0.8 mm. Sample taken from the Naoyingyan copper deposit, NE Yunnan.

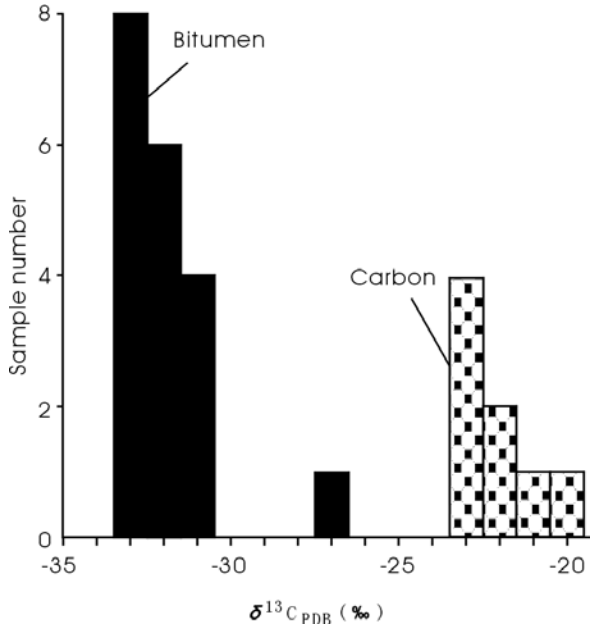

Figure 5: Carbon isotopic compositions of bitumen and carbon in basalt copper ores, NE Yunnan, SW China.

copper deposit, NE Yunnan. The $\delta^{13}C_{V\text{-}PDB}$ values of the bitumen in copper ore hosted in basalt range from –27.3‰ to –33.1‰, showing the organic carbon isotope feature and suggesting that the bitumen, unlike basaltic magma derived from the mantle, is of organic origin rather than inorganic origin. However, there is no relation between bitumen and its nearby carbon material in the carbonaceous mudstones, for the $\delta^{13}C_{V\text{-}PDB}$ values of the carbon material in copper ore hosted in carbonaceous sedimentary rocks range from –20.2 to –23.2‰, which is obviously different from those of the bitumen (Fig. 5). All these suggest that the palaeo-petroleum – the precursor of the bitumen – is allochthonous and epigenetic and that copper mineralization that occurred later than it is naturally also epigenetic (Li et al. 2004b; Mao et al. 2003).

4.3 Isotope chronological evidence

The ^{40}Ar-^{39}Ar ages of laumontite, actinolite and heulandite in the basalt copper ores in NE Yunnan range from 226 to 228 Ma, from 235.7 to 238.6 Ma and from 134 to 149.1 Ma respectively (Zhu et al., 2004). The U-Th-Pb isochron age of the bitumen copper ore is 136 Ma (Zhu et al. 2004). These ages are 30 to 120 Ma younger than the ages of the Emeishan basalt (260 Ma or so), suggesting that the basalt copper mineralization in the area is epigenetic. No age is presently available for the copper mineralization.

5 Discussion and conclusions

The Emeishan basalt, containing up to 200 ppm Cu and covering an area of >300,000 km^2, can provide adequate source materials for the epigenetic hydrothermal copper mineralization. The distinct epigenetic hydrothermal and stratabound features and extensive distribution of the basalt copper mineralization in NE Yunnan imply that large-scale epigenetic hydrothermal activities and copper mineralization occurred in the basalt area. This type of basalt copper mineralization is similar to the Keweenaw basalt copper deposit (Hamilton 1967; Bornhorst et al. 1988; Davis and Paces 1990; Hoa and Mauk 1990, 1996; Mauk et al. 1992; Buruss and Mauk 1996): both occur in continental flood basalt in the continental rift environment of a craton and might be related to the mantle plume; the dominant Cu mineral is native copper; the ore bodies are hosted in the amygdaloidal basaltic breccias and amygdaloidal basalt and their sedimentary interbeds in the upper part of the basalt flows. The dominant gangue minerals are characterized by a low-temperature assemblage of laumontite, epidote, and quartz. The hydrothermal mineralization is epigenetic; and the ages of mineralization are 20 to 30 Ma younger than those of basaltic eruption (Zhu et al. 2003; Li et al. 2004a). Therefore, compared to the Keweenaw native copper deposits, the native copper mineralization in the Emeishan basalt has a great ore potential for prospecting.

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