Research Advances

Fluid Inclusions and Isotope Geochemistry of the Emba Derho and the Debarwa VMS Deposits, Asmara District, Eritrea

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Objective

Recent exploration indicates several localities with significant gold, copper, and zinc resource potential in the Asmara district, Eritrea, including the Emba Derho and Debarwa volcanic-associated massive sulfide deposits. These deposits are hosted by the Neoproterozoic metamorphic volcanic rocks of Asmara green stone belt, which strike NNW–SSE and are 200 km long and 5–20 km wide, and the mineralization is often associated with the altered and deformed rocks. The Emba Derho deposit, located 12 km northwest of Asmara (Fig. 1a), the capital of Eritrea, is the largest Cu-Zn-Au VMS deposit in the Asmara metallogeny belt. It is estimated that the Emba Derho deposit of the Asmara project contains total reserves of 49.8×10^6 tons of copper ores and 16.8×10^6 tons of zinc ores. The gold grade of this deposit is about 0.31g/t. The Debarwa deposit, situated 26 km southwest of Asmara, has similar ore features with the Emba Derho deposit.

Many international literatures have described the geological features of these deposits, but few have focused on the deformation of ore mineral assemblages, fluid inclusions, and the source of ore-forming elements. This study initially provides some analysis of fluid inclusions and S-Pb isotopes of the Emba Derho and Debarwa deposits in order to understand the ore-forming process.

Methods

The ore mineral assemblages were studied in detail by microscope and SEM/EDS. Fluid inclusion thermometry was carried on by using a Linkam THGS600 stage and a Leitz Orthoplan-POL transmitted light microscope at USTB. Raman analysis of fluid inclusions was undertaken using a LABHR-VISLabRAM HR800 Raman spectrometer at IGGCA. Sulfur and lead isotope compositions were determined at BRIUG by Delta v plus and ISOPROBE-T mass spectrometers, respectively.

Results

Four mineralization zones can be recognized in the Emba Derho deposit from surface to underground: oxidation, secondary enriched, original Cu-rich, and original Zn-rich zones. The ores can be divided into two types: pyrite-Zn-Cu ores (Fig. 1b) and pyrite-Cu ores (Fig. 1c). The ore minerals are dominated by pyrite, chalcopyrite and sphalerite, with minor tetrahedrite and galena. There are small amounts of gangue minerals including quartz and biotite. Pyrite occupies 50%–80% of the Zn-Cu and Cu ore minerals, and usually occurs as brecciated grains, indicating an intensive deformation after VMS mineralization. Chalcopyrite occupies 7%–15% of ore minerals in Cu ores and is less than 5% in Zn-Cu ores; it fills the tiny fissures in pyrite. Sphalerite occupies 15%–25% of total ore minerals in Zn-Cu ores and 0–5% in Cu ores, and it usually replaces pyrite and is associated with chalcopyrite.

The ore types of the Debarwa deposit are also divided into Zn-Cu ores and Cu ores. Sphalerite is not as abundant as in the Emba Derho deposit, occupying 10%–25% of the total ore minerals, and is associated with chalcopyrite and tetrahedrite. Pyrite mostly occurs as small brecciaed grains, and is cemented by other sulfide minerals. Chalcopyrite may occupy 10%–60% of ore minerals in Cu ores. Tetrahedrite and galena can be seen in some samples.

Fluid inclusions are usually contained in sphalerite and quartz from both the Emba Derho and the Debarwa deposits. Fluid inclusions in sphalerite are two phase inclusions with 20vol% to 80vol% of liquid phases and sizes of 5 μm to 20 μm (Figs. 1d and 1e). Most of these inclusions appear no distinguished phase change when heating, and some inclusions were decrepitated at temperatures above 320°C. Only a few inclusions gave homogenization temperatures from 306°C to 381°C and ice melting temperatures ranging from −2.0 to −0.5°C, which are corresponding to 3.4wt%–0.9wt% NaCl eqv. of salinities.

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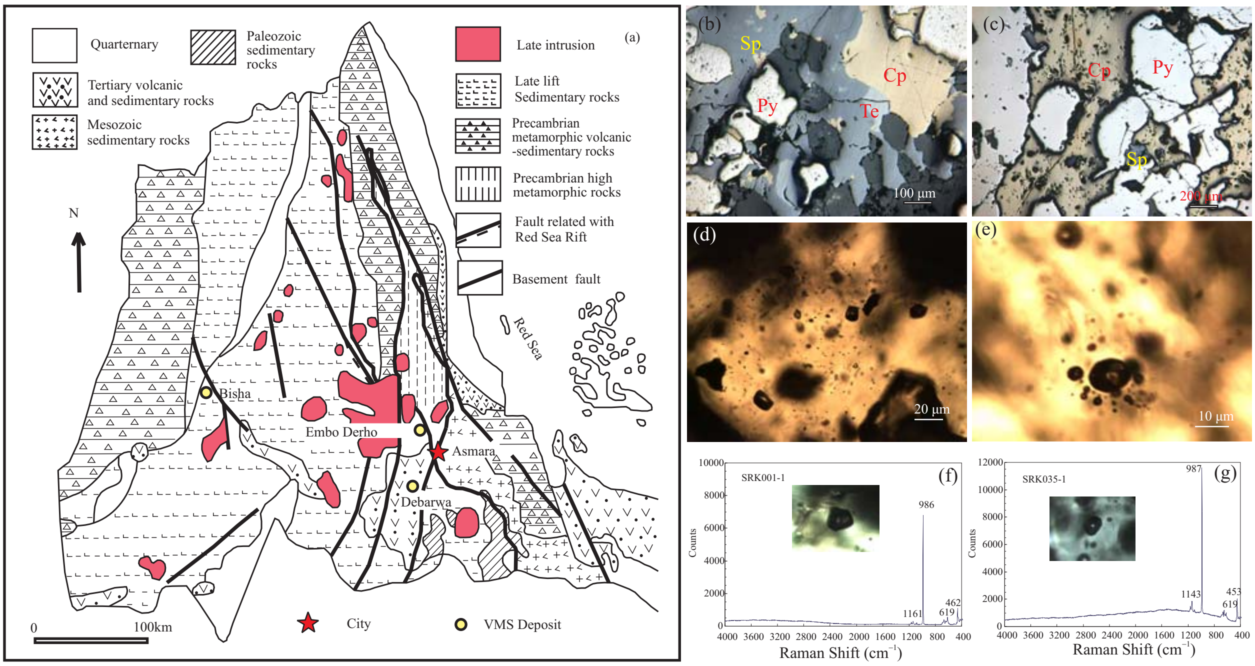

Fig. 1. (a), Sketch map of the Asmara District, Eritrea (After Ghebreab et al., 2009); (b), Pyrite type Zn-Cu ore, sphalerite(Sp) –chalcopyrite(Cp) –tetrahedrite (Te) replacing pyrite (Py), SRK-032-M, Debarwa; (c), Pyrite type Cu ore, chalcopyrite (Cp) replacing pyrite (Py) along tiny fissures, and associated with small amounts of sphalerite(Sp), SRK-009-M, Emba Derho; (d), Fluid inclusions with various V/L ratios in light brown sphalerite, SRK0035-M-3, Debarwa; (e), An implosive inclusion surrounding by many small inclusions, showing retrograde process after peak metamorphism, SRK003-M-1, Emba Derho; (f) and (g), Laser Raman spectrum of fluid inclusions in sphalerite from the Emba Derho and the Debarwa VMS deposits.

The data show that there are four spectral peaks near Raman shifts of 986–987 cm^{-1}, 453–462cm^{-1}, 619–650cm^{-1}, and 1143–1162cm^{-1}, which might reflect a group of spectral peaks of zinc sulfate (Figs. 1f and g). Previous studies of other areas believed that the Raman spectral peaks of 987 cm^{-1} (ν1), 452–462 cm^{-1} (ν2), 1082–1165 cm^{-1} (ν3) and 616–645 cm^{-1} (ν4) were barite, and the peaks of 988cm^{-1}, 461cm^{-1}, 616cm^{-1} and 1142cm^{-1} were lead sulfate. Hence, it is inferred that sulfur content might be very high in ore-forming fluids during the mineralization. On the other hand, a certain amount of ZnS in sphalerite might be dissolved in water of fluid inclusions after being trapped.

Sulfur isotope analysis of sulfides shows that the $\delta^{34}S$ values of pyrite from the Emba Derho deposit have a narrow range varying from 0.6‰ to 4.8‰, and those from the Debarwa deposit are from 0.4‰ to 1.7‰. The $\delta^{34}S$ values of chalcopyrite from these two deposits are 0.8‰–3.1‰, and those of sphalerite are 0.9‰–3.4‰. The ratios of lead isotopes of pyrite from the two deposits are 17.461–18.721 ($^{206}Pb/^{204}Pb$), 15.455–15.647 ($^{207}Pb/^{204}Pb$), and 36.952–39.111 ($^{208}Pb/^{204}Pb$). Both sulfur and lead isotope compositions indicate that the ores in the Emba Derho and Debarwa deposits have a magmatic or mantle source.

Conclusions

In summary, the ore textures of the the Emba Derho and Debarwa deposits show that these deposits have experienced deformation events related with orogeny after VMS mineralization. Fluid inclusions in sphalerite have homogenization temperatures higher than 300°C, and ore-forming fluids might be sulfur-rich fluids. The ore-forming elements may have a magmatic or mantle source.

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