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Ore-forming processes of the Laba porphyry-skarn Mo-polymetallic deposit, northwestern Yunnan, SW China: Evidence from petrology, mineralogy, and geochemistry of magnetite

Kun Xiang*, Chuandong Xue, Zengqian Hou, Tiannan Yang, Zhiming Yang, Lili Jiang, and Abdul Ghaffar

Kunming University of Science and Technology, Kunming, Yunnan, China, *e-mail, xiangk@aliyun.com

The Laba Mo-polymetallic deposit lies in the transitional area between the Yangtze block, Songpan-Ganze terrane, and the Yidun island arc, northwestern Yunnan, SW China. The investigation confirmed that there is a large porphyry-skarn type Mo-polymetallic metallogenic system with total reserves of 63.5 Mt Mo @ 0.11%, and associated 33.7 Kt Cu @ 0.22% and 14.7 t Au @ 0.65 g/t. Based on systematic fieldwork and petrographical observation, four types of magnetite are recognized at the deposit: type-I is disseminated in the porphyry, type-II is distributed in basalt and is nodular-shaped, and type-III and type-IV are banded in the skarn and veins in marble and limestone, respectively. Electron microprobe analysis (EMPA) of magnetite grains shows that there is a significant negative correlation between the content of FeOT and SiO_2, indicating the relatively basic environment is more suitable for the enrichment and precipitation of iron. Compared with type-I (0.039%), type-III (0.024~0.202%), and type-IV (0.004~0.055%), the Cr_2O_3 content of type-Ⅱ magnetite (2.60~2.86%) is highest, showing that the iron in the type-II magnetite is originated from the basalt and that in the other three types of magnetite is from the porphyry, or there is a little contribution from the basalt. In addition, the value of Fe^{3+}/Fe^{2+} is <2 in the basalt, equals 2 in the porphyry and skarn, and is >2 in the marble and limestone by calculation with the electricity price balance method, showing that the oxygen fugacity decreased gradually from carbonates, to porphyry and skarn, and then to the basalt. According to the Ca+Al+Mn vs. Ti+V discriminant diagram and the triangular figure of TiO_2-Al_2O_3-MgO of magnetite, the type-I magnetite is associated with magmatism and the type-III and type-IV are formed by hydrothermal processes,;the type-II magnetite is formed not only during magmatism but also by hydrothermal processes. The result of the related dot matrix of elements in magnetite shows that the replacement caused by isomorphism in the magnetite during hydrothermal processes is obviously weaker than the magnetite associated with magmatic activity. The data from EMPA shows that the content of Al_2O_3 is zero, the content of MgO and MnO (0.931~4.279%, 0.875~1.011%) is obviously higher in the magnetite formed during hydrothermal process than during magmatic activity (0~0.032%, 0~0.078%), and the content of TiO_2 (0~0.015%) in the magnetite formed by hydrothermal processes is lower than that associated with magmatic activity (0.088~0.775%). For the hydrothermal process, there is no linear relationship between the content of SiO_2 and the other major elements (except for FeOT), showing that hydrothermal fluids had multiple stages in the Laba deposit. Similarly, the hydrothermal fluids from magmatic processes also had multiple stages. According to the mineralographical observations, the magnetite associated with magmatic activity is related to the molybdenite, and the magnetite formed by hydrothermal processes is related to the chalcopyrite. Therefore, the molybdenite belongs to porphyry event and the chalcopyrite belongs to the skarn-forming event.