Episodic Magmatism Contributes to Sub-Seafloor Copper Mineralization: Insights from Textures and Geochemistry of Zoned Pyrite in the Ashele VMS Deposit

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We combine textural evidence, in situ analysis of sulfur isotopic composition with trace elements of pyrite from the well-preserved, large-tonnage Ashele volcanogenic massive sulfide (VMS) deposit (Central Asian Orogenic Belt, NW China) to elucidate the origin of the ore-forming materials and evaluate controlling factors of VMS deposits. Three texturally and compositionally distinct types of pyrite have been recognized. The first type of growth zones with high Cu, As, and volatile elements (e.g., Hg and Tl) concentrations and negative δ34S values (-7.83‰–-0.35‰) most likely formed from the input of magmatic volatiles from degassing of the underlying magmatic systems. The second type of Cu-As-rich growth zones is not enriched in volatile elements and has positive δ34S values (2.59‰–6.56‰), which is interpreted to have precipitated during fluid boiling. The third type of growth zones without Cu-As enrichment but having positive δ34S values (0.30‰–9.76‰) was probably formed without boiling or magmatic volatile input. Our results suggest that multi-stage magmatic degassing or fluid boiling accompanied by Cu precipitation recorded in individual pyrite grains can reveal episodic magmatic-hydrothermal activities, which are essential factors in forming large-tonnage VMS deposits.