

3.6.66

Trace element incorporation into garnet as a tracer of hydrothermal fluid flow and crystal growth

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Introduction

The incorporation of trace elements into minerals during hydrothermal crystallisation is a sensitive function of crystallography, speciation in the fluid, the mechanism of incorporation into the mineral, and the environment of crystallisation. Here we report the results of a study into the trace element composition of hydrothermal garnet from the Beinn an Dubhaich granite aureole, Isle of Skye, which shows the influence of these processes on the distribution of the REE.

Trace element composition of Garnet

Three garnet samples were analysed, recording different conditions of fluid flow. REE patterns are typically LREE-enriched, with a variable Eu anomaly. Individual zones that show evidence of dissolution of previously formed garnet on their inner margins, show major shifts from these patterns. Fe-rich zones show positive Eu anomalies, and an increase in the LREE relative to the HREE. Relatively Fe-poor zones show HREE-enriched patterns with negative Eu-anomalies. Zones immediately following these show a gradual depletion in the HREE.

Garnet growth and trace element partitioning

Garnet growth occurred under a range of conditions. LREE enriched patterns are interpreted to be the equilibrium pattern for calcic-garnets. Positive Eu anomalies accompanied by increases in the abundance of the LREE result from the introduction of new batches of external fluid into the skarn and the differences in substitution mechanisms between bivalent and trivalent REE. Increases in all REE to give MREE-HREE enriched patterns are attributed to garnet growth from super-saturated solution, leading to surface sorption control on the incorporation of trace elements. Close system crystallisation following resealing of the skarn system led to a steepening of the REE pattern and the generation of positive Eu anomalies. These changes can be simulated by simple crystallisation models. Other elements, including U, correlate with these effects, indicating a similar set of processes controls the distribution of other trace elements of geological interest. This study provides a clear indication of the utility of the REE in tracing hydrothermal processes. The observed variations in Sm-Nd ratio within individual crystals, without changes in metal source, may have major implications for geochronology.

3.6.P01

S-He isotope evidence for the origin of the giant Dachang Sn-polymetallic ore deposit in South China

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The Dachang Sn-polymetallic ore deposit in South China is a well-known world-class massive sulfide deposit. The ore genesis of this deposit has long been hotly debated with two major schools of thought, i.e., magmatic-hydrothermal replacement or submarine exhalative-hydrothermal mineralization.

A detailed isotope geochemical investigation revealed that at Dachang, sulfides from the Lamo Cu-Zn skarns near the granite boundary have $\delta^{34}\text{S}$ values of $-3\sim+4\%$ with a mean of near zero. The sulfur at Lamo is typical magmatic sulfur and was likely derived from the Longxianggai granite. Sulfides from the Gaofeng massive orebodies have high $\delta^{34}\text{S}$ values of $+5$ to $+12\%$, whereas sulfides from the Changpo-Tongkeng stratiform orebodies show lower $\delta^{34}\text{S}$ values of -7 to -0.2% . We proposed a model to suggest that the sulfur in the Gaofeng massive ores and the Changpo-Tongkeng stratiform ores was derived from inorganic reduction of coeval seawater sulfates. The significant difference of the sulfur isotope compositions between them is due to the different degree of sulfate reduction in the two settings and could be well interpreted by Rayleigh fractionation model. Although the sulfur isotope compositions of vein ores vary widely from -8 to $+10\%$, the peak value (-2.9%) is close to that of the stratiform ores (-3.6%). The sulfur in vein ores might be derived from the stratiform ores and it is also likely that they may have been contaminated by magmatic sulfur and sedimentary sulfur.

The Helium isotope data ($^3\text{He}/^4\text{He} = 1.7\text{-}2.5\text{Ra}$) of fluids inclusions trapped in pyrites from massive and stratiform ores indicated that mantle-derived fluids were involved in ore-forming fluids, and hence provide new evidence that favors the submarine exhalative-hydrothermal origin for the stratiform and massive sulfide mineralization in the Dachang deposit. The relationship of He and S isotope suggests that ore-forming fluids of massive orebodies were likely mixing of deep circulating seawater with mantle-derived fluids.

Acknowledgments

This work was financially supported by a China National Natural Science Foundation grant (No. 40221301)