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Molybdenite by metamorphism: Tracking orogenic cycles

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Re-Os dating of molybdenite is now a widely accepted means to accurately date magmatic events using disseminated or associated vein-hosted occurrences. Sample to sample age agreement permits use of the isochron method [1]. But, molybdenite is also a common accessory mineral in the metamorphic environment, from greenschist to granulite facies [2, 3]. The model age approach with replicates, targeting isolated occurrences, is key to obtaining reliable age information. And, these Re-Os data line-up very well with U-Pb data derived from metamorphic monazite and zircon.

Using examples from the Paleoproterozoic Svecofennian orogeny and the Mesoproterozoic Sveconorwegian orogeny in Sweden-Norway we illustrate the utility and enormous potential for the Re-Os chronometer in molybdenite for the purpose of dating events that define orogenic cycles. In lower grade terranes, molybdenite is particularly adept at recording waning metamorphism and the infiltration or late isolation of hydrothermal fluids that form mineralized metamorphic quartz veins, otherwise difficult to date events. In higher grade terranes, particularly upper amphibolite facies, where widespread migmatization may prevail, Re-Os dating of molybdenite may be used to date pulses of biotite dehydration melting associated with the formation of leucosomatic microcline-dominant melt, magnetite, and sulfides. These dehydration pulses may constitute a major interval in the orogenic history of a region and under certain tectonic conditions may play a crucial role in the formation of much debated Fe oxide Cu-Au REE deposits.

In northern and central Sweden Re-Os dating of molybdenite (leucosomatic melt formation), together with detailied field and petrographic data, suggest that a widespread granite suite (Lina and Revsund intrusions) may in fact be the local product of regional migmatization of Archean-Paleoproterozoic basement during the period 1810-1750 Ma. This interpretation accommodates disparate radiogenic isotope signatures for these suites. This remarkably widespread migmatization is the product of syn-exhumation decompression melting associated with uplift and unroofing of overthickened orogens grown during the main Svecofennian orogeny.

References

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Importance of mantle derived fluids during granite associated hydrothermal circulation

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Mantle He in S-type granitic systems

The $^3He/^4He$ ratios of fluids trapped in arsenopyrite from the 300 Ma Panasqueira hydrothermal deposit in central Portugal are between 5 and 6 Ra (where Ra is the atmospheric $^3He/^4He$ ratio = 1.39 e^{-6}). The mantle has a $^3He/^4He$ ratio of 6-8 Ra, therefore more than 75% of the He trapped in these arsenopyrites is derived from the mantle. This is surprising because a) production of ^4He by U and Th in the 300 Ma following entrapment has not swamped the mantle-derived He; and b) the Panasqueira vein deposits are spatially and temporally associated with an S-type granite.

It is difficult to reconcile $^3He/^4He$ ratios > 5Ra with a granite produced by crustal anatexis: He concentrations in crustal rocks are generally considerably higher than those of the mantle, and the crustal contribution is expected to dominate the He budget in S-type granites. The fluids that generated the hydrothermal system at Panasqueira do not appear to be related to the granite with which they are spatially and temporally associated. Instead, a pulse of mantle-derived fluids after the granite crystallized was the source of the high temperature component in the ore fluids

Heat sources in granite-associated hydrothermal systems

Conduction of heat, for example from a cooling granite into surrounding groundwaters will decrease $^3He/Q$ (where Q = heat). The $^3He/Q$ ratios in the Panasqueira fluids (1-10 x10^{-12} cm^3 STP J^{-1}, calculated using the $^3He/^{36}Ar$ ratio) are considerably higher than that of mantle-derived fluids: the mantle appears to transport ^3He and heat to the surface in relatively constant proportions ($^3He/Q$ = 0.1-1 x10^{-12} cm^3 STP J^{-1}). Therefore, it does not seem likely that gradual cooling of the pluton supplied heat to the hydrothermal system (as this would result in low $^3He/Q$ ratios).

It seems likely that both He and heat in this collision-related, granite-associated, crustal hydrothermal deposit were supplied from the mantle. The granite appears to have merely provided a high permeability pathway through the crust for the mantle-derived fluids.