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Thallium isotope fractionation in a metamorphic sulfide melt: The Lengenbach deposit, Switzerland, as an example.

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Thallium (Tl) is a rare metal with low abundances in most geological environments. Next to epithermal deposits, sulfide melts reveal the strongest enrichment of thallium on Earth. The Lengenbach Tl-Pb-As deposit is located in Triassic dolomites of the penninic units in the southern Swiss Alps. It is supposed to have formed due to the melting of a primary sulfide deposit similar to Mississippi valley-type deposits[1]. Since the Lengenbach deposit is unusually enriched in As, the nearby Variscan Cu-As deposit at the Wanni glacier has been considered to be a source of As in the Lengenbach deposit. We analyzed the thallium isotopic composition of sulfides from the Lengenbach deposit, sulfides (fahlore) and silicates (asbecasite) from the nearby Cu-As deposit at the Wanni glacier and sulfides from the Mississippi valley-type deposit Wiesloch, southwestern Germany.

The Tl isotopic composition of the primary sulfides of the Cu-As deposit at the Wanni glacier (ε^{205}Tl -3 to 0) is in the same range as porphyry deposits previously analysed. This supports the hypothesis of its Variscan granite-related formation[2]. Secondary silicates from this locality shows very similar values(ε^{205}Tl -2); accordingly, no isotopic fractionation during the alteration of the sulfides took place. However, the Lengenbach deposit shows distinctly heavier isotopic compositions of Tl (up to ε^{205}Tl 2) and hence, the release of As by the alteration of the primary sulfides at the Wanni glacier cannot be related to the formation of the Lengenbach deposit.

Since the Lengenbach deposit has also been proposed to have formed by metamorphic heating of a Mississippi valley-type deposit and related melting of the primary sulfides[3] we also compared its isotopic composition to a presumably similar central European Mississippi valley-type deposit (Wiesloch near Heidelberg, Germany). However, sulfides from this deposit have again lighter isotopic compositions of Tl (ε^{205}Tl -2.8 to -1.5). Therefore the results of our study do not support MVT hypothesis either.

In fact, the Lengenbach deposit shows an unusually heavy isotopic composition covering a broad range. This broad range can be explained by the internal differentiation of the sulfide melt, which probably occurred over a wide temperature range from about 550˚C to 300˚C. The change in the isotopic composition can generally be related to crystallising phases and their proposed crystallization sequence. The observed variations in the isotopic composition of thallium cannot be explained by mass-dependent isotope fractionation at these high temperatures since Tl is a very heavy element. In contrast, nuclear-volume-dependent fractionation has been shown to be important for Tl and is relatively strong at high temperatures up to 600˚C ($\sim$1 ε-unit for fluid-sulfide fractionation). This study shows that the isotopic compostion of thallium can be used to test various models for the generation of a specific ore deposit.

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