Thallium geochemistry in the metamorphic Lengenbach sulfide deposit, Switzerland: Thallium-isotope fractionation in a sulfide melt

KAI HETTMANN1, KATHARINA KREISSIG2, MARK REHKÄMPER2, THOMAS WENZEL1,*, REGINA MERTZ-KRAUS3 AND GREGOR MARKL1

1Fachbereich Geowissenschaften, Eberhard Karls Universität Tübingen, Wilhelmstrasse 56, 72074 Tübingen, Germany
2Department of Earth Science and Engineering, Imperial College London, U.K.
3Institut für Geowissenschaften, Johannes Gutenberg-Universität Mainz, Germany

ABSTRACT

The Lengenbach (Switzerland) Pb-As-Tl-Zn deposit was formed from a sulfide melt at about 500 °C during Alpine metamorphism, but details on its formation and especially the source of the metals are still under debate. In this study we present two sample sets to address these questions:

1) MC-ICP-MS analyses of thallium isotopes in sulfides, sulfosalts, and melt inclusions from the Alpine metamorphic Lengenbach deposit in the Binn Valley of Switzerland, the non-metamorphic Wiesloch Mississippi Valley-type deposit in Southern Germany, and the Cu- and As-rich mineralization at Pizzo Cervandone about 2 km SW of the Lengenbach deposit, which has been discussed as potential source of the Lengenbach metals.

2) LA-ICP-MS analyses of micas from the Lengenbach deposit and surrounding country rocks between the deposit and the Pizzo Cervandone to trace potential metal-bearing fluid pathways.

We found that Tl isotope compositions expressed as ε205Tl values in all investigated samples range from –4.1 ± 0.5 to +1.9 ± 0.5. The whole variation can be seen in the Lengenbach deposit alone, which hence records considerable fractionation even during high-temperature processes involving a sulfide melt. This large range of ε205Tl is thought to be caused by nuclear volume-dependent fractionation. Interestingly, the common fahlores at Lengenbach behave differently from all other investigated sulfosalts: based on their heavy isotopic composition together with a low As/S-ratio, they do not seem to be crystallized from the sulfide melt, but are interpreted to have formed from hydrothermal fluids enriched in the heavy Tl isotopes. Although As mobilization in the gneisses and dolomites surrounding the Lengenbach deposit is evident based on secondary arsenites, no traces of such a country rock fluid could be found in fissure micas at Lengenbach. Hence, considerations involving K/Rb, Rb/Tl, As/S, and Pb/Tl ratios in the sulfides and micas imply that the element enrichment in the Lengenbach deposit is either pre-Alpine or related to peak metamorphism, but occurred definitely before mica growth at Lengenbach.

Keywords: Sulfide melt, thallium isotopes, metal sources, sulfosalts

INTRODUCTION

The Lengenbach Pb-As-Tl-Zn deposit (Binn Valley/Switzerland) is well known for the occurrence of rare Tl-bearing sulfosalts and sulfides (Giusca 1930; Graeser 1965, 1975; Hofmann and Knill 1996; Graeser et al. 2008). It is the type locality of 31 mineral species, 16 of which have only been described from here (Hofmann et al. 1993; Graeser et al. 2008). This mineralogical diversity has been investigated in numerous publications since its discovery in the 19th century (Giusca 1930; Graeser 1965, 1975; Graeser et al. 2008).

The Lengenbach deposit formed under participation of a sulfide melt generated during regional metamorphism (Hofmann 1994). This process has been involved even in the generation of some world-class deposits, such as Broken Hill in Australia (Sparks and Mavrogenes 2005; Tomkins et al. 2007). A sulfide melt is produced if metamorphic temperatures are high enough to melt a precursor sulfide mineralization. The required temperature depends on the primary mineral composition, the mineral assemblages and fO2. In the course of fractional crystallization of the sulfide melt (Tomkins et al. 2007), As and Tl behave as incompatible elements. They are strongly enriched in the remaining melt fraction from which minerals such as jordanite and dufrenoisite crystallize.

Although the Lengenbach deposit was the subject of many scientific investigations, details of its formation and especially the source of the metals are still under debate: both the formation by melting of a hypothetical precursor mineralization (under nearly closed system conditions) and an external elemental input were discussed in the literature (e.g., Graeser and Roggiani 1976; Hofmann and Knill 1996). In this study, we determined the chemical and Tl isotopic composition of various Tl-bearing sulfosalts, sulfides, and micas from the Lengenbach quarry in the Lengenbach deposit. The un-