Geophysical Research Abstracts
Vol. 17, EGU2015-5003, 2015
EGU General Assembly 2015

Pb and Zn release from crustal sediments during metamorphism

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Our understanding of the genesis of Pb-Zn ore systems is currently limited by a lack of knowledge about from where these metals are sourced. While it is generally agreed that the temperature and salinity of fluids play a crucial role in mobilizing metals, the importance of the composition of the source lithologies is poorly constrained. Furthermore, fluid-rock processes that lead to element mobility are yet to be fully understood, especially in metamorphic environments. To address these gaps in our knowledge we examine metal distribution and mobility in rocks from a prograde metamorphic sequence of the Mt Lofty Ranges, South Australia, where temperatures range from $\sim$300 to 700˚C at $\sim$3.5 to 5 kbar. This regional metamorphic belt underwent regional up-temperature fluid flow, which allowed for favourable conditions for enhanced element mobility. By studying the distribution and concentration of Pb and Zn on both bulk-rock and mineral scales, in combination with bulk rock Zn-isotope data, we can monitor the behaviour of these elements during pressure and temperature changes. Our results show that in staurolite-absent siliciclastic metasedimentary rocks, biotite contains >80% of the bulk rock Zn, as well as a considerable proportion of the total Pb, irrespective of the metamorphic grade. Pervasive fluid flow during metamorphism through these metasedimentary rocks led to a continuous depletion of Pb and Zn on a mineral and bulk-rock scale, resulting in a mobilization of $\sim$80% of the bulk-rock Zn and $\sim$50% of the bulk-rock Pb, mainly through reactions involving biotite. We calculated that a minimum of 2.7Mt of Pb and 27Mt of Zn was mobilized/lost in the high-grade metamorphic zone (200 km2). Halogen contents of apatite and biotite and bulk-rock Zn isotope data provide evidence that Cl-rich metamorphic fluids were important for metal transport. Hence, fluid flow accompanying metamorphism of typical sedimentary rocks can mobilize base metals to the degree required to form significant Pb-Zn ore systems. Hence, continental-derived metamorphic terranes that were subject to flow of saline fluids may be promising exploration targets for Pb-Zn deposits. Similarly, post metamorphic igneous intrusions and related saline fluids can result in fluid-rock interaction where significant Pb and Zn leaching is possible. Our study indicates that a pre-metamorphic enrichment of base metals in metamorphic basements is not a prerequisite for the supply and liberation of large quantities of Pb and Zn during metamorphism, as "normal" crustal sediments can act as a metal source upon interaction with Cl-rich metamorphic fluids.