Mantle input into the mineralising fluids of the Colorado Mineral Belt: the noble gas story

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The use of noble gas isotopes as inert tracers of palaeo-hydrothermal fluids is a relatively new technique. However, in recent studies they are proving to be extremely useful in determining the origins of such fluids (Simmons *et al.*, 1987; Stuart *et al.*, 1995; Burnard *et al.*, 1998). This work reports such a study for selected ore deposits of the Colorado Mineral Belt. The noble gas budget of inclusion trapped fluids can come from three primary sources: the atmosphere, by way of air saturated ground waters (ASW); the crust and the mantle. These sources contain very distinct noble gas isotopic compositions, especially with respect to Helium and Argon.

The noble gas composition of the atmosphere and therefore ASW, is primarily characterised by the loss of He. Isotopic ratios of interest include a $^{40}Ar/^{36}Ar$ value of 295.5 and a $^{3}He/^{4}He$ value of 1.39×10^{-6} = the atmospheric $^{3}He/^{4}He$ value $\equiv 1R_a$ (All other helium ratios are quoted relative to this value). In comparison, the noble gas composition of the crust is dominated by radiogenic and nucleogenic production of ^{40}Ar and ^{4}He from K and U+Th respectively. The other He and Ar isotopes are considered to be essentially primordial in origin, although some small nucleogenic contributions do occur. Ratios of interest therefore reflect radiogenic elements, with $^{40}Ar/^{36}Ar$ value of >295.5 (up to 30,000) and a $^{3}He/^{4}He$ value of between 0.01 and 0.05 R_a. It should be noted that radiogenic production of He ($^{4}He^{*}$) in aquifer rocks will cause ground waters to have a $^{3}He/^{4}He$ value slightly lower than the expected value of 1 R_a. The mantle is characterised by high levels of primordial ^{3}He, trapped during accretion and the lack of

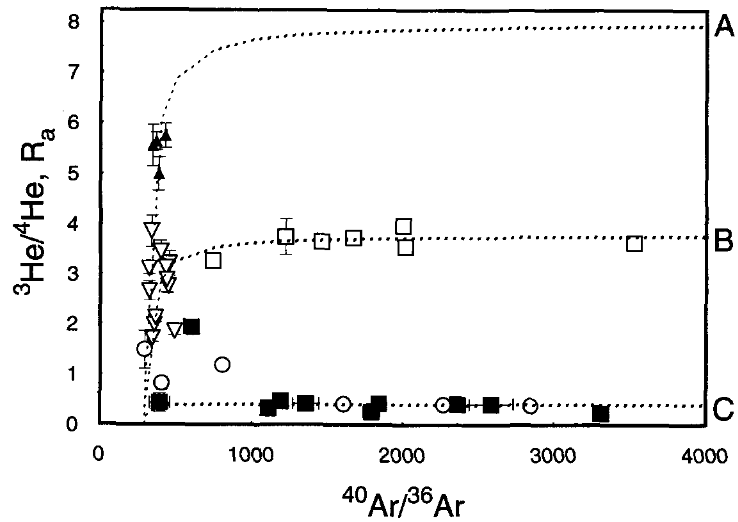

FIG. 1. Noble gas analyses for selected deposits of the Colorado Mineral Belt. (Open square: Columbia; open circle: Sherman; open triangle; Black Cloud; closed triangle: Sunnyside; closed square: London). Three mixing lines are plotted between a crustal fluid and three magmatic end member fluids (A, B and C).

primordial ^{36}Ar. Therefore mantle fluids exhibit a $^{40}Ar/^{36}Ar$ value of up to 40,000 and a $^{3}He/^{4}He$ value of between 6 R_a (for depleted mantle) and 30 R_a (for undepleted mantle). For the Colorado Mineral Belt area the range will be around 6 to 8 R_a.

Setting

The Colorado Mineral Belt is one of the most mineralised regions on Earth and has a mining history stretching back over 140 years. During this time over $3 billion of gold, silver, lead, zinc, molybdenum, tungsten and fluorspar have been mined from many world class and world famous deposits (Tweto and Sims 1963). A selection of mineral deposits of the Colorado Mineral Belt were chosen as sampling targets, some of which are discussed here.

'Leadville-type' mineralisation, of which both the Black Cloud and Columbia deposits are examples, are carbonate hosted Pb-Zn replacement deposits of mid-Tertiary age. Stable isotope investigations show these deposits formed from typical magmatic fluids (Thompson and Beaty 1990). The Sherman mine is an example of 'Sherman-type' mineralisation. These deposits are also carbonate hosted bodies, but have an Ag-Pb-Zn-Ba assemblage with an uncertain origin and age. The London mine is part of the London district Au deposits which have a disputed genetic link to Sherman-type mineralisation. The Sunnyside Mine is an Au-Ag-Te-base metal deposit, believed to have formed primarily from meteoric waters (Casadevall and Ohmoto 1977).

Samples analysed are pyrite (or where this is not possible, sphalerite) separates, which provide good noble gas traps. Samples are crushed under vacuum in order to analyse the noble gas isotopic composition of their inclusion trapped fluids, using an MAP215 noble gas mass spectrometer. The released gas is first purified using getters before the noble gas portion is split into light and heavy fractions which are then analysed separately.

Results

The noble gas analyses carried out on these ore deposits highlight a clear input of mantle derived ^{3}He (and therefore mantle heat) into the mineralising fluids of the Colorado Mineral Belt. These data fit three different mixing curves, indicating that the ore forming fluids in different deposits are isotopically distinct. These curves are plotted by varying the noble gas isotopic characteristics of the fluid sources and show that the deposits formed as the result of mixing between a crustal fluid and three very separate modified magmatic end members (A, B and C).

The data highlights the distinct noble gas isotopic signatures and therefore source regions for the ore forming fluids of the 'Leadville-' and 'Sherman'-type mineralisation styles, which have been the focus of ongoing debate. The two mineralisation styles fit very different mixing curves and therefore cannot have formed as part of the same mineralising system. Instead, the Sherman deposits seem to have a genetic link to the London gold mineralisation. These data also suggest a distinct mantle input into the Sunnyside mineralisation, a deposit previously regarded as forming from dominantly meteoric fluids.

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