

## Pb and Sr isotopic implication on the contribution of deep crustal fluid to epithermal Au deposit in the Hishikari mine, Japan

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The Hishikari mine in southwestern Japan, a world-class epithermal gold mine, is composed of three deposits of gold-bearing quartz-adularia veins, the Honko and Sanjin deposits developed in the sandstone and shale of the Shimanto accretionary prism and the Yamada deposit in the Pleistocene andesite. The Hishikari veins have a good correlation among the concentrations of Pb, Au, and Ag, and have a narrow hydrothermally altered zone. The Pb isotopic compositions of the veins are plotted along a line connecting two components. One has a Pb isotopic composition which is close to that of volcanic rocks with radiogenic Pb and the other one contains intermediate Pb between the Shimanto sedimentary rocks in the upper to middle crust and the underlying rocks considered to constitute an old subcontinental crust. These lines of evidences suggest that Pb and other heavy and precious metals in the Hishikari vein were not leached from wall rocks and the upper-middle crust, but derived largely from magmatic fluid and deep-crustal fluid which was generated around the boundary between the middle and lower crust due to the heat supply from upwelling mantle of southern Kyushu. The <sup>87</sup>Sr/<sup>86</sup>Sr of Hishikari veins (0.7068-0.7080) show a small variation, do not exhibit a distinct change among deposits in accordance with those of host rocks, and deviate from those of surrounding volcanic rocks (0.7044-0.7052) and the Shimanto rocks (0.715-0.720) but are close to the estimated <sup>87</sup>Sr/<sup>86</sup>Sr of lower crust (0.7077). This also suggests a dominant contribution of deep-crustal fluid for metals in the Hishikari mineralizing fluid. It is calculated that 40-100% of Pb and Au in the Hishikari fluid was attributable to the recycling of crustal materials. Although the contribution of deep crustal fluid to epithermal systems has not been reported, the possible presence of old subcontinental lithosphere and deep crustal fluid are compatible with recent geophysical and geochemical studies in southern Kyushu.

## Zircon He-Pb\* Dating: Approaches and Applications

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Combined (U-Th)/He and U/Pb dating of single zircon grains (He-Pb\* dating) has the potential to provide significantly more precise provenance constraints than other techniques because it produces both crystallization and cooling ages, allowing greater discrimination of source regions. The method also has possible merits as a chronostratigraphic tool, because in active margin settings the age of the youngest first cycle volcanic zircons ( $t_{pb} = t_{He}$ ) is a good proxy for the stratigraphic age of a deposit.

Here we describe progress in methodological development of He-Pb\* dating. Using standards and detrital zircons from a wide variety of settings we are currently exploring two possible analytical approaches. The first involves U/Pb age determination by LA-ICP-MS spot analysis on unpolished grains, followed by He extraction/measurement, followed by bulk U-Th measurement by solution ICP-MS. Replicate analyses of Fish Canyon tuff zircons by this method yield accurate and reproducible U-Pb ages of  $28.6 \pm 1.9$  Ma and (U-Th)/He ages (for the same single grains) of  $29.0 \pm 2.0$  Ma, indicating that the laser ablation does not cause significant He loss. This method requires only slightly more analytical time than standard (U-Th)/He dating, and provides spatial resolution on both U-Pb ages and U-Th concentrations for refinement of the  $\alpha$ -ejection correction. He-Pb\* dating of detrital populations from the Mississippi river, Jurassic eolian sandstones and active-margin turbidite sequences yields results that are compatible with U/Pb and fission track results from independent studies.

An alternative method we developed is simultaneous measurement of both bulk U-Th contents and U/Pb ages (by either solution ICP-MS or TIMS), following He measurement. This requires that Pb is not volatilized during He extraction at  $>1200$  °C. Three standards of Archean, Paleozoic and Cretaceous age were chosen to test this method. He was extracted from several single-crystal aliquots of each standard in Pt foil under variable laser intensities and lasing durations to test for Pb volatilization. Untreated multi-crystal and treated single crystal aliquots were analyzed using standard isotope dilution TIMS procedures. Treated single crystals yielded reproducible (U-Th)/He ages and accurate near-concordant U/Pb ages compared to their untreated reference material suggesting that Pb loss during He extraction was insignificant. These results show that measurement of U/Pb ages concurrently with bulk U-Th contents by solution ICP-MS could obviate need for an initial laser ablation step. However, the ultra-low Pb blanks required for precise single-grain ID-TIMS ages, and the spatial resolution of age and U-Th zoning information provided by laser ablation are important methodological considerations.