Th-U disequilibrium dating of young fluid-flow along old fractures: implications for rock-water interaction and radioactive waste depositories

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A Precambrian fracture from the Svappavaara area of northern Sweden, coated with titanite and stilbite (zeolite), has been dated at 1773.0±0.7 Ma (2σ) by U-Pb on titanite. An identical age obtained for stilbite ($^{207}Pb/^{206}Pb$ secondary isochron at 1750±110 Ma [2σ, MSWD=1.03] and discordia intercept at 1766±46 Ma [2σ, MSWD=0.346]) implies that the ambient temperatures in the Svappavaara area have remained below the thermal stability of stilbite (ca 150°C) for the past 1750 Ma. In contrast to the Pb isotopes, the U-Pb systematics of stilbite is disturbed suggesting a late loss of 75-85% uranium.

Stilbite readily exchanges ions hosted in its channel-sites with those dissolved in aqueous fluids. U-loss upset the ^{230}Th-^{234}U-^{238}U systematics of the stilbite, probably due to interaction with over-pressurized fluids from ice load during the last glaciation(s). Since U,Th isotopes in old minerals are in secondary equilibrium, $^{230}Th/^{232}Th$ at the time of disturbance can be obtained from the pre-disturbance $^{238}U/^{232}Th$ (known from $^{206}Pb_{rad}/^{208}Pb_{rad}$) and the age of the mineral. Thus, $^{230}Th/^{232}Th$ of the equipoint is deducible from the lead isotopes. It is therefore possible to calculate the minimum age of the fluid-flow disturbance from the measured ^{230}Th excess and Th, U concentrations and the calculated initial $^{230}Th/^{232}Th$. Hence, isotopic disequlibrium in old minerals from fractures and aquifers can be used to show if (or if not) there has been fluid-flow along fractures during the past 300 000 years and to estimate its timing. Such kind of information is an essential parameter for assessing the extend of rock-water interaction and the long-time safety of subsurface waste depositories.