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Mobility of U–Th radionuclides connected with fault porosity: A case study of the Schauenburg Fault, Rhine Graben Shoulder, Germany

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Abstract

This study focuses on the relationship between U- and Th-isotope distribution, and the porosity/permeability structure of a geological fault in the uplifted Rhine Graben shoulder (SW-Germany). This fault, known as the Schauenburg Fault, separates basement Variscan granite from Permian rhyolite, and is marked by a clay-bearing cataclasite. All fault rock samples are characterized by the redistribution of uranium and thorium isotopes within the last $\sim 10^6$ years, whereas in the granite and the rhyolite only uranium isotopes leaching (activity ratio <1) has occurred. The cataclasite samples, with $^{234}U/^{238}U > 1$, record a complex history of sorption and loss of uranium isotopes. The uranium activity ratios are higher for the samples collected close to the fault plane and lower for cataclastically deformed fault rock situated away from the principal displacement surface. The porosity measurements of the cataclasite show symmetrical variations across the core of the fault zone, similar to the pattern of uranium activity ratios. In order to relate the porosity data with the $\delta^{234}U$ value, a simple exchange model was developed assuming that the change in the uranium activity ratios results from uranium isotopic exchange with the aqueous phase. Best approximations were obtained by using an isotopic water/rock exchange coefficient for ^{234}U ranging from 2.5E−06 $[a^{-1}]$ in the core of the fault zone to 2.5E−05 $[a^{-1}]$ for the fault walls, whereby the isotopic water/rock exchange per year is the same dimension as the radioactive decay constant. Along the outer core of the fault zone, the increased porosity, and thus permeability, resulted in prolonged contact between water and rock. Here, a higher isotopic exchange of uranium with the aqueous phase has occurred. Within the core of the fault, the porosity is lower and the availability of circulating fluids restricted the exchange of uranium isotopes between the rock and the aqueous phase. The resulting exchange time for the isotopic exchange coefficient is 70 ka, which suggests a young fluid–rock interaction event possibly related to the last stage of Rhine graben fault activity along this structure.

Keywords: U–Th radionuclides; Granite; Fault zone; Porosity; Water–rock interaction; Exchange model

1. Introduction

Quantifying the changes in composition and concentration of radiogenic isotopic elements in the Earth's crust that occur during fluid–rock interaction are essential to our understanding of crustal processes, for the exploration of mineral deposits, and for the safer disposal of nuclear waste materials in underground repositories. In the upper portion of the crust, faults constitute the principal sites of high

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