



## Production, migration, redistribution and loss of helium isotopes in sedimentary rocks

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The importance of shales layers being a principal source of helium isotopes in adjacent sandstone layers has been shown for the aquifer-aquitard system of the Permo-Carboniferous Trough (PCT) in the Molasse Basin, Northern Switzerland (e.g., Tolstikhin et al., 1996; Lehmann et al., 2003). In this contribution we define processes responsible for He atoms behaviour in PCT and model these processes in order to quantify helium migration parameters.

Using U, Th, K and Li concentrations as well as He and Ar isotope abundances obtained for the shale-sandstone-water system of the PCT, we show that: (i) the inventory of the parent elements and He isotopes indicates an intra-basin production and loss of radiogenic helium, (ii) sandstones contribute only little to the inventory of both radiogenic helium isotopes, but serve also as a sink (!) for shale-produced helium and (iii) the simplest estimate of the residence time of He-atoms (as a ratio of He abundance over its production) is long, approaching 100 Ma.

Processes controlling the He isotope abundance in PCT include: (i) the production of radiogenic He isotopes in the rocks, mainly in shales, which are enriched in the parent elements, (ii) the loss of radiogenic He atoms from the rock minerals into porewaters, (iii) the migration of He along concentration gradients from the porewater of the shale layers into the porewater of the sandstone layers and there into lattice defects of sandstone-forming minerals such as quartz and feldspars; (iv) the migration of He atoms in the porewater through the connected interstitial pore space towards the aquifer groundwaters with low He concentrations from where it is removed from the system.

We model these processes using simple diffusion model envisaging the following conditions: (i) last hydrothermal overprint of the Crystalline basement (infinite thick layer, 315 Ma ago) and subsequent formation of the Permian (285 Ma) to Muschelkalk (240 Ma) sediment layers, each of them including observed aquifers; (ii) helium production in each layer as a function of the average U, Th and Li concentrations; (iii) helium diffusion in each layer along the concentration gradients; (iv) helium removal from the layers via migration into sandstone minerals and/or by flowing groundwater in the aquifers.

Considering diffusion as the only mechanism of helium migration across the different rock layers yields reasonable agreement between the calculated concentrations and those observed in the PCT groundwaters for diffusion coefficients with a best fit value of 0.001 square m / yr. Such diffusion coefficient is similar to that derived by Rübel et al. (2002) for Opalinus Clay aquitard at Mont Terri, Switzerland.

However, diffusion alone is not able to remove enough He from rock-groundwater system of the Crystalline basement. There the required advective removal of He by the groundwater suggest a He residence time within the Crystalline aquifers of approximately 1 Ma.

These estimates indicate that the PCT rock-groundwater system is an appreciably stagnant one: the residence time of the highly mobile helium atoms in this system is longer than 10 Ma.

Lehmann B.E., et al. (2003) *Earth Planet. Sci. Lett.* 211, 237-250; Rübel et al. (2002) *Geochim. Cosmochim. Acta*, 66, 1311-1321; Tolstikhin et al. (1996) *Geochim. Cosmochim. Acta* 60, 1497-1514.