Residence times of ancient water in Outokumpu (Finland) revealed by noble gases

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Deep saline groundwaters in the Precambrian crystalline bedrock of Outokumpu, eastern Finland, host ecosystems that may be remarkably old. Based on water stable isotopes, these waters have been suggested to be recharged during climatic conditions up to 10°C warmer than at present, which would be indicative of residence times on the order of tens of millions of years [1].

In order to better define residence times, concentrations of radiogenic (^{4}He, ^{40}Ar), nucleogenic (^{21}Ne) and fissiogenic (^{134}Xe, ^{136}Xe) noble gas isotopes were measured in water and gas samples covering a depth range from 500 m to 2450 m in the Outokumpu Deep Drill Hole.

The observed vertical variation of geochemistry and microbiology together with hydrogeological and geophysical measurements indicate negligible fluid flow in the bedrock. Furthermore, more than 99 % of the air-corrected He is crustal in origin with an average ^{3}He/^{4}He ratio of $1.5 \cdot 10^{-8}$, and no concentration gradient indicative of diffusive flux through the crust was observed. Therefore an *in situ* accumulation model [2] using average values for porosity, density and concentrations of radioactive elements (U, Th and K) in the Outokumpu deep drill core [3] was applied to calculate residence times.

Residence times between 12 and 45 Ma are indicated by the ^{4}He accumulation. Similarly, ^{21}Ne and ^{40}Ar ages fall between 5 and 70 Ma whereas ^{134}Xe and ^{136}Xe indicate longer residence times. The results thus confirm the existence of ancient groundwaters in Outokumpu. This should be taken into account when rates of microbial metabolism, adequacy of substrates, and biological cycling of elements within the deep subsurface are considered.

[1] Kietäväinen *et al*. (2013) *Appl. Geochem.* **32**, 37-51. [2] Torgersen (1980) *J. Geochem. Explor.* **13**, 57-75. [3] Kukkonen (2011) *Geol. Surv. Finl. Spec. Pap.* **51**.

Can radioactive cesium be used as a hydrological tracer for crater lake study?

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The Fukushima Dai-ichi Nuclear Power Plant (FDNPP) accident in March 2011 resulted in serious radiological contamination in areas adjacent to the plant. Meanwhile, radioactive cesium originated from the accident was detected over a wide range of the northeastern half of Honshu, the main island of Japan. In this study, we discuss the possible use of radioactive cesium newly deposited on the ground from the FDNPP accident as a hydrological tracer for crater lake study in Japan, taking crater lakes of the Kusatsu-Shirane volcano, located about 240 km west-southwest from the FDNPP, for example. Water budget of crater lakes, especially on active volcanoes, is very complicated, because most of them are closed ones. The budget and circulation of water in active crater lakes provide very important information connected to the hydrothermal activities and subsurface structures of the volcanoes.

The Kusatsu-Shirane volcano with three crater lakes on its summit area is one of the most famous active volcanoes in Japan. Yugama, the largest and deepest one among the three is well known as an active crater lake filled with water of high salinity and strong acidity. We determined the contents of radioactive isotope of cesium, ^{134}Cs and ^{137}Cs, and the stable isotope, ^{133}Cs, and their content ratios in waters of three crater lakes of the Kusatsu-Shirane volcano collected in 2012. The obtained activity ratio of ^{134}Cs/^{137}Cs revealed that the radioactive cesium released by the accident has reached the summit area of the volcano. However, the concentration of radioactive cesium was not uniform among the three crater lake waters. This ununiformity is most probably ascribable to the difference in the water supply and circulation system among the three. This suggests that the temporal changes in the concentration of radioactive cesium and their concentration ratios against the stable isotope can provide us useful information to clarify the water budget in the summit area of the Kusatsu-Shirane volcano. In this context, we are now investigating the temporal changes in the concentrations of ^{134}Cs, ^{137}Cs and ^{133}Cs in the crater lakes.

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