Helium flux from a sedimentary basin

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Helium flux from the solid Earth may provide useful informations on the atmospheric helium budget, U and Th contents of the crustal rocks, heat generated by the radioactive decays of these elements, and release of primordial ^{3}He from the mantle. It is also used as a parameter against which the igneous flux of carbon and nitrogen are calibrated. Therefore the helium flux has been estimated by many investigators, although mainly for oceanic areas. There are a few such data for continental land areas. The continental flux estimates based on helium excess in lakes, aquifers and helium isotope gradients in gas wells are comparable with the steady-state flux of 2.8×10^{10} atoms/m^{2}s proposed by O'Nions and Oxburgh (1983) and the flux of $0.9-1.9 \times 10^{10}$ atoms/m^{2}s reported by Torgersen (1989). I report here a steady helium flux from a sedimentary basin based on the observation of tritium-^{3}He age and excess ^{4}He of groundwater in Saijo basin, non-volcanic frontal arc region of Southwestern Japan. In addition I present a catastrophic helium flux at water well in Nishinomiya city close to the epicenter of the 1995 Kobe Earthquake, Southwestern Japan.

Experimental

Five groundwater samples with the similar depth of about 8m were collected in Saijo Basin by a standard technique and ^{3}He/^{4}He and ^{4}He/^{20}Ne ratios were measured by a noble gas mass spectrometer after extraction and purification of helium and neon at the laboratory. Tritium concentrations were determined by β-counting after enrichment by electrolysis. Nitrogen and argon isotopes of the samples were also analysed. Seventeen groundwater samples were collected from six wells with various depths in the vicinity of Nishinomiya city before and immediately after the Kobe Earthquake. At the laboratory we measured δD and δ^{18}O values of groundwater samples using conventional methods in addition to analysis of ^{3}He/^{4}He and ^{4}He/^{20}Ne ratios, and tritium concentrations. Overall errors of ^{3}He/^{4}He and ^{4}He/^{20}Ne ratios are about 3% and 6%, respectively, estimated by repeated measurements of atmospheric standard (Sano and Wakita, 1985). Errors of tritium concentration, δD and δ^{18}O values are 0.5 TU, 2‰, and 0.15‰, respectively, determined by standard methods.

Results and discussion

The ^{3}He/^{4}He ratios of samples in the Saijo Basin vary from 1.61×10^{-6} to 1.98×10^{-6} and are significantly higher than those of atmosphere, 1.39×10^{-6} and air-saturated water (ASW), 1.37×10^{-6}. Dissolved ^{4}He concentrations are ranging from 4.7×10^{-8} to 5.5×10^{-8} cm^{3}STP/g, again higher than those of ASW, $4.65\ 10^{-8}$ cm^{3}STP/g at 10°C and 4.55×10^{-8} cm^{3}STP/g at 15°C. Observed tritium concentrations are comparable with those in present day precipitation of about 10 TU in the area studied. In order to estimate the tritiogenic ^{3}He content, observed ^{3}He should be deconvolved into several components such as atmospheric ^{3}He dissolved in groundwater and crustal and mantle derived ^{3}He. The ^{20}Ne concentrations are used to separate atmospheric and non-atmospheric helium, since ^{20}Ne is almost atmospheric origin. Since the Saijo Basin is located in the frontal arc, about 50 km south of the present volcanic front, it is likely that the groundwater samples do not contain mantle derived He with a high ^{3}He/^{4}He ratio (Sano and Wakita 1985). Therefore major part of excess ^{3}He is due to tritiogenic in origin. Calculated tritium-^{3}He ages of groundwater vary from 11.7 to 16.3 years and indicate a negative correlation with the piezometric heads. Based on the geographical distribution of the sampling sites and their ages, a groundwater flow velocity of about 7 10^{-4} cm/s is estimated. Dissolved ^{4}He concentrations in the samples increase with their ages, which is probably explained by helium degassing from the deeper geological formations. Calculated ^{4}He flux of $1.2\ 10^5$ atoms/cm^{2}s is significantly smaller than those of $2 \sim 3\ 10^6$ atoms/cm^{2}s reported in the literature.

The ^{3}He/^{4}He ratios of groundwaters at Nishinomiya city close to the epicenter decreased immediately after the 1995 Kobe Earthquake in Japan, while the ^{4}He/^{20}Ne ratios increased. The δD and δ^{18}O values of the groundwaters were identical before and after the earthquake. Apparent ground-

water ages calculated by tritium-^{3}He concentrations also did not change, if we correct the addition of radiogenic helium into the samples by the earthquake. These observations may be attributed to either degassing of radiogenic He from the aquifer rocks, in the amount of about $4.0 \pm 1.3 \times 10^{-9}$ cm^{3}STP/cm^3-rock. It is possible to calculate the total He degassing related to the Kobe earthquake, 4×10^{11} cm^{3}STP, which is about 3% of the steady-state global He flux of 1.2×10^{13} cm^{3}STP/year. Earthquake may play an important role in He degassing from the solid Earth.

References

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