Proceedings of the 4th Mini Conference on Noble Gases in the Hydrosphere and in Natural Gas Reservoirs
held at GFZ Potsdam, GERMANY, 28.02.-02.03.2007

Variations in Helium and Carbon Isotopes and Relative Abundances in Geothermal Fluids of Western Anatolia, Turkey

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The aim of this study is to investigate helium and carbon isotopic compositions and associated $CO_2/^3He$ ratios of water and gas samples collected from 12 geothermal fields in western Anatolia. Based on the results of previous surveys in the region [1-2], the fields targeted in the present study are those where there is available enthalpy information but little or no He (and/or carbon) isotope data. The fields represent two regions: the northern part hosting the western extension of the North Anatolian Fault Zone (NAFZ), and the central part dominated by extensional grabens. The geothermal fields from the northern part are Tuzla, Kestanbol, Çan, Hisaralan, Manyas and Gönen, and those from the graben systems are Seferihisar, Balçova, Afyon, Gazlıgöl, Germencik and Kızıldere fields. Both natural springs and production wells were utilized during sampling. Gas samples were collected from high-enthalpy fields (Tuzla, Hisaralan, Seferihisar, Germencik, Kızıldere); with the exception of one sample taken from the steam phase in a production well, all the gas samples were collected as free gas phases from bubbling springs/pools. The R/R_A values (where R = sample $^3He/^4He$ and R_A = air $^3He/^4He$) of the samples range from 0.27 to 1.67 and are significantly higher than the crustal production value of 0.02-0.05 R_A. Fluids with relatively higher R/R_A values are generally found in areas of significant heat potential. $CO_2/^3He$ ratios of the fluids exhibit a large variation ($1.6x10^9$–$2.3x10^{14}$) and are generally higher than that of the mantle ($\sim 2x10^9$). In comparison to waters, gas samples in the region are characterized by a greater range of $CO_2/^3He$ ratios. The $\delta^{13}C$ (CO_2) and $\delta^{13}C$ (CH_4) values of fluids vary from –8.04 to +0.35‰ and –25.80 to –23.92‰ (vs. PDB), respectively. Oxygen-hydrogen isotopic compositions of the waters are consistent with the Mediterranean Meteoric Water Line and indicate a meteoric origin. Evaluation of He-C abundances together with the carbon isotope data indicates that degassing has significantly fractionated the elemental ratio ($CO_2/^3He$): however, degassing may not be the major process affecting the carbon isotope variations. Mixing between the mantle and various crustal-derived volatile sources appears to be the main control on the C-isotopes. The temperatures calculated with various CH_4-CO_2 isotope geothermometers are around 334-371°C and are about 100-150°C higher than the estimates from chemical geothermometers. This suggests that either equilibrium is not attained for the isotope exchange reaction or the chemical composition of waters is easily modified by mixing with shallow waters: at this stage, the possibility of the achievement of isotopic equilibrium at levels even deeper than the geothermal reservoir cannot be ruled out.

References

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DOI: 10.2312/GFZ.mga.016