# Three-dimensional magmatic volatile flux into the groundwater system around Kutcharo caldera, NE Hokkaido, Japan, based on measurements of helium isotopes in groundwater

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The groundwater flow system of a caldera area is greatly influenced by variation of hydrological structure due to caldera formation. As a scale of volcanic activity for a caldera forming volcano is very large, the magmatic volatiles supplied to groundwater system is supposed to be large. Kutcharo caldera located in northeast Hokkaido is the largest caldera in Japan. In this study, we estimate the fluxes of magmatic $^{3}He$ and other magmatic volatiles such as C by an applied method using helium isotopes for the quantitative evaluation of influence of magmatic volatiles into the groundwater in and around the Kutcharo caldera. And, we show the three-dimensional distribution of magmatic volatiles into the groundwater system.

Magmatic $^{3}He$ and C fluxes in and around the caldera have value of wide range. Three-dimensional distributions of magmatic volatile fluxes and concentrations show remarkable differences between three areas (caldera area, north and south sides from caldera). The shallow and deep groundwater inside the caldera indicate shorter residence time with low $^{4}He$ concentrations and have high magmatic $^{3}He$ flux of more than $10^{-11}$ mol/m$^2$/y with high concentrations of magmatic volatiles regardless of depth. In the north of caldera, the deep groundwater indicates long residence time with high $^{4}He$ concentration, but has high magmatic $^{3}He$ flux ranging from $10^{-12}$ to $10^{-11}$ mol/m$^2$/y even in a place 30 km far from the caldera. In contrast, the deep groundwater in the south of caldera with longer residence time than that in the north of caldera has hardly received influences of magmatic volatiles. The magmatic $^{3}He$ flux is significantly low, ranging from $10^{-15}$ to $10^{-13}$ mol/m$^2$/y. As for shallow groundwater system, the high $^{3}He$ flux is observed inside the caldera, and is hardly observed outside the caldera. The high flux in groundwater found inside the caldera regardless of depth would result from the highly permeable structure where fractures advanced to the depths. The anisotropic distribution of magmatic volatiles in the deep groundwater outside the caldera suggests that the groundwater flow system and/or the supply pathway of magmatic volatiles are restricted by the hydrological structures. Magmatic $^{3}He$ and C fluxes inside the caldera is from one to two orders of magnitude larger than that of north area, and is from two to four orders of magnitude larger than that of south area. In conclusion, large amounts of magmatic volatiles are preferentially supplied to the groundwater inside the caldera and dispersed through the deep groundwater system to the north area.