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An attempt to investigate the impacts of long-term sea level changes on groundwater systems using ^{36}Cl and ^{4}He

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In the Japanese islands, long-term sea level fluctuations induced by climate change can have caused large impacts on groundwater flow regime especially in coastal areas. This study explores the evidence of such influence in coastal deep groundwater, which has been formed through the repeated mixing of meteoric groundwater (freshwater) and seawater. A coupling approach between ^{36}Cl and radiogenic ^{4}He was adopted in crystalline rock and sedimentary rock areas.

In the subsurface, both of the production of ^{36}Cl and the accumulation of radiogenic ^{4}He can theoretically be described with residence time (age). When seawater-derived saline water mixes with meteoric groundwater, the ^{4}He concentration would be enriched or diluted depending on the relative difference in their ages, and the ^{36}Cl/Cl ratio would change accordingly with Cl concentration. Therefore, any deviation of measured data from an equal age line (a "growth curve") in a ^{4}He-^{36}Cl plot can be interpreted as a result of freshwater-seawater mixing.

The Seto Inland Sea area is characterized by granitic rocks, which can constitute fractured-rock aquifer systems. Majority of saline deep groundwater samples exhibited extremely low ^{36}Cl/Cl ratios (~1 x 10^{-15} or less) with radiogenic ^{4}He concentrations greater than the growth curve, clearly indicating the mixing of younger seawater and older meteoric groundwater. The ages of seawater and meteoric groundwater fractions were separately calculated from the ^{36}Cl/Cl ratios of seawater end-members and the ^{4}He concentrations of meteoric groundwater end-members, respectively. Seawater ages in saline deep groundwaters were mostly less than a few tens of thousands years, while meteoric groundwater fractions showed older ages. This may indicate that the seawater intruded into the aquifer during the Holocene transgression period. The results in turn suggest that the groundwater in a fractured granitic aquifer is relatively easily replaceable during a transgression-regression cycle.

The sedimentary basin in Aomori Prefecture is mainly filled with Neogene to Quaternary sediments including "Green Tuff" formations of lower to middle Miocene ages. Deep groundwater samples were more likely to show radiogenic ^{4}He concentrations comparable to or less than the growth curve, which suggests the mixing of older seawater and younger meteoric groundwater. Assuming a young meteoric groundwater end-member of ^{36}Cl/Cl = 100 x 10^{-15} (Cl = 5 mg/L), ^{36}Cl/Cl ratios of seawater fractions (Cl = 19,000 mg/L) were calculated to estimate their ages. Overall, calculated seawater ages become older from coastal to inland areas. Relatively old ages of seawater fraction were encountered in the west of Lake Ogawara, corresponding to the deepest part of the basin as indicated by the negative gravity anomaly. At the same time, in the central Kamikita Plain, relatively young seawater ages range inland from the coastal area. These results may imply hydrogeological controls on the flow of old seawater and on the intrusion of young seawater during transgression in a sedimentary rock area.

Keywords: deep groundwater, groundwater dating, ^{36}Cl, ^{4}He, sea level change