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Origin of groundwater associated with natural gas in Higashi-Niigata gas field.

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Commercial petroleum and natural gas fields have been developed in the northeast area along the Japan Sea. The Higashi-Niigata gas field produces natural gas dissolved in water. In this study, we show chemical and isotopic compositions of the deep groundwater associated with natural gas in the Higashi-Niigata gas field and discuss the origin of deep groundwater.

Groundwaters associated with natural gas in the Higashi Niigata gas field were collected from the reservoir named Nishiyama (1000m), Haizume (450-600m) and Uonuma (250-430m) formations. Lower formation (Nishiyama and Haizume) is composed of marine sediments, and upper formation (Uonuma) is composed of non-marine sediments. Under these reservoirs, a structural natural gas reservoir exists (Shiiya formation).

Relationships between chemical and isotopic compositions of the groundwaters and the formation of each aquifer are summarized as follows.

1) The chlorine (Cl) concentration becomes high as production depth becomes deep. The Cl concentration of the deepest groundwater is nearly equal to the present seawater, and dD and $d^{18}O$ values are slightly lower than those of the present seawater. These results suggest that the deepest water is originated from isotopically modified old seawater. The Cl concentration, dD and $d^{18}O$ values of groundwater from the upper formation are all low, and have large contribution of meteoric water.

2) The groundwater is concluded to be a mixture of meteoric water and old seawater, because of the strong linear relationship among the Cl concentration, dD and $d^{18}O$. A small difference between the shallow and deep groundwater is found on the mixing line having two plausible end-members, meteoric and old seawater. Different end-members of meteoric water and old seawater for the shallow and the deep groundwaters were estimated. Difference in dD and $d^{18}O$ of the meteoric end-members between the shallow groundwater in the upper formation and the deep groundwater in the lower formation suggest that the meteoric waters were recharged at different period.

3) Chemical compositions of the old seawater end-member found to be different from those of present seawater. Compositions of the old seawater in lower formation are rich in Na, K and are poor in Mg, Ca, SO_4. On the other hand, the old seawater in the upper formation is richer in Mg and Ca than that in the lower formation, suggesting that the groundwater is relatively young.

Helium isotope compositions are mixtures of atmospheric component and deep source component with $^{3}He/^{4}He$ ratio of 0.7 Ra (groundwater from upper and lower formations) or 3.0 Ra (structural natural gas). $^{4}He/^{20}Ne$ ratio of groundwater in the lower formation is high, so that the contribution of deep source component is large. Average residence time of the old seawater in the lower formation was estimated to be several hundred thousand years using the revised groundwater dating method by use of helium isotope compositions with a box model composed of two steps of aquifers. This estimated age is younger than the sedimentation age reported for the lower formation (4 Ma). This suggests that the infiltration of young seawater and recharge of younger meteoric water from a hinterland occurred after deposition. The aquifer in the upper formation also received the infiltration of relatively younger seawater and recharge of younger meteoric water. We propose that the groundwaters in this study area are formed as mixtures of old seawater of different ages from deep and shallow formation and meteoric water with different recharge period.