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Sulfur isotope constraint on the provenance of salinity in a confined aquifer system of the southwestern Nobi Plain, central Japan

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Abstract

A combination of $\delta^{34}S$ values and chemical compositions of brackish groundwater were used to examine the provenance of salinity in a confined aquifer system in the southwestern Nobi Plain, central Japan. A tongue of brackish confined groundwater ($Cl^- > 1000$ mg/L), which extends from the shoreline of Ise Bay inland, has somewhat lower SO_4/Cl ratios and higher $\delta^{34}S$ values ($\sim 79‰$) than those of the present seawater. Although the cation compositions of the brackish groundwater are consistent with values calculated for a mixture of fresh recharge water and seawater, the anion compositions cannot be adequately interpreted as derived from such a mixing process alone. Using a Rayleigh distillation model, we found that the groundwater chemistry could be explained by sulfate reduction in combination with the mixing of two types of seawaters, the present seawater and SO_4-free seawater, with the fresh recharge water. The SO_4-free seawater may consist mainly of fossil seawater that was trapped in an aquiclude for thousands of years. Model calculations based on Cl^- and SO_4^{2-} contents and $\delta^{34}S$ values showed that the present and fossil seawaters compose at most 10.7 and 9.4%, respectively, of the brackish groundwater volume, and the reduced SO_4^{2-} content is up to 353 mg/L in the confined aquifer. The model's discrimination of the two seawaters is also in agreement with the spatial distribution patterns of groundwater composition. From the west to the east in succession, the main influence on the groundwater chemistry is fresh recharge water, the present seawater, and the fossil seawater. Moreover, the area of intrusion of present seawater predicted by the model agrees well with the area of seawater intrusion determined from water quality data obtained a decade ago, indicating that the model calculations can be reasonably used to discriminate quantitatively between present and fossil seawaters.

Keywords: Sulfate reduction; Confined groundwater; Anaerobic conditions; Rayleigh distillation model; Fossil seawater

1. Introduction

Groundwater salinization in coastal regions is frequently observed in confined aquifers as well as in unconfined aquifers (Gilboa, 1966; Ikeda, 1985; Barbecot et al., 1998; Grobe and Machel, 2002).

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In the case of unconfined aquifers in coastal regions, water salinization is usually induced by seawater intrusion relative to a decline in the piezometric level, which associated with excessive pumping of groundwater. In the case of coastal confined aquifers, the groundwater is generally isolated from seawater by confining bed of argillaceous sediments, which have frequently deposited in the latest transgression and lies toward seafloor successively. As a result of such isolations, the water salinization process in the confined aquifer system is more complicated. In southwestern Nobi Plain, Mori (1979, 1985) reported that the confined brackish groundwater had lower SO_4/Cl ratios than seawater and that the Cl^- contents varied in relation to the piezometric level. Mori (1985) attributed the salinity

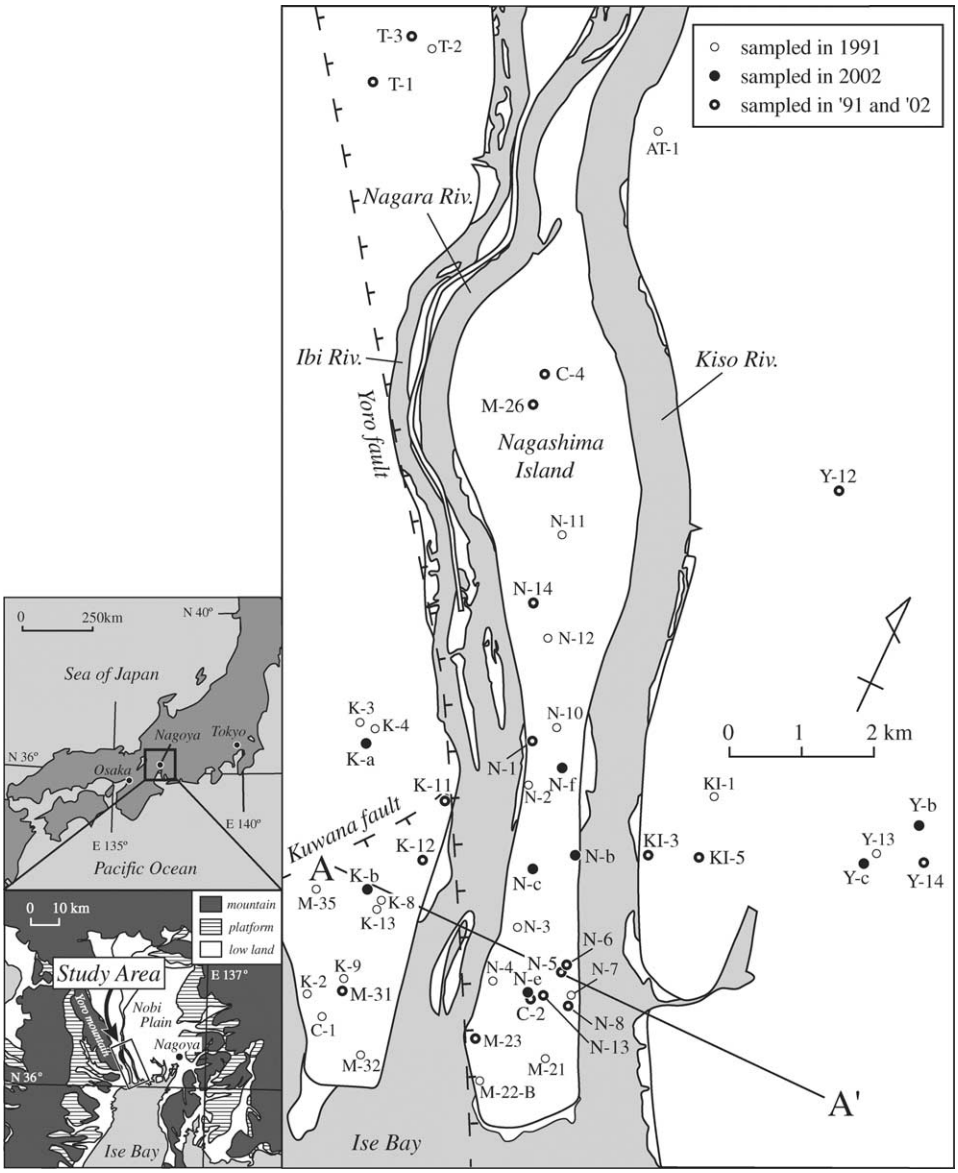

Fig. 1. Map of the southwestern Nobi Plain (SWNP) showing the sampling sites.