4.3 Hydrochemical investigations

4.3.1 Overview

4.3.1.1 Objectives

The objectives of the hydrochemical investigations, based on the goals set for the entire MIU Project and its Phases, are set as follows [(7)].

① Data acquisition on hydrochemical properties of groundwater in the individual geological formations and geological units (faults, fracture zones, etc.) between the surface and depth at the Shobasama Site

② Clarification of the mechanism(s) that control the evolution of groundwater chemistry, construction of a hydrochemical model and testing its accuracy by comparison with data

③ Prediction of change in hydrochemical properties of groundwater with the advance of the shaft excavation

④ Development of methodologies for systematic investigations and analyses of hydrochemical properties of groundwater

4.3.1.2 Performance of the study

It is important for hydrochemical investigations to know whether the data on hydrochemical properties of groundwater obtained by investigations at the Shobasama Site are representative of the chemistry of the groundwater widely distributed there. This necessitates specifying the evolution of groundwater chemistry (reaction between water and rock) by investigating geological structures, and chemical and mineralogical compositions of rocks. Furthermore, it requires the knowledge reaction time between rock and water. Consequently, it becomes important to know the residence time of groundwater. In addition, it is thought that the residence time of groundwater could provide data to support groundwater flow simulation results [(72)]. In addition, examination of the evolution of groundwater chemistry and the residence time necessitate hydrochemical data on rainwater and river water as indicators of initial conditions.

4.3.2 Current status

4.3.2.1 Knowledge obtained from the RHS Project

The following is a synopsis of the knowledge obtained during the RHS Project carried out in the area including the Shobasama Site.

① River water collected at 29 locations has been classified as Ca^{+2}-Na^{+}-$HCO3^{-}$ -type [(61)]. This fact indicates that this type of groundwater is one of the candidate water chemistry types expected in the Seto and Mizunami Groups and the shallow part of the Toki Granite. It suggests that the groundwater of the RHS Project area is of meteoric-type [(61)].

② Chemical analyses of groundwater collected at 20 points in 6 boreholes and measurements of physicochemical parameters were carried out. The results indicate that groundwater in the shallow part (< 300 m in depth) of the granite is also of Ca^{+2}-Na^{+}-$HCO3^{-}$ -type, neutral (pH 7) and oxidizing (Eh>0 mV). On the other hand, the groundwater in the deeper part (> 300 m in depth) is Na^{+}-$HCO3^{-}$ -type, alkalic (pH 9) and reducing (Eh<-300 mV) (Figures 4.59, 4.60) [60].

③ The following knowledge on microbes in groundwater is obtained by determining the total bacteria population and analysis of specific bacteria types (sulfate reducing bacteria, iron oxidizing bacteria) in groundwater in the Toki Granite and Mizunami Group.

- The total number of bacteria ranges from 10^6 to 10^7 cell/ml, regardless of rock type or depth.
- There are depth ranges that lack sulfate reducing bacteria and some with as little as 10^3CFU (Colony Forming Unit)/m.
- The number of iron oxidizing bacteria ranges from 10^4 to 10^5 cell/ml throughout the entire range of depths sampled.

④ Chemistry of groundwater in the Toki Granite is formed by dissolution of pyrite and calcite, argillization of feldspars, and ion exchange between groundwater and clay minerals [60].

⑤ Results of measurement of hydrogen-oxygen isotope ratios indicate that groundwater in the Toki Granite is of meteoric water origin. However, the measurement of ^{14}C suggests that the residence time is some ten thousand years for groundwater around 1,000 m depth [15].

4.3.2.2 Current status of investigations in the MIU Project

Simultaneous data acquisition from the various study fields in the same borehole is not only time-saving but advantageous for comparative examinations of the data from different perspectives. In borehole investigations in the initial stage of the RHS Project, physical logging, hydraulic tests and pumping tests were carried out in this order after borehole drilling using fresh water. However, incidents such as borehole collapse at large-scale fracture zones and loss of drilling fluid into the rock mass, rendered it difficult to collect representative groundwater.

Based on this experience, groundwater sampling in MIU-1, 2 and 3 was planned to be carried out after geophysical logging, hydraulic tests, installation of the MP system in the boreholes and long-term pumping. Thus, MP systems were installed in MIU-1 and 2 in the reporting period; it was also planned that this system be installed in MIU-3 in 2000 FY. However, groundwater sampling in MIU-1 and 2 could interfere with other simultaneous borehole investigations (including hydraulic tests, etc.). Therefore sampling has yet to be carried out. The timing of water collection will be decided based on the progress of borehole investigations.

Based on the failure to efficiently collect water in MIU-1, 2 and 3, a change in investigation procedure was planned for MIU-4 investigations (planned in 2000 FY). According to this change, water collection would be carried out in combination with pumping tests subsequent to immediate suspension of drilling, if drilling fluid loss occurred [45]. In addition, a known concentration of dye would be added to drilling fluid to identify residual drilling fluid in the groundwater lost during pumping. This would be to ensure that samples representative of in situ groundwater are obtained and also, that data quality in the determination of the hydrochemistry of the groundwater would be maintained. Also, different dyes would be used in the sedimentary rocks, in the hanging wall and in the footwall of the Tsukiyoshi Fault on the assumption that these zones might have different hydrochemical properties and to check on possible interconnectivity of the rock units Pumping tests carried out as part of hydraulic tests are utilized to prepare for groundwater sampling by removal of drilling fluid. The pumping would stop when the concentrations of dye added to the drilling fluid has been reduced to a predetermined value and also, in consideration of the physicochemical parameters obtained by continuous monitoring of groundwater.

Furthermore, hydrochemical data is obtained as part of the study on the evolution of groundwater chemistry using rock core. Measurements of the ratio between Fe^{3+} and Fe^{2+} in the granite indicate that Fe^{3+}/Fe^{2+} is higher at shallow levels (< 300 m depth), but decreases with depth (> 300 m in depth). This indicates that oxidation-reduction environment in the granite probably changes at around 300 m in depth.

4.3.3 Future tasks

In the reporting period, no data on hydrochemical properties of groundwater were obtained in the MIU Project. Therefore, the collection and analysis of groundwater are the priority tasks of future investigations. Based on an improved plan of borehole investigations of the MIU-4, high quality data is expected to be obtained.

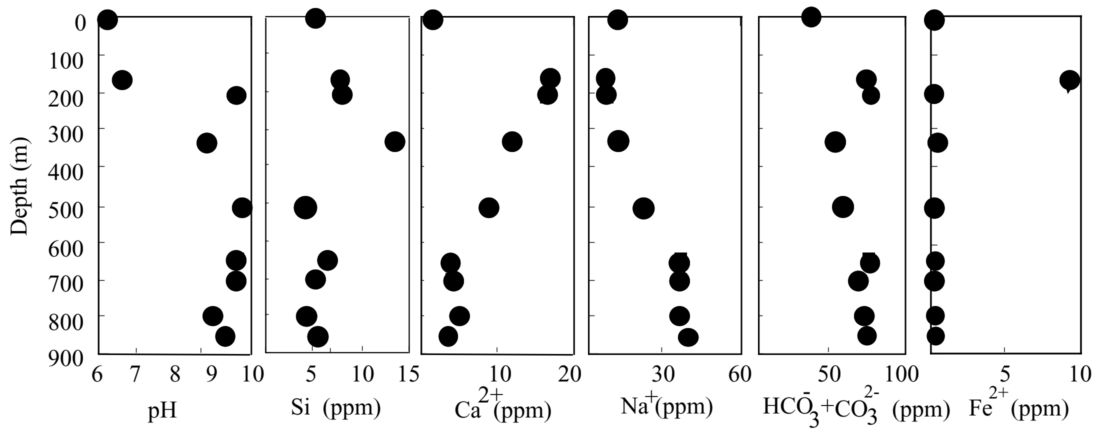

Figure 4.59 Changes in ground water chemistry in granite in the Tono area by depth

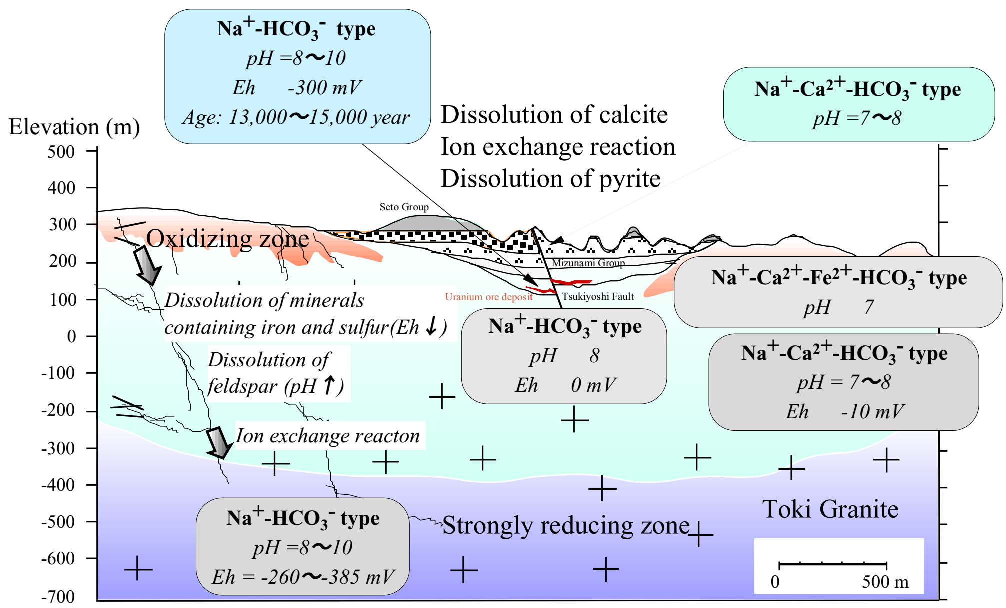

Figure 4.60 Geochemical evolution of the groundwater in the study area [59)]