The Hydrogeological Conditions in the Granitic Area for the Research Program of HLW Disposal in Korea

Chunsoo Kim, Daeseok Bae, Kyungsu Kim, Yongkwon Koh and Geonyoung Kim

Korea Atomic Energy Research Institute,

P.O.Box 105, Daejeon 305-600, Korea

ABSTRACT

The geological research as a part of HLW disposal program in Korea is carried out to provide necessary data for the establishment of the reference repository system in term of design and safety assessment in the crystalline rock terrains. Six deep boreholes were drilled to obtain hydrogeological and hydrochemical data from Jurassic granites in the Yuseong area, Korea. The core observation, televiewer logging and hydraulic testing were carried out during and after drilling and multi-packer system were installed in the borehole of 500m depth for hydraulic and hydrochemical monitoring including environmental isotopes. The integration of hydrogeochemical and hydrodynamic data would be built greater confidence for the understanding of groundwater system in fractured rock mass. This geoscientific program could be possible to suggest a general guideline to develop the reference disposal concept of high-level radioactive waste in Korea.

INTRODUCTION

The Korea Atomic Energy Research Institute (KAERI) is conducting the research program of high level radioactive waste (HLW) disposal in Korea. KAERI launched a three-step research and development (R&D) program in 1997 to develop a reference geologic repository system for HLW by 2006. The second step activities include deep borehole investigations of crystalline rock masses to produce the data required for the establishment of the preliminary system. Now, the last step for the R&D program is devoted to further development of the preliminary system by using more refined information about reference site characteristics.

Geological formation plays an important role as a barrier system of nuclide migration in a deep repository for radioactive wastes and the geological setting of a repository also provide an equally important role to isolation and protection for the engineered barriers. The main tasks of geoscientific study were focused mainly on a near-field condition of deep geological environment for the reference disposal system of HLW at the current stage in Korea, which could be characterized and defined as three categories such as geosphere stability, isolation and retention properties in geological barrier.

In this study, it aims to define and produce the geologic conditions including rock fracture systems, hydrogeological and hydrogeochemical characteristics of groundwater. The more detailed study on rock block continues in the study sites of Jurassic plutonic rock mass accompanied with the deep drilling program.

STUDY AREA

Geological Settings

The basement rocks exposed in more than the half area of the Korean peninsula consist of Precambrian metamorphic rocks and Paleozoic and Mesozoic plutonic rocks. Precambrian rock types were subjected to severe regional metamorphisms, in turn to form a gneiss complex system roughly grouped into gneisses, crystalline schists and granites. The majority of plutonic rocks are granites and their varieties. Especially, Jurassic granite and Cretaceous granite are important for their large distribution area and tectonic movements in relation to each igneous activity. Sedimentary and volcanic rocks of the Paleozoic and Mesozoic eras are distributed on those basement rocks accompanied with tectonic movements. Various rock types and their areal proportions are summarized in the KAERI (2002).

Based on the distribution area of each unit, the Mesozoic plutonic rock mass was considered as the primary host rock for detailed study, firstly. The alternatives for a preferred host rock could be crystalline gneisses of the Precambrian basement and Cretaceous massive volcanic rocks, and would be desirable to be studied in near future.

In this study, the Yuseong site was selected as one of the study areas, one from the eastern coastal area and the other in the mid-western low mountain region as Yuseong site. The Yuseong site is located at the Kum river drainage basin of the western peninsula. The topography of the study site is well characterized as fairly rolling hills surrounded by the upland of EL. 300-500m. The highest point in the distant area is about EL.850m and most of the lowlands are located at EL.50m.

The bedrock of the Yuseong area consists partly of the pre-Cambrian gneissic basement of 460 Ma old and Jurassic plutonic rocks of 160 Ma. The basement rock composed mainly of biotite gneisses and schists in the northwestern region of the study area. The plutonic complex is composed of biotite granites, two mica granites and various dykes. Two-mica granite with discernible foliation is a major rock type in the drilling site. The major minerals observed under a petrology microscope are quartz, plagioclase, biotite and mica with minor amounts of K-feldspar, chlorite and epidote. A sericitization is commonly observed along twins or grain boundaries of plagioclase and a chloritization along cleavages in the biotite.

Boreholes

In the part of the research program, the drilling campaign in a Jurassic granitic terrain has been established to obtain the geologic data for a reference repository system. One of the investigation objectives is to acquire sufficient information on lithological homogeneity, bedrock structures and fracture characteristics, and hydrochemistry in a deep geologic condition at the study sites. This presentation provides the fracture systems of the drilling sites and the fracture data from boreholes, and hydrochemistry related to the fracture systems.

Five 76mm diameter boreholes were drilled in the study site. The length of the boreholes is normally 200 ~ 500m. The following investigation methods are used to obtain a variety of geological information such as core logging, televiewer logging (BHTV), hydraulic testing during drilling, visual inspection of fracturing and fracture conditions and the filling materials, mineral coating the fracture. Also, groundwater monitoring in borehole using the multipacker system (Westbay Co, Canada) was installed in the selected borehole (YS-01), which were isolated to 14 sections by packers according to depth and fracture system. The following items are periodically monitored such as groundwater pressure measurement and groundwater sampling from each packed-off section. Water level changes of the open boreholes are obtained by an automatic recording system.

For long term monitoring of groundwater chemistry, groundwater samples collected from each isolated section in the MP system are analyzed the following propereties like index properties (pH, Eh, EC, DO, TDS and Temp.), major/minor elements, isotopes (18O, 2H, 3H). And, for the future activities are planning such as hydraulic interference tests (short and long terms), tracer tests (short and long terms), additional installation of the Multi-Packer system and continued groundwater monitoring in all boreholes.

RESULTS

Fracture Characteristics

The dominant conductive fractures are characterized as vertical to sub-vertical and the sub-horizontal fractures (Set 3) decrease remarkably with the depth. That is, sub-horizontal fractures are very sparse and the corrected proportion of Set 2 is higher than those of Set 1 and 3 (Table 2.11). The semi-open type fractures are predominant among the conductive fractures as much as 86%.

Sub-horizontal fractures (Set 3) of the Yuseong site decrease remarkably with the depth, whereas sub-vertical fractures (Set 1 and 2) have been developed in the similar pattern with the depth. Also, the conductive fractures have a decreasing trend with the depth. It is characterized that Set 2 mainly dominates the fractures around GL. -500m of the borehole YS-01. Besides the main fracture zone developed around GL. –105m, the fracture zones from GL. -200m to GL. -300m and around 500m are considered to be a minor conducting zone.

Based on the modified Terzaghi correction method, the fracture frequency for each fracture set was corrected into the cumulative scan length (710m). The conductive fracture's spacing can be calculated as 9.6m (Set 1), 11.0m (Set 2) and 142m (Set 3), which has very low density under one tenth of all fractures.

The aperture size decreases rapidly under GL. –350m in the borehole YS-01. All the data are distributed in a lognormal distribution pattern with the geometric mean of 0.835mm and the arithmetic mean of 2.34mm.

Hydraulic Properties

By comparing the hydraulic conductivity distributions of 4 boreholes, the water conducting zones are located at around GL. -100m, -160m, -250m, -350m, and -500m as well as near surface. But the depths of these conducting zones don't always match between each borehole due to fracture dipping. A number of impermeable zones are also exist in the Yuseong site and the hydraulic conductivity of the conducting zones reaches to about 1x10-7m/s.

With the constant pressure injection test, the pulse test is also recommended in the low permeable rock mass such as granite. The pulse tests (Kpulse) were carried out in the monitoring zones, which were divided by the Multi-packer system (Westbay Co., Canada) in the borehole YS-01. In addition, the slug test (Kslug) for a whole borehole section was carried out.

The geometric mean for the transient state analysis of all data is estimated 7.23x10-10m/s, which is two times greater than that of the steady state analysis of 3.47x10-10m/s. Based on the vertical distribution of the hydraulic conductivities of 4 boreholes at the Yuseong site, the boundary of the upper and lower hydrogeologic units can be confirmed around 160m below the ground surface. The lower hydrogeologic unit has permeability slightly less than that of the upper unit. The effective hydraulic conductivity of the upper and lower units ranges 5.3x10-10m/s~8.6x10-10m/s and 2.5x10-10m/s~6.0x10-10m/s, respectively. It is considered that these ranges are resulted from the difference between the steady and transient state analysis (KAERI, 2002).

Geochemical Conditions

Field measurements including temperature, pH, redox potential, electrical conductivity. dissolved oxygen and alkalinity of groundwater were carried out. Since the installation of MP system on Sep. 2001, the groundwater was sampled and analyzed in 7 times. Although the groundwater from the open boreholes before MP installation was monitored, the data are not included in this report. The geochemistry of the indicated lots of difference between before and after the installation MP system. The thermal gradient is 0.26oC/100m obtained from measurement by the MP probe at the groundwater sampling depth, which is almost duplicated during each measurement. The grouting activity, affecting groundwater quality, was inevitably carried out before the MP installation on the zone with Portland cement.

The groundwater of the section affected by grouting has abnormally high pH (12.7), whereas the pH value of groundwater of 200m below surface reaches almost constant value as about 10.0. The redox potential of groundwater varied with depth and more negative values were recognized in deep groundwater. Except the section affected by grouting materials, the concentrations of Na, Ca, Mg, K, Cl, HCO3 and SO4 of groundwater are almost constant below GL -200m. Fluorine in deep groundwater shows high concentration up to 12.7 mg/l and tends to increase with depth, indicating that water-rock interaction increases with depth.

Although the chemical characteristics of natural shallow groundwater were not identified from the borehole, due to the grouting, the geochemical data of shallow groundwater in the vicinity of the borehole can be used for the comparison with deep groundwater. Surface water and shallow groundwater mainly reacted with soil shows Ca-HCO3 type or Ca-Na-HCO3 type, whereas deep groundwater below 250m from the surface belongs to typical Na-HCO3 type. Although the tracer, like urine, was not used for drilling fluid, the variations of geochemical data of groundwater with time shows whether the groundwater is stabilized after drilling and the installation of MP system. It shows that field parameter and chemical compositions were stabilized to natural state within 6 months after the installation of MP system. According to the monitoring data using MP system and analyzed such as hydraulic head and geochemical compositions, it is considered as slightly downward flow or nearly lateral flow condition. The period for stabilization of geochemical conditions is related to the properties of groundwater flow along the fractures.

The δ18O and δD values are nearly plotted along the worldwide meteoric water line, which is indicating that groundwater from the borehole was recharged from local meteoric waters under present climate conditions. It is noteworthy that isotopic compositions of deep groundwater are lighter than those of surface and shallow groundwater in the borehole of Yuseong area. It is likely that deep groundwater was recharged from the area of higher elevation. Considering the altitude effect (0.19‰/100m, δ18O) of isotope fro precipitation in Korea (Kim and Nakai, 1988), the recharge area of the deep groundwater is estimated to high elevations than the local land surface. Tritium contents close to zero are observed in the deep groundwater, thus confirming a long residence time of deep groundwater. On the other hand, high tritium values characterized in the shallow groundwater are considered as recent waters with a very short circulating time. The tritium content of the intermediate section is 5.4 to 6.7 TU, indicating that the residence time of the groundwater is less than 50 years or the mixing process between old water and local young water prevails.

DISCUSSIONS

According to the integrated data using the upper stated areas, it is supposed to be roughly divided into two regimes such as upper and lower condition at the depth of 200~250m from surface. In fracture characteristics, it would be defined as fractured and massive and, hydraulically active and low flow zone in physical hydrological aspect, oxidizing and reducing zone in hydrogeochemical considerations. There is no significant unstable condition in rock mechanical consideration according to the stress ratios with depth, but it has been confirmed to show a linear and stable variation from 150~200m in depth.

In these results, the integration of hydrogeochemical and hydrodynamic data, would be built greater confidence for understanding of the groundwater system in the fractured rock mass. Also. it could be possible to suggest a general guideline to develop of disposal concept including performance assessment at the current status in Korea.

REFERENCES

1. KAERI, Korea Atomic Energy Research Institute, "A progress report of the geoscientific research on plutonic rock mass for a HLW disposal in Korea", KAERI/TR-2266/2002, 166pp (2002).
2. Kim, K.H. and Nakai, N., "Isotopic compositions of precipitations and groundwaters in South Korea", Jour. Geol. Soc. Korea, Vol 24, 37-46 (1988).