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Geochemistry of Geothermal Water in Pohang, Korea

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ABSTRACT

Hydrogeochemical and isotopic characteristics were investigated for groundwater of the Tertiary basin in southeastern part of Korea where deep drilling is in progress for geothermal investigation. According to geology, the aquifer was distinguished as alluvial, tertiary sedimentary bedrock (bedrock groundwater), and fractured volcanic rock (deep groundwater). Groundwater of each aquifer is distinctively separated in Eh-pH conditions and concentrations of Cl, F, B and HCO_3. Deep groundwater has very low levels of ^3H and ^{14}C whereas alluvial groundwater has those of recent precipitation level. However one of deep groundwater show mixed characteristics in terms of hydrochemistry which indicates effect of pumping. Deep groundwaters have temperature of 38 to 43°C whereas bedrock and alluvial groundwater have temperature less than 20°C. Fractured basement rock aquifer has a different hydrogeological setting from the bedrock and alluvial aquifer considering hydrogeochemical and isotopic characteristics, and temperature.

1. INTRODUCTION

Geothermal investigation is now in process for feasibility of low-temperature geothermal resource development in the southeaster part of Korean peninsula near central area of Pohang basin by Korea Institute of Geoscience and Mineral Resources. The first phase of deep drilling was completed 3 km south of Heunghae town near the center of the basin filled with Cenozoic rocks. Final depth of the borehole is planned to be 2 km. Cenozoic rocks including the study area have highest geothermal gradient in South Korea (Kim et al., 2002).

We investigated hydrogeochemical and isotopic characteristics of ground water for the alluvial and Tertiary aquifer around the test drilling site to assess vertical groundwater flow system and identify the source of geothermal water (Fig. 1). One of deep ground water, K1 is taken from a 1km-deep test drilling borehole of the project.

2. GEOLOGY

Cretaceous shale and sandstones is a basement of the basin and Eocene tuffs, felsite and biotite granite intruded the basement. The basin is mainly filled with Miocene Yeonil formations, which are semi-consolidated sandstones and mudstones of marine origins with terrestrial sedimentary rocks at the bottom.

Yeonil formation is about 400m thick near the test drilling site though it is known to be thicker than 1000m in the basin. From the core logging of the test drilling site, 100 m thick tuffs underlies Yeonil formation and 300m thick rhyolite underlies the tuffs. Alternated formation of mudstone and sandstone is vertically distributed to the bottom of the borehole. Alluvium covers the tertiary sedimentary rocks.

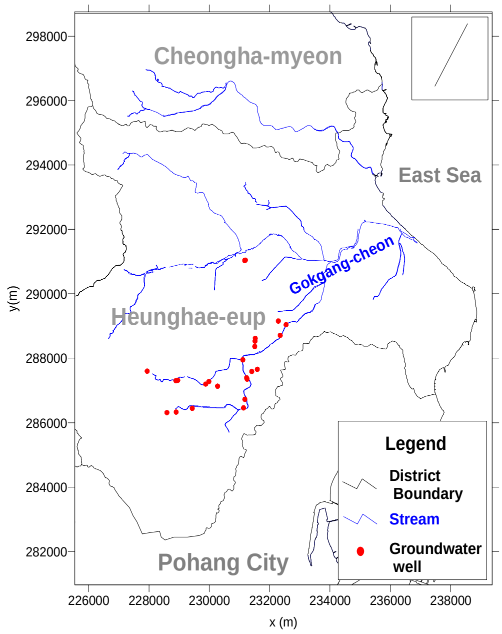

Figure 1: Sample location

3. METHODS

Groundwater can be classified as alluvial, bedrock and deep ground water according to temperature and geochemistry in the basin. Bedrock groundwater is taken from irrigation and public water-supply wells which completed in Tertiary sedimentary bedrocks. The depth of the wells is usually less than 200m. Deep ground water is collected from two deep wells (about 500m deep) used for hot spar and a 1km-deep test drilling borehole, which presumably taps fracture zones near boundary of Tertiary mudstones and volcanic rocks and/or within the volcanic rocks. Alluvial ground water was collected at dug wells whose depth is less than 20 m. Hydrogen sulfide, ferrous ion, boron was determined in the field by spectrophotometry (Hach). ^3H and ^{14}C were measured at Institute of Geological and Nuclear Sciences, New Zealand. Stable isotopic compositions of water were measured at Korea Basic Scientific Institute. Major elements were determined in Korea Institute of Geoscience & Mineral Resources.

4. RESULTS AND DISCUSSION

Bedrock and deep ground water is low in dissolved oxygen and have detectable sulfide ion. Measured Eh shows continuous distribution from oxidizing and reducing conditions. pH of alluvial groundwater is less than 6 whereas bedrock and deep groundwater have pH greater than 8. Groundwater has different water types according to aquifers. Alluvial groundwater is Ca-SO_4 type, bedrock groundwater is Na-HCO_3(SO_4) type and deep groundwater is Na-HCO_3 type (Fig. 2).

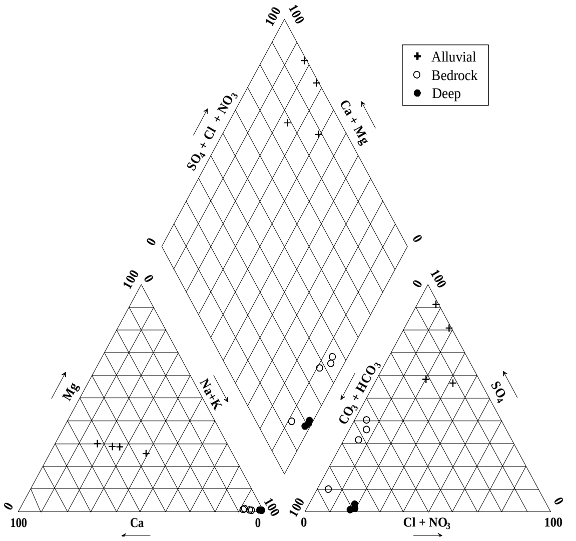

Figure 2: Piper diagram of groundwater

Nitrate is relatively higher in shallow and bedrock groundwater, which appear to be due to the extensive paddy fields in the basin. Deep groundwater has negligible nitrate indicating little effect of shallow ground water. Higher fluoride in deep ground water appears to be derived from the igneous rocks of the basement. From Fig. 2, stable isotopic compositions shows ground water orginates from meteoric water and it seems summer rains most contributes to recharge from the comparison with isotopic characteristics of precipitation in Pohang area (Lee and Chung, 1997). Depleted isotopic signature of ^{18}O and D of deep groundwater indicates that its recharge area is higher than those of bedrock and alluvial groundwater.

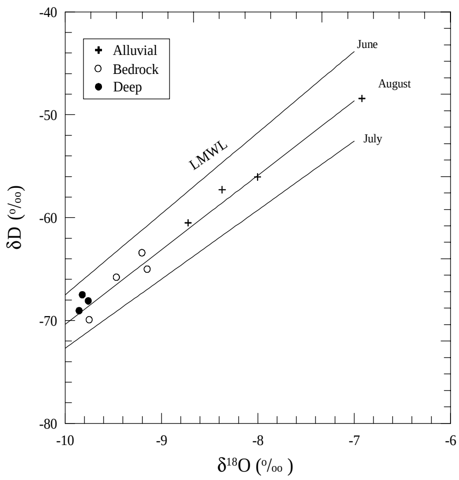

Figure 3: Stable isotopic composition of groundwater. LMWLs (local meteoric water line) were drawn for each summer month.

^{3}H and ^{14}C shows bedrock and deep groundwater are distinctively separated from alluvial ground water (Fig. 4).

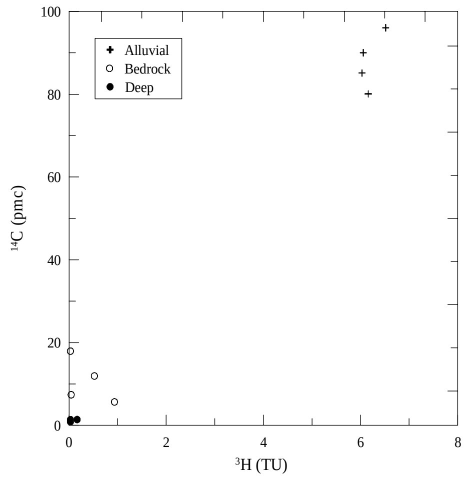

Figure 4: ^{3}H and ^{14}C concentration of groundwater

Alluvial groundwater has ^{3}H concentration of about 6 TU and ^{14}C of above 80 pmc. Deep groundwater ^{3}H concentration lower than 0.2 TU and ^{14}C less than 2 pmc. Bedrock groundwater is located between the two groundwaters in ^{3}H and ^{14}C though it is close to deep ground water. This suggests deep groundwater has little fraction of alluvial ground water. However, among deep groundwater samples, H2 shows characteristics of mixing. H2 may be interpreted as a binary mixture of deep groundwater and shallow groundwater in comparison of nitrate and fluoride (Kim et al., 2004), and in comparison of ionic concentration and temperature. Bedrock groundwater shows $\delta^{13}C$ of up to -4.0 $^{00}/_{0}$ whereas $\delta^{13}C$ of deep groundwater is about -12 $^{00}/_{0}$. This suggests that bedrock groundwater was affected by marine carbonates contained in Miocene sedimentary rocks.

Deep groundwaters have temperature greater than 35°C, which is much higher than 13.8 °C, mean annual air temperature in Pohang area (http://www.kma.go.kr). Temperature of bedrock and alluvial groundwater is less than 20 °C. Deep groundwater also has distinctively higher concentration of B, Cl, F and HCO_3 than bedrock and alluvial groundwater. Separation of deep ground water from bedrock and alluvial groundwater is also identified in ^{3}H and ^{14}C. This indicates that flow of geothermal water is related to the fractured zone in the volcanic rocks below Miocene sedimentary rocks. From detectable Br, an effect of seawater on deep groundwater is discernible though chloride concentration is much lower than saline groundwater.

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