Influence of Mineral Assemblage to form the Groundwater Quality in Altered Rock Area

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Abstract

Groundwater geochemistry which is distributed at the Hakkouda Tunnel in the Sankaku-dake Mountains, Aomori prefecture, was surveyed to understand the mineral assemblage effecting onto the water quality of groundwater. We collected and analyzed the primitive groundwater samples that were gushed out from the cutting face and the pilot drilling. The groundwater geochemical characters were compared with the geological, petrographical and mineralogical features of the surrounding rock mass. From the results of the consideration, we conclude the influences of hydrothermal alteration to the ground water geochemistry as follows. 1) The groundwater distributed around the Hakkouda Tunnel is classified into the calcium-bicarbonate type and/or the calcium-sulfate type. 2) The groundwater in the hydrothermal alteration area shows geochemical feature of the calcium-sulfate type, and the feature becomes more remarkable as the degree of alteration increases. 3) At the strong acidic alteration zone in which pyrophyllite are included, the groundwater exhibits low ion concentration and low pH. 4) The quality of fissure water in hard rock mass depends on the mineral assemblage of aquifer and is not homogenized in geochemical by mixing due to groundwater flow.

Keywords: groundwater quality, altered rock, minerals assemblage, hydrothermal alteration

1. Introduction

Recently groundwater pollution caused by the heavy metal elements from natural rock mass becomes serious issue, and is widely noticed. It is well known for example that the seepage water from mines has strong acidity and has high heavy metal elements concentration (Saskatchewan Environment and Public Safety Mine Pollution Control branch, 1992). It is suggested that the wide area arsenic pollution of groundwater depend on the hydrogeology of aquifer (Shimada, 2003). On the other hand, it is afraid that concrete materials such as lining of tunnels are deteriorated by the long-term seepage of acid groundwater and that agricultural environment around tunnels is influenced by constant alkaline water seepage.

The groundwater quality will be changed by the reaction between water and minerals and will attain to chemical equilibrium condition in the aquifer. It is probable therefore that the geology of aquifer influence to groundwater quality (Seki et al., 1999). It is expected that acidification and concentration of heavy metal are occurred in groundwater contacting ore-vein around the mines. The relationship between the secondary mineral assemblage and the groundwater quality are not clear. It is not clear how much range influence on groundwater quality by the thermal alteration extends to. We have no knowledge for the difference of water quality between thermal alteration and diagenesis alteration.

In this report, we will discuss the influence of mineral assemblage to form groundwater quality from the result of comparison between water quality and mineral assemblage in spatial at Hakkouda Tunnel.

2. Geological setting

The Neogene rocks in Kanegasawa Formation, Yotsuzawa Formation, Wadagawa Formation and Ichinowatari Formation distribute around the Hakkouda Tunnel, and the Neogene igneous rocks intrude into these formations (Fig.1). The Quaternary pyroclastic flow deposits from the Hakkouda volcano cover these Neogene rocks. Mudstone distributes mainly in Yotsuzawa Formation and Wadagawa

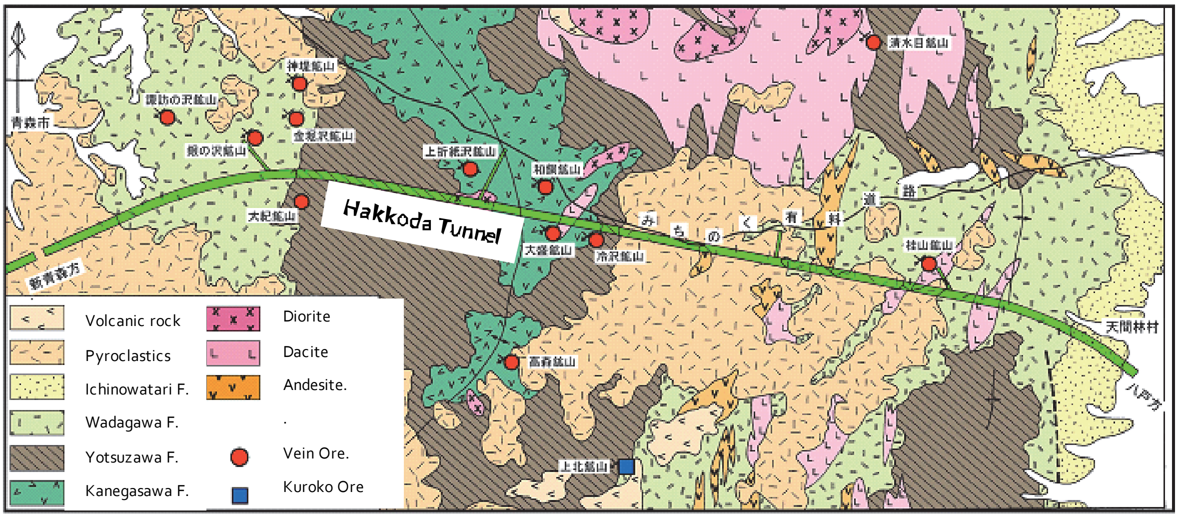

Fig.1 Geological map around the Hakkouda Tunnel

Formation. Yotsuzawa Formation was formed at the same time as Nishi-Kurosawa Formation that is known as the "Kurokou" formation. Wadagawa Formation was deposited simultaneously with Onnagawa Formation that contains oil. Kanegasawa Formation that is the lowest formation in this area distributes around the summit of this tunnel. The upper formations distribute to the west and east entrances of the tunnel. Therefore, the structure of the Neogene formations around this tunnel is an anticline to extend the axis from north to south at the summit of this tunnel.

There are many abandoned mines, e.g. the Kitakami Mine, around this tunnel. The abandoned mine to be distributed over less than 3km from this tunnel is 11 mines, e.g. the Taisei Mine (Fig.1). These abandoned mines classified as ore vein type mines, which consist of pyrite, chalcopyrite and sphalerite mainly, distributed at Kanegasawa Formation, Yotsuzawa Formation and Wadagawa Formation.

3. Groundwater quality in each Formation

We already reported the groundwater quality in each formation distributed around the Hakkouda Tunnel (Shimofusa et al., 2003). The summaries of the feature of groundwater quality are as follows:

The groundwater in Ichinowatari Formation is classified into calcium-bicarbonate type, and indicates 7.5 to 8.5 in pH (Fig.2). In Wadagawa Formation, the groundwater quality is different in each rock type. If the aquifer consists of basaltic rocks, the groundwater shows the features of calcium-sulfate type, and if tuff breccias the groundwater is classified into calcium-bicarbonate type (Fig.3). The pH of the groundwater in Wadagawa Formation shows from 7.5 to 9.0. The groundwater in Yotsuzawa Formation, which shows 8.0 to 9.0 in pH, is rich in sulfate and is classified as calcium-sulfide regardless of rock type (Fig.4). If the

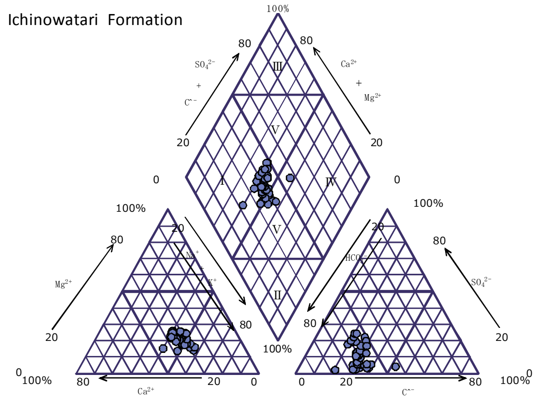

Fig.2 The Piper diagram of the groundwater in Ichinowatari formation

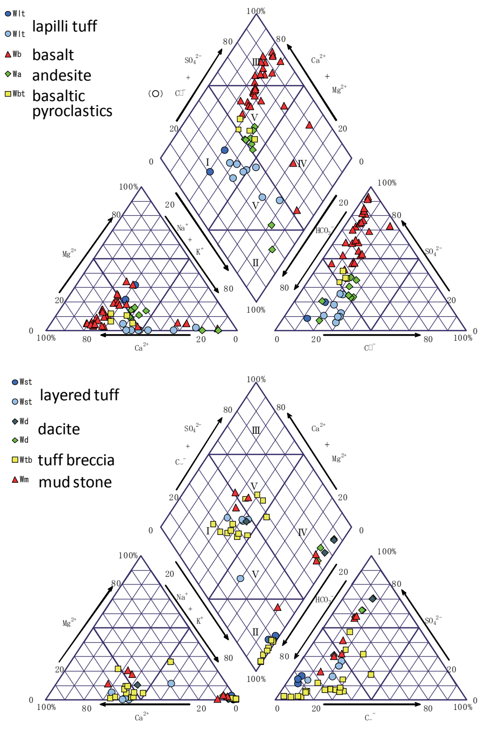

Fig.3 The Piper diagram of the groundwater in Wadagawa formation

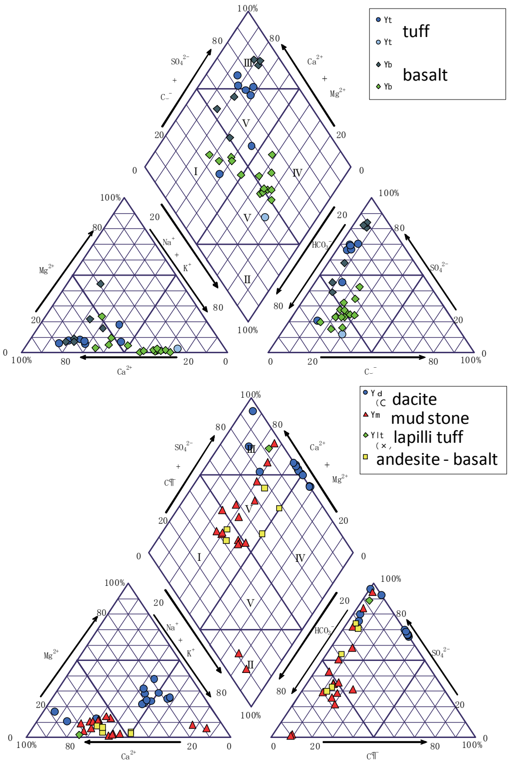

Fig.4 The Piper diagram of the groundwater in Yotsuzawa formation

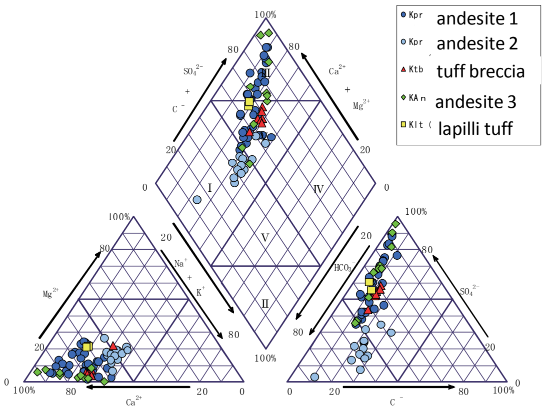

Fig.5 The Piper diagram of the groundwater in Kanegasawa formation

aquifer consists of tuff and tuff breccias in Kanegasawa Formation, the groundwater feature shows calcium-bicarbonate and/or calcium-sulfate and is in range from 8.0 to 9.0 in pH (Fig.5). The major groundwater in intrusive body shows the feature of calcium-sulfate type and/or calcium-bicarbonate type, and sodium-sulfide in minor (Fig.6). These ground waters are in range from 8.0 to 9.5 in pH.

4. Mineral assemblages and groundwater quality

4.1 Spatial distribution of mineral assemblages

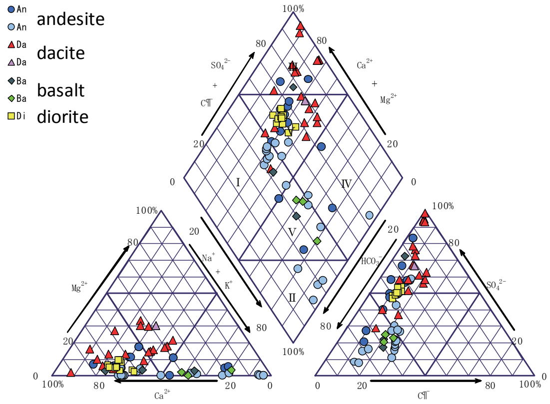

Fig.6 The Piper diagram of the groundwater in intrusive body

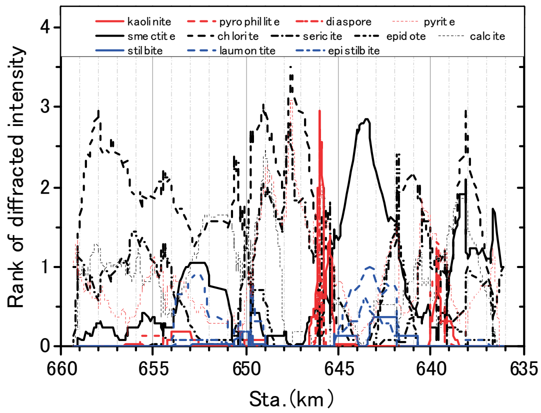

Fig.7 Spatial distribution of mineral assemblage

The representative samples were examined by X-ray powder diffraction (XRD) in order to grasp the influence of the mineral assemblage on the groundwater quality. We examined 580 rock samples.

The diffracted intensity of each mineral detecting in samples by X-ray powder diffraction is divided into 4 grades qualitatively. Fig. 7 indicates the spatial distribution of the diffracted intensity of each mineral. In this figure the diffracted intensity shows as proximity average grade of 20 samples approaching it. Because it is not a sampling of the equal distance, the proximity average of the number of the uniform samples does not express correct qualitative grade. However we can understand the distribution of the diffracted intensity of minerals in a large sense at the wide spatial range shown in Fig. 7.

Chlorite and smectite are distinguished in the section between 636km and 639km, at 641km to 645km the rock mass is enriched in smectite including zeolite. Chlorite excels from 646km to the end of the tunnel generally. Sericite is included in the section from 646km to 650km. Smectite and laumontite are included in the section between 651km and 654km, and at the end part of tunnel from 654km, sericite and calcite are included. I In these areas, the mineral assemblages show the feature of the neutral altered zone with the feature of alkaline altered, therefore diagenesis was the dominant alteration process.

Acidic alteration minerals such as kaolinite and pyrophillite are enriched remarkably in 639km to 640km, 645km to 646km. Then the rock masses in these areas are affected by hydrothermal alteration notably. The rock masses at 640 – 641km, around 642km, 646 – 650km, 653 – 656km and 658 – 659km include many pyrites. It is considered that these rock masses were affected by hydrothermal alteration with diagenesis as dominant alteration process, because pyrite is a dominant phase in the ore vein distributed around the Hakkouda Tunnel.

4.2 Spatial distribution of groundwater quality

We collected and analyzed 1,006 primitive groundwater samples that were gushed out from the cutting face and the pilot drilling to confirm the spatial distribution of the groundwater quality.

To understand the spatial distribution of groundwater quality in a large sense, we illustrate the spatial variation of proximity average values of pH, electrical conductivity (EC), cations and anions concentrations of 10 samples coming close to in Figs.8-10. The groundwater distributed in the area in which diagenesis was the dominant alteration process is in range from 8.0 to 9.0 in pH and ranges from 10 to 30 mS/m. At the areas affected by both hydrothermal alteration and diagenesis with many pyrites the EC of groundwater exceed 40mS/m. If the rock masses include calcite with pyrite at the same level especially, e.g. 640 to 641km, 648 to 650km, around 655km, the groundwater has more than 80 mS/m of EC. On the other hand, the groundwater in rock masses affected by remarkable acidic alteration, 645 to 646km, indicates strong acidity, lower than 4.0 of pH. The pH of groundwater at 639 to 640km including acidic alteration minerals becomes lower than that of peripheral groundwater.

Comparing the concentration between the four major cations, Na^+ and Ca^{2+} are dominant in the groundwater and there is much Mg^{2+} next. K^+ concentration in the groundwater is very low at studied area. If the calcite and pyrite of quantity at same level are contained in rock mass, the concentration of Ca^{2+} and Mg^{2+} in the groundwater becomes higher than peripheral area. The concentrations of Na^+, Ca^{2+} and Mg^{2+} in the groundwater are slightly low at the area in which the mineral assemblages of neutral to alkaline alteration, such as zeolite, are recognized.

It is only sulfate that a remarkable concentration change is seen in anions. SO_4^{2-} concentrations in groundwater become high at the area in which acidic altered minerals distribute and at the diagenesis alteration area which contain many pyrite. SO_4^{2-} concentration in the groundwater at neutral and alkaline alteration zone indicates low value.

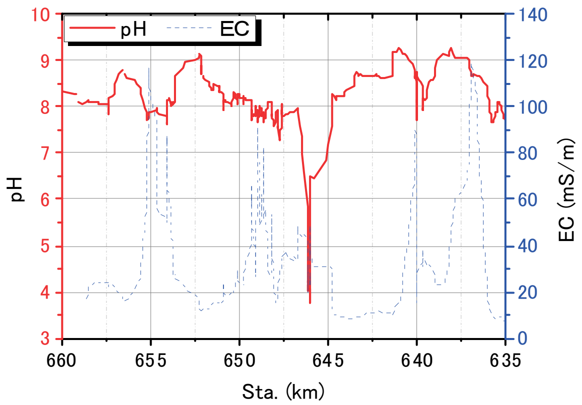

Fig.8 Spatial distribution of pH and EC in groundwater

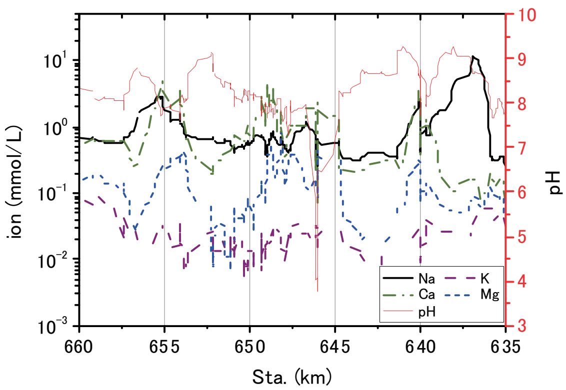

Fig.9 Spatial distribution of cations in groundwater

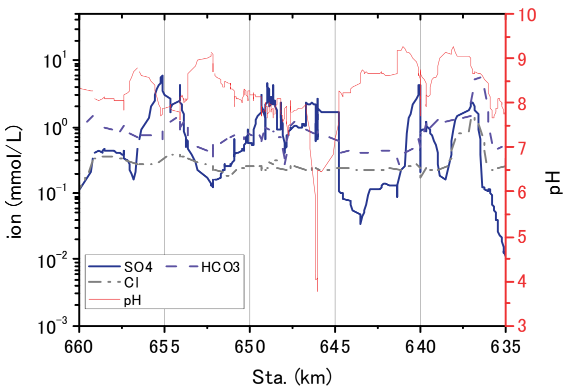

Fig.10 Spatial distribution of anions in groundwater

5. Discussion

From the comparison between mineral assemblages and groundwater quality, it is clear that the ion concentration in the groundwater become higher at the section affected by hydrothermal alteration, which formed pyrite vein in rock mass. If the rock mass suffer strong acidic hydrothermal alteration which precipitate the acidic alteration minerals, many elements in rock mass are dissolved throughout alteration process. Therefore, the groundwater in this rock mass shows low concentration in ions and becomes acidic with low pH. On the other hand, at the rock mass that is affected by alkaline alteration precipitating zeolite during diagenesis process, ion concentrations in groundwater become low. From this fact, it is assumed to absorb ions into zeolite.

Comparing between the spatial distribution of mineral assemblages and groundwater quality, we can confirm that the distribution of groundwater affected by hydrothermal alteration is limited at or near the hydrothermal alteration area. Therefore, the water quality of fissure water in hard rock mass such as the mountain around the Hakkouda Tunnel depends on the mineral assemblage of aquifer and is not homogenized in geochemical by mixing due to wider groundwater flow.

6. Conclusions

We examined the relationship between the mineral assemblage and the groundwater quality to understand the influence of mineral assemblage to form the groundwater quality. From the results of the consideration, we conclude the influences of hydrothermal alteration to the groundwater geochemistry as follows.

1) The groundwater distributed around the Hakkouda Tunnel is classified into the calcium-bicarbonate type and/or the calcium-sulfate type.

2) The groundwater in the hydrothermal alteration area shows geochemical feature of the calcium-sulfate type, and the feature becomes more remarkable as the degree of alteration increases.

3) At the strong acidic alteration zone in which pyrophyllite are included, the groundwater exhibits low ion concentration and low pH.

4) The quality of fissure water in hard rock mass depends on the mineral assemblage of aquifer and is not homogenized in geochemical by mixing due to groundwater flow.

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