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# HYDROTHERMAL ALTERATION IN THE FUSHIME GEOTHERMAL FIELD, KYUSHU, JAPAN

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## ABSTRACT

Petrographical and geochemical studies on cores and cuttings from the Fushime geothermal wells were carried out using microscopy, XRD, XRF, and EPMA. The petrographical studies revealed that the alteration mineral assemblage in the geothermal reservoirs is characterized by the occurrence of K-feldspar and sericite. This assemblage is subdivided into three mineral zones: 1) a K-feldspar-quartz assemblage, 2) a sericite-quartz assemblage, 3) an albite-chlorite assemblage. The geochemical study shows that potassium and rubidium are enriched in the K-feldspar-quartz assemblage zone. The authigenic K-feldspar observed with EPMA indicates that precipitation of K-feldspar and sericite contributed to enrichment of the alkali elements. In comparison with the temperature-recovery survey, the alkali-enriched zone corresponds to a hydrothermal discharge.

## INTRODUCTION

More than 10 wells have been drilled in the Fushime geothermal field in southern Kyushu, Japan (Fig.1), the deepest of which is approximately 2600m. Maximum measured temperatures are in the range from 200 to 350°C. The fluid discharged from the wells is a mixture of steam and hot water with neutral to acidic pH and high $Cl^-$ and $SiO_2$ concentrations.

Mineralogical investigations using microscopy and XRD in the Fushime geothermal field have already been done by Yoshimura et al. (1988). This study aims to clarify the mineral assemblage and chemistry of the active hydrothermal discharge zone using observations by microscopy, XRD, XRF, and EPMA.

## GEOLOGY AND GEOLOGICAL STRUCTURE

The geology of the field has been described by Yoshimura et al. (1988). The underground rocks are dacitic to andestic pyroclastics and lavas (Fig.2). The geological structure is characterized by a small-scale east-west trending graben of Pleistocene age. An intrusive dacite lies almost in the center of this graben. A low-permeability welded tuff which occurs in the lower part of the Yamakawa Formation plays an important role as a cap rock for the geothermal reservoir.

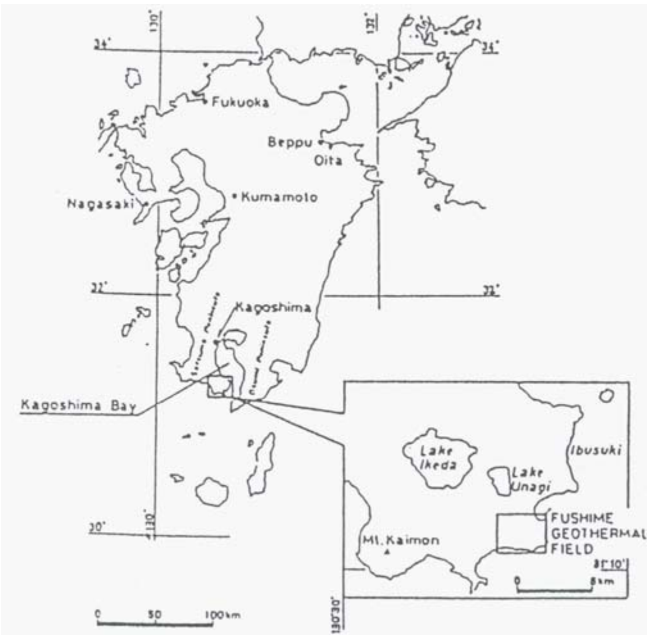


Figure 1: Location of the Fushime geothermal field, Kyushu, Japan.

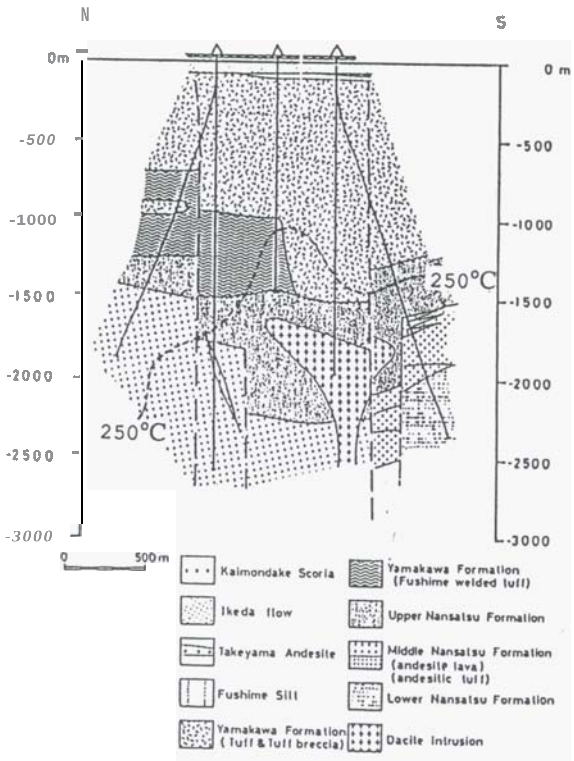


Figure 2: N-S geological cross-sections through the Fushime geothermal field with 250°C isotherm contour (after Yoshimura et al. 1988).

## ALTERATION MINERALOGY

The discharge zone of the Fushime geothermal field is subdivided into three zones according to mineral assemblage: 1) a K-feldspar-quartz assemblage, 2) a sericite-quartz assemblage, 3) an albite-chlorite assemblage (Fig.3).

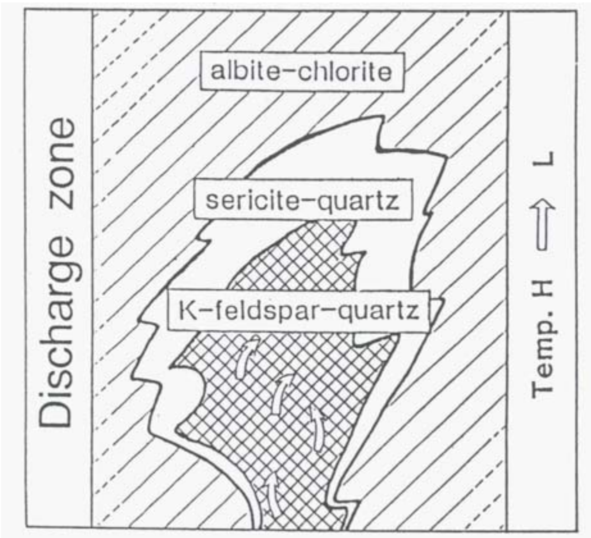


Figure 3: Schematic model of alteration mineral assemblages in a hydrothermal discharge zone, Fushime geothermal field.

The K-feldspar-quartz assemblage zone occurs in the center of the discharge zone at temperature above 220°C. Interstitial or matrix-replacing K-feldspar is present in association with quartz overgrowths. Matrix-replacing albite and epidote in radial or fan shapes usually coexist with K-feldspar. In addition, matrix-replacing sericite, chlorite, and pore-filling anhydrite are common associated minerals in this assemblage. EPMA study shows that this K-feldspar with orthoclase composition is distinguished from primary K-feldspar with anothoclase composition.

The sericite-quartz assemblage zone usually encircles the K-feldspar-quartz assemblage zone. In this assemblage minute crystals of sericite fill a matrix of authigenic quartz. Matrix-replacing wairakite, albite, and chlorite are commonly associated minerals in this assemblage, but K-feldspar is absent.

The albite-chlorite assemblage zone occurs in the most outer part of the hydrothermal discharge zone, Matrix-replacing albite and chlorite coexist with quartz in this assemblage.

## CHEMICAL CHARACTERISTICS OF ALTERED ROCK

Compositions of whole rocks derived from the wells are plotted in Fig.4. The data points are divided into the three mineral assemblages mentioned above. Most of the rocks classified to the K-feldspar-quartz assemblage are plotted in the stable area among K-feldspar, albite and sericite. Composition changes linearly from low potassium of the albite-chlorite assemblage to extremely high potassium of the K-feldspar-quartz assemblage.

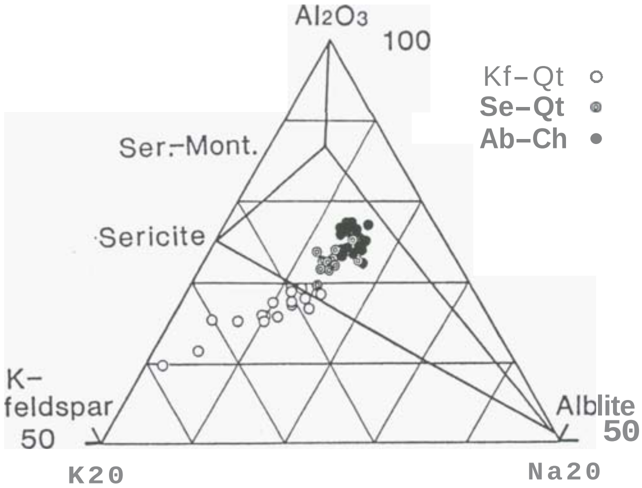


Figure 4: Compositions of whole rocks in $Al_2O_3$(50~100%) - $K_2O$(0~50%) - $Na_2O$(0~50%) triangle diagram. The data points are divided into the three mineral assemblages.

Rubidium and strontium of the same whole rocks are plotted in Fig.5. Rubidium increases significantly in the rocks of the K-feldspar-quartz assemblage, while strontium decreases. The rocks of the K-feldspar-quartz assemblage are notably enriched in potassium and rubidium.

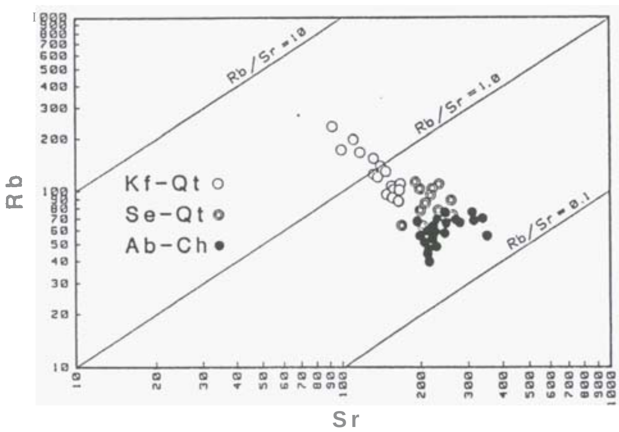


Figure 5: Compositions of whole rocks in logarithmic graph of rubidium and strontium concentrations (ppm). The data points are divided into the three mineral assemblages.

## DISCUSSION

The homogenization temperatures of fluid inclusions in anhydrite coexisting with K-feldspar almost equal the present temperatures of the hydrothermal discharge zones. Furthermore, the $Cl^-$ concentrations estimated from the melting temperatures of these inclusions are the same as those of the present geothermal fluids. These fluid-inclusion observations show that K-feldspar has been precipitating from the present hydrothermal fluid in the reservoir of the Fushime geothermal field.

Authigenic K-feldspar commonly appears in hydrothermal discharge zones with good permeability at Wairakei, Broadlands, Waiotapu in New Zealand, and Cerro Prieto in Mexico (Steiner 1968, Browne and Ellis 1970, Hedenquist and Browne 1989, Hoagland and Elders 1978). The geothermal reservoirs of those fields are acidic volcanic and pyroclastic rocks or sedimentary rocks which have relatively high potassium contents compared to basaltic rocks. However, authigenic K-feldspar does not commonly appear in a basaltic-rock reservoir in Iceland (Kristmannsdottir, 1975). Authigenic K-feldspar is also found continuously in the reservoirs of the Fushime geothermal field. The reservoir rocks in the Fushime geothermal field are acidic volcanic and pyroclastic rocks.

## CONCLUSION

In the Fushime geothermal field, the center of the discharge zone is commonly characterized by precipitation of K-feldspar, and the high concentrations of alkali elements such as potassium and rubidium are attributed to precipitation of K-feldspar.

## ACKNOWLEDGEMENT

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