Quaternary Contact Metamorphism in the Kakkonda Geothermal Field Revealed by Using Deep Hole Drilling Cuttings

*Nizar Muhamad Nurdin[1], Geri Agroli[1], Atsushi Okamoto[1], Masaoki Uno[1], Noriyoshi Tsuchiya[1]

1. Graduate School of Environmental Studies, Tohoku University

The Kakkonda geothermal field locates in the Hachimantai volcanic zone in Northeast Japan and is one of the most extensive liquid-dominated geothermal fields. It has been developed with an installed capacity of 80 MWe by two power generation units. The deep geothermal drilling program (WD-1) reached 3,729 m in 1995, with downhole temperatures exceeding 500˚C. At a depth of 2,860 m, it penetrated the Quaternary Granite rock (Kakkonda Granite), which acts as a heat source. Contact metamorphism due to the granite intrusion was revealed by cutting samples from deep hole drilling. Contact metamorphism occurs adjacent to igneous intrusions, resulting in high temperatures and pressure associated with the igneous intrusion.

The objective of this research is to confirm the isograd of several mineral indexes and calculate the temperature estimation of contact metamorphism. Cutting samples were collected from the WD-1a well in Kakkonda geothermal field from 1,500-3,700 m depth with intervals of 100 m each. Using cuttings of periodical depths enables a better look at the natural temperature profile, even the metamorphism temperature. The X-ray Diffraction (XRD) method determines some minerals index to indicate the degree of metamorphism experienced by rocks. Electron probe microanalyzer (EPMA) was performed on polished thin sections to determine the mineral chemistry of the cutting samples at several depths. The metamorphic minerals such as biotite and chlorite are caused by strong heat conduction from Kakkonda granite identified in the drilling cuttings. Biotite and chlorite are essential minerals in metamorphic rocks over various bulk compositions and metamorphic grades. Titanium-in-Biotite and Aluminum-in-Chlorite geothermometers are used to determine the biotite and chlorite mineral formation temperature. The formula to calculate temperature estimation based on Titanium content of biotite with equation: $T(^\circ C) = \{[\ln(Ti)-2.3594-1.7283(X_{mg})^3]/4.6482 \times 10^{-9}\}^{0.333}$ (Henry, 2005) and Aluminum content of chlorite with equation: $T(^\circ C) = 318.5 \times Al_{IVC} - 68.7$ (Jowett,1991). The estimated result can depict the temperature changes trend with depth.

Several index mineral assemblages were confirmed based on XRD analysis, including biotite, chlorite, albite, and cordierite minerals. The concentration of Titanium in biotite and Aluminum in chlorite has been considered a primary indication of changing temperature conditions in rocks and has been proposed as a potential geothermometer. The temperature estimation based on Ti-in-Biotite calculation, the temperature trend increases with depth from 1,600 meters up to reach a depth of 3,300 meters. Then the temperature is relatively constant in the range of 730˚C until the final depth. This also shows the conduction heat transfer in the contact metamorphosing process. On the other hand, temperature estimation based on Al-in-Chlorite from a depth of 1,500-2,500 meters relative constant range from 240-360˚C, suggesting the convection heat transfer occurred at these depths. Moreover, it shows a good relationship between chlorite temperature calculation and natural well temperature profiles (Ikeuchi, 1995), and it might be applied as a new technique for calculating actual well temperature.

Keywords: Contact metamorphism, Temperature estimation, Kakkonda geothermal field