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Depth estimation and evaluation of geothermal resource by melt inclusion analysis

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Geothermal power generation in Japan has abundant resources. However it requires long periods of time for survey: the amount and distribution of geothermal resource have been estimated by the volumetric method, and by the reservoir layer evaluation method for narrower region. In this study, melt inclusions in volcanic products were utilized for a faster and simple method for evaluation of geothermal resource. As melt inclusions remain the composition of the magma prior to eruption, they provide thermal-chemical conditions of the magma chamber at depth. To evaluate the depth, distribution and amount of geothermal resource, melt inclusions in quartz was analyzed for Shirasawa caldera,Japan.

Shirasawa caldera is located in west of Sendai city and erupted in late Pliocene. Shirasawa layer is composed of mud and sand deposited on the Old Sendai Lake in center of caldera. The high-temperature region (Low-velocity region) in the Shirasawa caldera at 2~5 km has been confirmed by seismic reflection survey. [1]

Eight samples were collected from the center of the caldera to the south, and 4 samples were collected from north end in Shirasawa caldera. These are classified into tuff sandstone, tuff breccia and pumice tuff.

Quartz crystals were picked up from the samples, and the crystals were encased in resin flake. The compositions of melts included in quartz crystals were analyzed by electron micro probe analyzer (EPMA) for 10 elements (Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, P). Three samples from north end of the caldera were not analyzed because the crystals were trace amount and small. The depth of crystallization was estimated from percentage of quartz(Qtz)-albite(Ab)-orthoclase(Or) by CIPW norm calculation (Fig.1). As the eutectic line changes position by pressure and the melt in the quartz crystal is located on the eutectic point of the Ab-Qtz phase diagram, the crystallization pressure was decided from the plot and eutectic line on Qtz-Ab-Or diagram [2].

Eight samples from the center and south part of caldera were classified into low-alkali tholeiitic rhyolite, and 1 sample from caldera north(09) was high- alkali tholeiitic rhyolite. The norm percentage of 44 melt inclusions is Qtz: 30~43%, Ab: 35~52%, Or: 9~26%, and forms a straight line on Qtz-Ab-Or diagram, with the exception of some samples. Crystallization pressure is 0.1~320 MPa, and most of the samples concentrate on 30~50 MPa. Certain samples (2305) were plotted in 5~320MPa. Assuming the density of ryholite magma as 2.0 g/cm^3, the crystallization pressure was estimated to be 16~1.5 km. It is suggested that magma had assent from about 16 km depth, become a gravitational equilibrium at 1.5~2.5 km, and subsequently erupted. In the other samples, crystallization depth is concentrated at 1.5~2.5 km. The depth of magma decided by melt inclusion in quartz is consistent with the high-temperature region observed by seismic reflection. Considering the sample location, Or rich sample considered to be derived from another magma reservoir.

Based on these data, the depth, distribution and amount of geothermal resource associated with the magma chamber will be discussed.

[1] Sato et al. (2002) Earth Planets Space,54,1039-1043.
[2] Blundy and Cashman (2001) Contributions to Mineralogy and Petrology,54,631-650.

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