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Chemical compositions of hydrothermal fluids derive from a shallow emplacement granite body in Tsushima, Japan.

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Fluid inclusions in quartz from miarolitic cavities, quartz veins, and a Pb-Zn ore deposit at the Miocene granite pluton, Tsushima Islands, Japan, were analyzed by particle-induced X-ray emission (PIXE) to examine chemistries and behaviors of hydrothermal fluids in granite body with shallow emplacement level. The Tsushima granite pluton is mainly composed of biotite-granites and numerous mafic microgranular enclaves. Small miarolitic cavities are relatively common in the granite, and quartz veins are rare. An estimated emplacement level of the granite is 2-6 km deep. Quartz in the miarolitic cavities and the quartz veins contains abundant polyphase inclusions with large halite crystal and vapor-rich inclusion, a small amount of liquid-rich two-phase inclusion, and a few low-salinity liquid-rich inclusion and CO2 inclusion. Salinities of the polyphase inclusions were of 28-60 wt % NaCl eq., and the homogenizing temperatures (Th) ranged from 460 to 200 C. Two-phase inclusions of the miarolitic cavities showed almost Th of 400-200 C. Quartz in the ore vein contains abundant two-phase inclusion, and a few polyphase inclusion, vapor-rich inclusion, low-salinity liquid inclusion, and CO2 inclusion. Salinities of the polyphase inclusions were of 28-49 wt % NaCl eq., and the Th ranged from 450 to 250 C.

Element concentrations (average) of polyphase inclusions in the miarolitic cavities, determined by PIXE, were as follows: about 25 wt.% for Cl, 1-5 wt.% for Fe and K, several hundreds to several thousands ppm for Ca, Mn, Ba, Zn, Pb, Br, 200-400 ppm for Cu and Rb, and several tens ppm for Sr and Ge. The compositions are thought to correspond to the original contents of hydrothermal fluid released from the Tsushima granite during solidification. The determined values are several times higher than the values of original hydrothermal fluid estimated from miarolitic quartz from the Miocene Kofu granite (Japan) that has relatively deeper emplacement level (5-8 km deep). The polyphase inclusions of the Tsushima granite were probably formed by decompression boiling of the original hydrothermal fluids during the granite solidification because of the shallow emplacement level. The high contents of transition-metal elements in the polyphase inclusions are also attributable to the element partitioning at the phase separation by boiling. Polyphase inclusions in the quartz veins and the ore vein have compositions similar to those in the miarolitic cavities. Br/Cl ratios (by weight) in the liquid-rich two-phase inclusions are mostly less than 0.0034 of sea values: 0.0014 for the miarolitic cavities, 0.0022 for the quartz veins, and 0.0027 for the ore vein, respectively. On the other hand, the polyphase inclusions have higher values of Br/Cl ratios, and the values are different for each occurrence: 0.0015 to 0.0043 for the miarolitic cavities, 0.0020 to 0.0108 for the quartz veins, and 0.0019 to 0.0124 for the ore vein, respectively.

Keywords: Fluid inclusion, trace element, X-ray analysis, granite, PIXE, ion beam