Quantitative PIXE analysis of trace elements in fluid inclusions from the Tsushima granite pluton, Japan

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Fluid inclusions in quartz from miarolitic cavities at the Miocene granite pluton, Tsushima Islands, southwestern Japan, were analyzed by particle-induced X-ray emission (PIXE) to examine chemistries and behaviors of granite-derived fluids in granite body with shallow emplacement level. The Tsushima granite pluton is mainly composed of biotite-granites and numerous mafic microgranular enclaves. The granite contains abundant miarolitic cavities and rarely quartz veins, and the estimated the emplacement level is 2-6 km deep. Quartz in the miarolitic cavities includes so many polyphase inclusions with large halite crystal. Salinities of the polyphase inclusions were of 28-48 wt % NaCl eq. and the homogenizing temperatures (Th) ranged from 460 to 200 C. Vapor- and liquid-rich two-phase inclusions were also included. Two-phase inclusions of the miarolitic cavities showed almost Th of 400-200 C. Element concentrations (average) of the polyphase inclusions, determined by PIXE, were as follows: 25 wt.% for Cl, 7 wt.% for Fe, 1-5 wt.% for K, Ca and Mn, 7000 ppm for Ba, 1000-3000 ppm for Zn, Pb, Cu, and Br, 100-300 ppm for Rb and Sr. 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 poluphase inclusions in 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. Thus, a shallow emplacement level of granite body is important to formation of granite-derived fluids with high salinity and high metal content.