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Evolution of the trachydacite and pantellerite magmas of the bimodal volcanic association of Dzarta-Khuduk (Central Mongolia): evidence from melt inclusions

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Using various methods of melt inclusion investigation, including electron and ion microprobe techniques, we estimated the composition, evolution, and formation conditions of melts producing the trachydacites and pantellerites of the Late Paleozoic bimodal volcanic association of Dzarta-Khuduk, CentralMongolia.

Dzarta Huduk paleovolcano occupies an area of more than 120 square kilometers. A sequence of felsic agpaitic volcanics rests on subalkali basalts and consists of intercalating alkaline trachydacites, pantellerites, and comendites. Their mineralogical and chemicall characteristics correspond to silicic peralkaline rocks of the K-Na series with an agpaitic index of >1 and high contents of F, Zr, Li, Rb, and REE.

Primary crystalline and melt inclusions were detected in anorthoclase from trachydacites and quartz from pantellerites and pantelleritic tuffs. Among the crystalline inclusions, we identified hedenbergite, fluorapatite, and pyrrhotite in the trachydacites and F-arfvedsonite, fluorite, ilmenite, and the rare REE diorthosilicate chevkinite in the pantellerites. Melt inclusions in anorthoclase from the trachydacites are composed of glass, a gas phase, and daughter minerals (F-arfvedsonite, fluorite, villiaumite, and anorthoclase rim on the inclusion wall). Melt inclusions in quartz from the pantellerites are composed of glass, a gas phase, and a fine-grained salt aggregate consisting of Li, Na, and Ca fluorides (griceite, villiaumite, and fluorite). Melt inclusions in quartz crystalloclasts from the pantelleritic tuffs are composed of homogeneous silicate glasses. The phenocrysts of the trachydacites and pantellerites crystallized at temperatures of 1060–1000°C.

During thermometric experiments with quartz-hosted melt inclusions from the pantellerites, the formation of immiscible silicate and salt (fluoride) melts was observed at a temperature of 800°C. Homogeneous melt inclusions in anorthoclase from the trachydacites have both trachydacite and rhyolite compositions (wt %):68–70 SiO_2, 12–13 Al_2O_3, 0.34–0.74 TiO_2, 5–7 FeO, 0.4–0.9 CaO, and 9–12 Na_2O + K2O. The agpaitic index ranges from 0.92 to 1.24. The glasses of homogenized melt inclusions in quartz from the pantellerites and pantelleritic tuffs have rhyolitic compositions. Compared with the homogeneous glasses trapped in anorthoclase of the trachydacites, quartz-hosted inclusions from the pantellerites show higher SiO_2 (72–78 wt %) and lower Al_2O_3 contents (7.8–10.0 wt %). They also contain 0.14–0.26 wt % TiO_2, 2.5–4.9 wt % FeO, 9 –11 wt % Na_2O + K_2O, and 0.9–0.15 wt % CaO and show an agpaitic index of 1.2–2.05. Homogeneous melt inclusions in quartz from the pantelleritic tuffs contain 69–72 wt % SiO_2. The contents of other major components, including TiO_2, Al_2O_3, FeO, and CaO, are close to those in the homogeneous glasses of quartz-hosted melt inclusions in the pantellerites. The contents of Na_2O + K_2O are 4–10 wt %, and the agpaitic index is 1.0–1.6. The glasses of melt inclusions from each rock group show distinctive volatile compositions. The H_2O content is up to 0.08 wt % in anorthoclase of the trachydacites, 0.4–1.4 wt % in quartz of the pantellerites, and up to 5 wt % in quartz of the pantelleritic tuffs. The content of F in the glasses of melt inclusions in the phenocrysts of the trachydacites is no higher than 0.67 wt %, and up to 1.4–2.8 wt % in quartz from the pantellerites. The Cl content is up to 0.2 wt % in the glasses of melt inclusions in the minerals of the trachydacites and up to 0.5 wt % in the glasses of quartz-hosted melt inclusions from the pantellerites. The investigation of trace elements in the homogenized glasses of melt inclusions in minerals showed that the trachydacites and pantellerites were formed from strongly evolved rare-metal alkaline silicate melts with high contents of Li, Zr, Rb, Y, Hf, Th, U, and REE.

The analysis of the composition of homogeneous melt inclusions in the minerals of the above rocks allowed us to distinguish magmatic processes resulting in the enrichment of these rocks in trace and rare earth elements. The most important processes are the crystallization differentiation and immiscible separation of silicate and fluoride salt melts. It was also shown that all the melts studied evolved in spatially separated magma chambers. This caused the differences in the character of melt evolution between the trachydacites and pantellerites. During the final stages of differentiation, when the magmatic system was saturated with respect to ore elements, Na–Ca fluoride melts were separated and extracted considerable amounts of Li.