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Possible sources for CH4-rich fluid inclusions in olivine from troctolitic rocks of the Bathtub intrusion (Duluth Complex, U.S.A.)

Kurt Krenn (1), Sara Raič (2), and Aberra Mogessie (3)

(1) University of Graz, Institute of Earth Sciences, NAWI Graz Geocenter, Austria (kurt.krenn@uni-graz.at), (2) University of Graz, Institute of Earth Sciences, NAWI Graz Geocenter, Austria (sara.raic.hr@gmail.com), (3) University of Graz, Institute of Earth Sciences, NAWI Graz Geocenter, Austria (aberra.mogessie@uni-graz.at)

Cumulus olivine from the Babbitt deposit in the troctolitic Bathtub intrusion (Duluth Complex) contains abundant CH4-rich fluid inclusions with common hydrous silicate and carbonate precipitates at their inclusion walls. Given the active rifting environment in which the magmas of the Duluth Complex have intruded as repeated pulses, fluid inclusions in olivine are traceable throughout an entire stratigraphic drill core section with comparable textural features that enable a classification of three generations: (1) “primary” CH4-rich fluid inclusions oriented parallel to growth planes of olivine or arranged in clusters; (2) intragranular fluid inclusion planes of CH4-rich fluid inclusions extending towards grain boundaries and (3) transgranular fluid inclusion planes of CH4-rich fluid inclusions, closely associated with serpentinization, a process that happened after the initial growth of olivine. Generations (1) and (2) were modified by necking down as a result of cooling; their similarities in texture and composition suggest that their methane content originated from a homogenous magmatic fluid of CO_2-H_2O composition, which was modified during cooling below 700°C and decreasing fO_2 to a CH4-rich fluid that contains carbonates and hydrous silicates. The formation of late secondary fluid inclusion planes of generation (3) is connected with extensive magma-country rock interaction. Their inclusions indicate reduction of CO_2 to CH4 during serpentinization in an upper stability limit of 620°C. This study emphasizes fluid inclusions as powerful indicators in remodeling chemical changes of the magmatic fluid during crystallization of cumulus phases, magma-country rock interaction and subsequent alteration.