Final research report (K-119535)

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Fulfilled work

Of the planned activities, the following were met on alkaline and carbonatite rock samples C8/A, C8/B, C11, E32/B, Ltop/1, L0/B, L15/A, L14E (basanite, nephelinite, phonolite, magnetite-perovskite ore and ijolite):

- 20 double-polished thin sections
- Microthermometric experiments on ~ 150 melt and fluid inclusions
- 15 heating-quenching experiments in high temperature furnace
- ~ 700 pieces of quenched melt inclusions
- ~ 200 successfully exposed melt inclusion (precision polishing)
- ~ 500 Raman point measurements on the rock-forming minerals and phases in the fluid and melt inclusions
- 10 Raman-maps (melt and fluid inclusions)
- FIB-SEM slice and view analyses on 5 fluid inclusions
- ~ 300 EMPA analyses on the rock-forming minerals and the quenched melt phases (silicate and carbonatite melts)
- ~ 400 SEM-EDS-SDD analyses on the rock-forming minerals and the quenched melt phases (silicate and carbonatite melts)
- ~ 150 LA-ICP-MS analyses on the rock-forming minerals and the fluid inclusions

Results

Due to Berkesi Márta's maternity leave and effects of COVID-19, the original work plan has been modified with the consent of the NKFIH. An important result of this change is that the LA-ICP-MS and EMPA analyzes were performed late and not as planned. Considering the situation and keeping in mind that compliance with the publication commitments is paramount to the success of our project, I have decided to focus on the work of review article. In addition to our published results, there are three papers under review or immediately prior to submission.

The most important results of the project:

- 3 international publications as we undertook
- 3 successfully defended MSc theses
- 2 new and active PhD students (at Eötvös University and University of Szeged) with our co-supervising
- 2 second places in National Scientific Student Conferences (Eger and Szeged)
- Second and third places in Hungarian Young Earth Scientists Conference (Zalakaros)
- 8 oral presentations in international conferences (ECROFI, Goldschmidt)
- 6 oral presentations in National conferences (Kőzettani Vándorgyűlés)
- Organizing and successfully conducting the ECROFI-2019 international conference
- More than 10 abstract papers

Summary

We published our scientific results in Guzmics et al. (2019), Berkesi et al. (2020) and Yaxley et al. (2022), see publication summary of this proposal. The most important points are briefly summarized in the following. From Kerimasi volcano (East African Rift, Tanzania) we presented evidence for the presence of coexisting nephelinite melt, fluorine-rich carbonate melt, and alkali carbonate fluid. The compositions of these phases differ from the composition of Oldoinyo Lengai natrocarbonatites; therefore, it is unlikely that natrocarbonatites formed directly from one of these phases. Instead, mixing of the outgassing alkali carbonate fluid and the fluorine-rich carbonate melt can yield natrocarbonatite compositions at temperatures close to subsolidus temperatures of nephelinite (<630–650 °C). The high halogen content (6–16 wt%) in the carbonate melt precludes saturation of calcite (i.e., formation of calcite carbonatite) and maintains the carbonate melt in the liquid state with 28–41 wt% CaO at temperatures ≥600 °C. Our study suggested that alkali carbonate fluids and melts could have commonly formed in the geological past, but it is unlikely they precipitated calcite that facilitates fossilization. Instead, alkali carbonates likely precipitated that were not preserved in the fossil nephelinite rocks. From Oldoinyo Lengai volcano (East African Rift) results of a detailed melt inclusion study provided insights into the important role of degassing of CO_2-rich vapor in the formation of natrocarbonatite and highly peralkaline nephelinites. Nepheline phenocrysts trapped primary melt inclusions at 750–800 °C, representing an evolved state of the magmas beneath Oldoinyo Lengai. Raman spectroscopy, heating-quenching experiments, low current EDS and EPMA analyses of quenched melt inclusions suggest that at this temperature, a dominantly natrite$_{ss}$-normative, F-rich (7–14 wt%) carbonate melt and an extremely peralkaline (PI = 3.2–7.9), iron-rich nephelinite melt coexisted following degassing of a CO_2 + H_2O-vapor. We furthermore recommended that the degassing led to re-equilibration between the melt and liquid phases that remained and involved 1/ mixing between the residual (after degassing) alkali carbonate liquid and an F-rich carbonate melt and 2/ enrichment of the coexisting nephelinite melt in alkalis. We think that in the geological past similar processes might be responsible for generating highly peralkaline silicate melts in continental rift tectonic settings worldwide. We suggested new definitions for the most important parts of carbonatite systems such as, carbonatite melt, syn-, para- and postmagmatic fluid. We worked out a new classification scheme for carbonatites and drew attention to the potential challenges and difficulties facing carbonate researchers. Considering our results from melt inclusions over the years together with

experimental analogues, it is likely that fossil carbonatite rocks do not representative of the melt from which they formed. The processes of immiscibility and fractional crystallization inferred for the Oldoinyo Lengai and Kerimasi volcanoes of the East African Rift System may be the standard petrological mechanism by which alkali-poor calcite and dolomite carbonatites are produced, also in the geological past. It seems likely that alkali carbonate fluids and melts have been so far overlooked in the geological record because of the lack of previous detailed inclusion studies.

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