

Experimental constraints on oceanic carbonatite formation in alkaline silicate melt systems

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Physical separation of carbonatites from CO₂-bearing alkaline silicate melts may explain their common spatial association in alkaline rock complexes such as the subvolcanic intrusive unit on Brava Island. Previous carbonatite–silicate liquid immiscibility experiments used bulk compositions prepared from carbonate-doped natural silicate whole-rock powders or synthetic oxide + carbonate mixtures located well inside the “forbidden” melt miscibility gap. As a result, the majority of measured carbonatite–silicate melt pairs include silicate compositions too alkali-rich to match the alkaline silicate rock record.

We present new isobaric crystallization and immiscibility experiments at 1250-900 °C, 1 GPa, on chemically complex CO₂-bearing subvolcanic rocks including basanites, nephelinites and nepheline syenites from Brava Island. In our experiments, carbonatites exsolve from silicate melt along an estimated basanitic-nephelinitic liquid line of descent (LLD) between 1100 and 950 °C. Liquid immiscibility is suppressed below 950 °C by the onset of nepheline crystallization that effectively deflects the silicate melt away from the two-liquid field. While evolving through the two-liquid field, silicate melt SiO₂ increases from 46-51 wt.% and (Na₂O+K₂O)/CaO (by weight) increases from 1.2-8.7, which reproduces the observed compositional array of intrusive alkaline silicate rocks from Brava. The conjugated moderately alkaline Ca-carbonatites have 5-9 wt.% SiO₂ and (Na₂O+K₂O)/CaO ratios that increase from 0.2 at 1100 °C to 0.6 at 950 °C.

We also present partition coefficients among truly conjugated carbonatite–silicate melt pairs and their equilibrated crystal phase assemblage including cpx, apatite, titanite and calcite between 1100-975 °C and 1 GPa. Our partitioning data shows that alkaline silicate melts are passively enriched in incompatible trace elements during early olivine + cpx crystallization. However, when silicate melts pass through the two-liquid field they progressively become depleted in alkalis, alkaline earths and REE due to multiple carbonatite liquid immiscibility events.