Immiscible Iron- and Silica-Rich Liquids in the Upper Zone of the Bushveld Complex

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The formation of immiscible silicate liquids in the Upper Zone of the Bushveld Complex (South Africa) has been debated and controversially interpreted to have either not occurred or produced large-scale separation of iron- and silica-rich melts at the hundreds-meter scale. The debate is on-going but no consensus has been reached.

Samples from the Bierkraal drill cores 1 and 3 cover the entire Upper Zone of the western limb in the Bushveld Complex. Apatite appears rhythmically over the 2-km-thick cumulate sequence in gabbros and nelsonites. This mineral commonly contains various types of inclusions, with polycrystalline assemblages containing daughter phases (plagioclase, pyroxenes, amphiboles). Such inclusions are commonly interpreted to represent crystallized equilibrium melt trapped during the growth of apatite. They have thus the potential to record the composition of stable melts and therefore the immiscibility process. In this study we selected two Fe-Ti-oxide-bearing gabbros and performed re-homogenization experiments of the inclusions. Apatite grains were separated with SELFRAG and heated at 1 kbar using an internally heated pressure vessel. Analyses of major elements were performed with an electron probe microanalyzer.

Re-homogenized quenched melts cover a wide range of compositions with two presumable end-members that are iron-rich (35 wt % FeO; 28 wt % SiO_2) and silica-rich (5 wt % FeO; 65 wt % SiO_2). The compositional range of melt inclusions is typical for immiscible products in ferrobasalts and support unmixing of iron- and silica-rich liquids during the crystallization of the Upper Zone of the Bushveld complex. Immiscible melts in a single sample display a range of compositions suggesting that paired unmixed products were trapped in apatite at different temperatures along the binodal surface during cooling. The two-liquid field is reached shortly after silica-enrichment caused by magnetite crystallization. Our results indicate that the immiscible process occurred most likely at the scale of layers, potentially producing nelsonite horizons.