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Trace element profiles through the Bushveld UG2 chromitite: alkali mobility and post-cumulus reworking in a redox potential gradient

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We have studied vertical variations in mineral and bulk composition in drillcore profiles through the UG2 chromitite at two separate locations in the western Bushveld. The profiles include footwall and hanging wall pyroxenites. Compositions of chromite, cumulus and intercumulus pyroxene and plagioclase were analysed by electron microprobe, and bulk composition was obtained by application of synchrotron-based XRF microscans of the core sections with a 1 mm x 20 mm window. We collected data through the entire profile with a 1 cm step-size.

We find large and abrupt changes in chromite composition at the contacts between chromitite layers and silicate cumulates, and the same is true for intercumulus plagioclase. Chromite in chromitite layers has constant, high $Mg/(Mg+Fe^{2+})$ and Fe^{2+}/Fe^{3+} ratios, whereas these ratios are highly variable and also lower in disseminated chromite from the silicate layers. Plagioclase intercumulus grains in chromitite are enriched in REE compared with plagioclase from outside, as expected for intercumulus liquid fractionation, but strongly depleted in Li, K and Rb. This decoupling of alkalis from equally incompatible REE elements is a feature in all cores examined and it cannot be explained by equilibration with intercumulus liquid. Furthermore, orthopyroxene shows the same sense of variation in alkalis as plagioclase. Ongoing studies of their chromitite layers in the critical zone (MG, LG) suggest that this is not limited to UG2.

To explain these features, Veksler et al. [1] proposed a new model of post-cumulus processes in the crystal-liquid mush which can produce selective migration of alkalis and also intensify modal layering to produce the sharply-bounded, nearly monomineral layers of chromitites, pyroxenites and anorthosites that are observed. The crucial process in this model is a redox potential gradient between chromitite cumulates and the adjacent silicate layers due to peritectic reactions of crystals and intercumulus melt in the chromitite mush. The intercumulus melts are ionic electrolytes with Na^+ as the main charge carrier and therefore, the redox gradient induces electrochemical migration of Na^+ and other alkali ions, i.e., a selective mobility of alkalis. From the observed variations in ferric/ferrous iron ratios in chromite from within and outside chromitite layers and from the Fe distribution in plagioclase, we estimated a redox gradient on the order of 0.9 log units fO_2 per metre, which equates to 60 mV/m. Rough material transport rate estimates suggest that this gradient may be sufficient to mobilize about one-third of the Na contained in a metre-thick mush layer within 10 years. Addition of Na from the chromitite intercumulus melt into surrounding silicate layers is expected to cause some re-melting and recrystallization of the latter, which enhances the development of sharply-divided monomineral layers.

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References:

[1] Veksler IV et al (2015) J Petrology 56: 1229-1250.

