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A Chill Sequence to the Bushveld Complex – Insight into the First Stages of Emplacement and the Parental Magmas to the World's Largest Layered Intrusion

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Evidence of the initial stages of magma emplacement in large mafic chambers is commonly lacking because of resorption of early-formed chills and complicated by the fact that the first magmas that entered the chamber were usually more evolved than the true parental magma. Deep drilling has revealed a rare occurrence of a chill sequence from the eastern Bushveld Complex at the base of a previously unrecognized thick succession of ultramafic rocks that forms part of the Lower Zone. The chill sequence (1.8 m thick) includes a true chill against quartzite floor rock, crystalline quench textured and orthopyroxene spinifex textured rocks. Importantly the chill composition represents a relatively evolved magma formed by the separation of high-Mg olivines prior to its emplacement, probably in a conduit or a pre-chamber. An overlying pyroxene dunite represents the extract that gave rise to the chill and was emplaced either as a crystal slurry derived from the feeder conduit or as the crystallization product from a slightly later influx of primitive magma of komatiitic composition. This highly-Mg rich pyroxene dunite most likely acted as a barrier to the thermal erosion of the chill sequence as the chamber filled.

The olivine in the pyroxene dunite layer is the most primitive yet recorded for the Bushveld Complex at Mg# 0.915, and the cores of associated orthopyroxene are Mg# 0.93. Compositions of the orthopyroxene in the quench and spinifex textured units range from Mg# 0.91 to 0.72 and preserve cores close to the original liquidus as well as tracking the complete in-situ solidification process. Olivine contains abundant dendritic exsolution structures of Cr-spinel and Al-rich clinopyroxene indicating that they formed at high temperature from incorporation of Ca, Al and Cr into olivine, with little time to equilibrate before emplacement. Chromite in the section is the most primitive yet recorded for the Bushveld Complex.

The komatiite magma that was initially emplaced into the Bushveld chamber contained 19-20% MgO but trace element analysis indicates that it was derived from melting of a more primitive komatiite source which digested about 40% of typical Kaapvaal basement to give the strong crustal signature represented by trace elements and Sr isotopes. The evolved B1 magma, which compositionally is only broadly constrained, is regarded as the parental magma to the Lower and Critical Zones, but this is shown to represent a number of different magmas also derived from a komatiitic source with relatively high degrees of crustal contamination.

The komatiite source to the Bushveld magmas could have been derived from subducted Archean ocean crust such as the silica- rich but highly depleted Commondale-type komatiites, as well as Barberton-type komatiites and komatiitic basalts. A mantle peridotite source is not considered a suitable bulk source because the Ni content in the Bushveld olivines (up to 4000 ppm) is indicative of a pyroxenite source in the mantle.