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High resolution U-Pb CA-ID-TIMS dating documents out of sequence emplacement of layering in the Upper Critical Zone of the Rustenburg Layered Suite, Bushveld Complex, South Africa

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The Rustenburg Layered Suite (RLS) of the Bushveld Igneous Complex is the world's largest mafic-ultramafic layered intrusion and provides the archetypical example of stratiform accumulations of Pt and Cr ores. In the Critical Zone of the RLS the ores are hosted by characteristic sequences of layering consisting, in an idealized Unit, of basal chromitite overlain by pyroxenite and then by norite. The norite layer is not always present. Some such units occur stacked directly on top of each other, whereas in other cases a sharp upper contact above the pyroxenite or norite is followed by anorthosite, and the sharp basal contact of chromite sits on chromite-bearing anorthosite. The anorthosites grade upward above the Units and downward below the Units into massive to weakly layered norite or gabbronorite.

High precision U-Pb CA-ID-TIMS[1] dates were obtained on drill core samples of gabbronorite from the Main Zone and of pyroxenites from the Units containing the Merensky Reef Pt deposit, and the UG1, MG4 and MG2 chromitites. The age of the Main Zone gabbronorite is 2055.86±0.15 Ma, 0.32 Ma older than the 2055.54±0.27 Ma age of the underlying Merensky Reef. The age of the UG1 pyroxenite is 2056.28±0.15 Ma, which is 0.24 Ma older than the underlying MG4 pyroxenite (2056.04±0.15 Ma) which in turn is 0.60 Ma older than the MG2 pyroxenite below that (2055.6±0.20 Ma). The chromitite-pyroxenite Units were therefore emplaced under pre-existing norite or gabbronorite in at least three separate instances in the Upper Critical Zone.

We account for the out-of-sequence emplacement of the Merensky Reef, MG4 and MG2 Units by suggesting that they and probably all of the other chromitite-pyroxenite Units in the Critical Zone were emplaced as sills into slightly older mafic rocks now preserved as the massive to weakly layered norite and gabbronorite of the Upper Critical and Main Zones. The ubiquitous development of anorthosite along both upper and lower contacts of the ultramafic Units resulted from partial melting of the enclosing norites[2], a process that generated liquids locally preserved as mafic pegmatites and left behind plagioclase or plagioclase-chromite restites that solidified as anorthosite.

The remarkably parallel disposition of the ultramafic sills containing the chromitite-pyroxenite layers can be accounted for by a simple first order thermoelastic model of the stress field generated around a cooling sill in an infinite medium. The plane stress produced by thermal expansion under an infinite hot sheet induces a stress field with vertical minimum compressive stress, guiding subsequent intrusions to assume the form of sills that propagate exactly parallel to the previous, overlying sills.

References:

[1] Mattinson J.M. (2005) Chem. Geol. 220, 47-66.
[2] Naslund H.R. (1986) Contrib. Mineral. Petrol. 93, 359-367.