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Analysis of pre-impact and impact-induced geological structures in the northern collar of the Vredefort Dome, South Africa

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ABSTRACT

Rocks of the Neoarchaean Witwatersrand Supergroup exposed in the collar of the impact-induced 2.02 Ga Vredefort Dome exhibit complex geological structures. These structures are generally considered to have been formed by the Vredefort impact event, through rapid deformations on time scales of seconds to minutes associated with the relatively brief impact processes. However, geological mapping of the structures and petrographic analysis from the northern collar of the dome show that the collar hosts at least three generations of pre-impact structures. In contrast to impact-induced structures, these pre-impact structures indicate slow and progressive deformations that are uncharacteristic of impacts.

The pre-impact deformations comprise: (a) an extensional D1 deformation characterised by listric faults up to kilometre-scale; (b) Syn-metamorphic ($M_{2(NC)}$) D2 ductile deformation characterised by regional S_2 foliation, which locally indicates northwest-directed vergence; and (c) D3 deformation that crenulated the pre-existing S_2 foliation (S_3). Pre-impact structures can be distinguished from impact-induced structures by: (1) difference in the geometry and sense of slip between D1 faults and D4 impact-induced faults; and (2) crosscutting relationships between impact-induced D4 features and D2 and D3 pre-impact features.

In their present (rotated) orientation, the D1 faults exhibit an apparent strike-slip separation, which translates to normal-slip fault geometries when impact-induced overturning of strata is undone. Displacement affects the Witwatersrand and Ventersdorp Supergroup rocks but no offset is observed of the base of the Transvaal Supergroup. The faults also exhibit a listric geometry, curving into parallelism with bedding in the lower West Rand Group. In their restored orientation, faults define half-graben and horst blocks, synthetic and antithetic faults, and rollover and drag folds, which are typical for extensional tectonics. These geometries and crosscutting relationships of the D1 faults are similar to that of the Neoarchaean listric faults described in the Witwatersrand goldfields and the wider Kaapvaal craton, that exhibit a general west-side-down sense of slip (2.70-2.64 Ga Hlukana-Platberg extensional event).

Metamorphic grade in the study area decreases from amphibolite- to greenschist-facies away from the centre of the dome. These are largely $M_{2(NC)}$ metamorphic assemblages that are attributed to elevated regional heat flow related to 2.06 Ga Bushveld magmatism. There is some evidence that $M_{2(NC)}$ metamorphic mineral assemblages developed along the same stratigraphic units differ across the large D1 faults, indicating the pre-impact nature of the D1 faults and implying that the $M_{2(NC)}$ metamorphism occurred after the Hlukana-Platberg event. Also, $M_{2(NC)}$ assemblages are syn-tectonic to the S_2 foliation hosted in metapelite units of the West Rand Group and knotted quartzite horizons of the Central Rand Group. The S_2 foliation is attributed to the post-Transvaal Supergroup, compressional, Ukubambana Event. Crosscutting relationships in the study area indicate a

deformational period of 2.06 Ga to no less than 2.02 Ga. The northwest-directed vergence exhibited by the S_2 foliation is broadly consistent with the regional, general north-directed, vergence exhibited by post-Transvaal Supergroup foliation developed in the northeastern collar and the Johannesburg Dome. The S_2 foliation and $M_{2(NC)}$ mineral assemblages are crosscut by D4 pseudotachylitic breccia, micro-faults and kinks, and $M_{4(NC)}$ metamorphic features associated with the impact.