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Shock petrography of the target rocks and impactites from the M4 Drillcore, Morokweng Impact Structure, South Africa

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The final rim diameter and morphology of the 145 ± 2 Ma Morokweng impact structure (MIS) in northwestern South Africa has long been an issue of debate, with estimates ranging from 340 km [1] or ~240 km [2] based on geophysical interpretations and borehole data, to 75-80 km [3,4]. This latter value was based on an intersection by rotary (to a depth of 600 m) and diamond drilling of structurally undisturbed pre-impact strata (with a single suspected suevite vein) 35 km SW of the centre of the magnetic anomaly [4]. With most of the structure buried beneath 100-150 m of <70 Ma Kalahari Group sediments and calcrete, most of the available evidence of impactites is provided from drillcores into the central magnetic anomaly and chip samples from water boreholes over a wider area [2]. The central drillcores intersected mostly differentiated granophyric impact-melt rock, which reaches a thickness of 800 m in the M3 core. Although granite was intersected at a depth of ~240 m in the WF05 core [4], it is not clear if this represents the crater floor beneath the melt sheet or a clast-rich zone within it [5]. A single central drillcore, M4, located 18 km NNW of the centre of the central magnetic anomaly contains no melt sheet; instead, it intersects megabrecciated Archaean granitoids and meta-dolerite that are cut by abundant cataclasite, suevite and melt-matrix breccia veins and dykes. Investigation of microscopic shock effects in target and impactite lithologies intersected in the 368-m-deep core reveals planar fractures, feather features, decorated planar deformation features (PDF), mosaic extinction and toasting in quartz; reduced birefringence and patchy (mosaic) extinction, and oblique and chevron-style spindle-shaped lamellae in plagioclase and microcline, as well as kink bands in biotite and planar fractures in titanite. Universal Stage measurements of PDF sets in quartz from 13 representative samples (7 target rocks; 6 impactites) reveal five dominant sets: 0° - c (0001), 66°- s $\{11\bar{2}1\}$, 74°- $\{21\bar{3}1\}$, 77° - $\{22\bar{4}1\}$; 82° - $\{51\bar{6}1\}$, with no significant decrease in shock intensity with depth nor differences in PDF type or intensity between melt-matrix breccias, suevites and target rocks. Melt clasts and the melt-matrix breccias reveal incomplete mixing of feldspathic and mafic mineral constituents; however all glasses are highly altered to smectite and/or zeolite. Based on these observations the average peak shock pressures are estimated to vary from ~10 GPa to ≥22 GPa on a sample by sample basis. The elevated shock pressure estimates favour the M4 sequence having been originally located close to the transient crater floor; however, the lack of vertical variation in shock pressure effects suggests that the level corresponding to the original modified transient crater floor was eroded prior to deposition of the overlying Kalahari sediments. The M4 sequence is, thus, interpreted as part of the eroded megabrecciated peak ring of the MIS. In comparison with large impact structures, a peak-ring radius of 18-20 km would correspond to an original crater diameter of 70-100 km. Regional erosion after 145 Ma is, however, likely to have considerably reduced the diameter over which unequivocally impact-generated effects might still be found.

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