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Systematic characterisation of target and impactite lithologies in the M4 drillcore, Morokweng impact structure, South Africa

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The 145 ± 2 Ma Morokweng impact structure (MIS) in northwestern South Africa is largely buried under <70 Ma Kalahari Group sand and calcrete [1, 2]. The subsurface geology of the MIS is known largely from drillcores recovered from the ~30 km wide central magnetic anomaly (CMA), of which 3 have intersected several hundred metres of impact-melt rock; and from percussion holes drilled for groundwater in the wider region [1, 2, 3, 5, and 6]. The 368-m-long M4 drillcore was drilled on a prominent magnetic "high" close to the margin of the CMA, 18 km NNW from the inferred centre of the CMA and only 6 km from the M3 drillcore which intersected the thickest (~800 m) impact-melt rock intersection. M4 is anomalous among the central drillcores in that it comprises crystalline Archaean TTG gneisses (granodiorite, tonalite, granite and diorite) and meta-dolerites of unknown age, with subsidiary suevites and melt-matrix breccias that constitute up to 20% of the core. Individual breccia thicknesses range from 1 mm up to 3 m. The core contains abundant evidence of both pre- and syn-impact fracturing and cataclasis, with pre-impact quartz and post-impact calcite veining. Preferential injection of suevite and melt-matrix breccia along cataclasites is suggestive of a crater floor environment ("injection suevite"), rather than a crater fill fallback megabreccia [4]. Geochemical and petrographic analysis reveals a diverse lithic clast population in the suevites, with granitoid-derived lithic and mineral clasts dominating. Melt particles are pervasively hydrothermally altered to a secondary mineral assemblage of zeolites and smectites, attributed to impact-induced hydrothermal fluid circulation in the MIS [7]. Petrographic, geochemical and petrophysical evidence support the local derivation of the impactites and melt particles from target rocks found in the M4 core, with little evidence for exotic components or rocks of high magnetic susceptibility. The melt-matrix breccias are also compositionally distinct from the granophyric impact-melt sheet. Shock petrography suggests a relatively consistent peak shock pressure of ≥22 GPa throughout the core. From these features we conclude that the M4 drillcore intersects a megabreccia section of the inner peak ring subcrater basement of an originally 70-100 km wide impact structure. Observations of a lack of overlying crater fill in any of the central drillcores suggest at least 1-1.5 km of post-impact erosion of the MIS prior to deposition of the Kalahari Group. Whilst post-impact faulting cannot be ruled out to explain the marked lithological differences between, particularly, the M4 and M3 cores, these relationships are consistent with evidence from the Popigai [8] and Manicouagan [9] structures, which are of similar diameter to the MIS. It may be that a highly irregular crater floor is characteristic of impact craters in the 100 km diameter range.

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