PETROGRAPHIC OBSERVATIONS OF SHOCK DEFORMATION BETWEEN ~18 AND 20 KM RADIUS IN THE MOROKWENG IMPACT STRUCTURE, SOUTH AFRICA.

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Introduction: The Morokweng impact structure situated in the North West Province of South Africa was formed at ~145±2 Ma, i.e. close to the Jurassic-Cretaceous boundary, by an impact of LL-6 chondrite [1-5]. The target rocks are mostly Archaean granitoids with scattered occurrences of Archaean meta-volcanics (ca. 3.0 to 2.9 Ga) and some Proterozoic metasediments (carbonates and banded iron formation) of the overlying Transvaal and/or Griqualand West Supergroups [6].

The structure is mostly buried beneath <70 Ma Kalahari Group continental sedimentary rocks and calcrete; consequently, debate remains about its actual diameter [6]. Estimates based on geophysical interpretations range from ~340 km [7] to ~70 km [8, 9], and more geophysical and borehole-based studies are, thus, needed to evaluate the details of the original impact crater. Previously-studied boreholes MWF03, -04 and -05 intersect impact-melt rocks within the central ~6 km radius of the structure (Fig. 1), with only MWF05 intersecting underlying suspected basement at a depth of ~225 m [6, 9]. Another borehole, M3, situated ~6 km SE of M4, intersected 870 m of impact melt-rock below an eroded upper contact [5]. As a contribution to our on-going investigation of this enigmatic structure, we present in this study our preliminary lithologic and petrographic observations from two additional boreholes - M1 and M4 - drilled respectively near the SW and NW edges of the central geophysical anomaly (interpreted as the melt sheet [8, 9]). Plans exist to study additional boreholes, including certain De Beers boreholes (DB) drilled at a distance of ~33 km NNE of centre (Fig. 1).

Borehole M1. This borehole was drilled ~20 km SW of the center of the structure (Fig. 1) to a depth of ~150 m. It intersected Kalahari Group sediments to a depth of ~124 m. Near the base of the Kalahari Group, between ~107.8 and 117.4 m, the core intersected calcretized conglomerate containing sub-rounded pebbles of basement granite and Proterozoic supracrustal cover rocks [10]. The lower part of the core comprises mainly granite gneiss, with brittle deformation features between ~143.7 and 144.8 m.

Petrography: Under the microscope, the conglomerate (~115 m depth) overlying the basement contains subrounded to angular grains of quartz and feldspar in a carbonate matrix containing patches of opaque oxides. The quartz grains show two sets of PDFs along with undulose extinction. Locally, individual subangular polycrystalline quartz grains contain both shocked and unshocked quartz (Fig. 2a). Conglomerate from a deeper horizon (~121 m) additionally contains subrounded fragments of basement granitoid that contain quartz showing PDFs and extreme granulation along irregular planes.

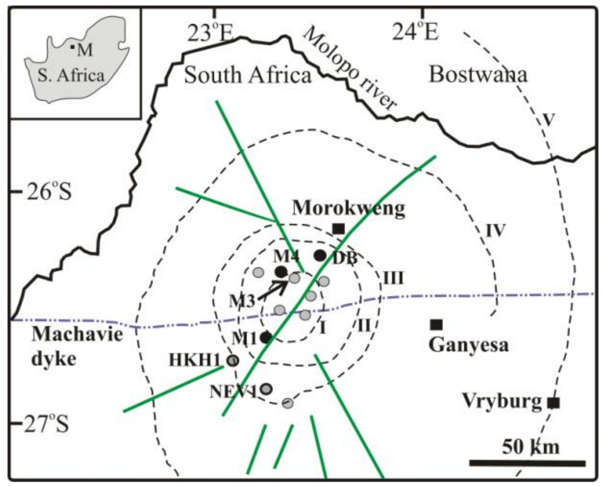

Fig. 1. Sketch map of the Morokweng impact structure based on geophysical interpretation [10, 11]. Major structural features include: concentric ring-like structures (I to V), faults (solid lines) and a major E-W dyke (dot-dash line) . Black circles (M1 and M4) are boreholes studied in the present work. Grey circles are other boreholes not considered in this study.

The basement below the Kalahari unconformity, down to the depth of ~141 m, consists of biotite granitoid gneiss in which quartz grains show both PFs and one or two sets of PDFs (Fig. 2b). One or more sets of kink bands were noted in biotite grains, which are generally chloritized and rimmed by secondary opaque grains. Subhedral apatite grains, associated with biotite, display one set of fractures. Between ~142 and 144 m the granitoid gneiss is extremely brecciated, with quartz in the clasts decorated by PDFs. Below this zone, to the bottom of the hole, the biotite granitoid gneiss shows only minor brecciation and some shock deformation features (mostly PDFs in quartz).

Borehole M4. Located ~18 km NW of the center of the impact structure (Fig. 1), this borehole was drilled to a depth of 370 m. The core intersects a mixed association of target rocks (predominantly trondhjemitic to granitoid gneisses, with granite, amphibolite and banded ironstone and magnetite-rich gabbros) interspersed with polymict suevite and a fine-grained mafic rock of, as yet, unknown origin. The cumulative thickness of suevite is slightly more than 20 m, with individual occurrences up to 3 m thick but with most dikes a few centimeters to decimeters thick. The suevite dikes decrease in abundance and width with depth, being completely absent below ~350 m. The suevites range in color from gray to reddish brown and have a diverse lithic and mineral clast population that is dominated by granitoid target rocks. Both lithic and melt clasts range from <1 mm to several centimeters in size, and from angular to subrounded and highly elongate shapes. Locally, suevite grades into melt-matrix breccia.

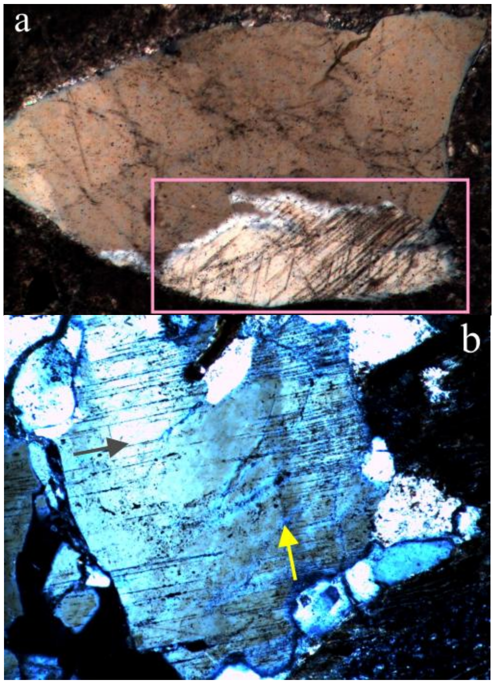

Fig. 2. Shock deformation in the M1 borehole. (a) Subangular polycrystalline quartz grain in Kalahari Group conglomerate showing well-developed PDFs (in box) (b) Quartz grain in granitoid gneiss shows prominent one set of PDF (grey arrow) and a kink lamella (yellow arrow) (magnifications 100x).

Petrography. Shock metamorphic features in both the country rocks and impactites include two to three (rarely four) sets of decorated PDFs in quartz grains, PDFs and ladder structure in plagioclase, diaplectic glass and mosaic texture in quartz and feldspar. The impactites are cut by calcite veins and extensive evidence exists both for post-impact devitrification of glass and oxidation of both the impactites and country rocks.

Discussion: Preliminary findings of the M1 and M4 borehole studies reveal further details of the nature of the Morokweng impact crater beneath the Kalahari Group cover. The results confirm that the original crater must have undergone significant erosion prior to Kalahari Group sedimentation. This erosion may go some way to explaining the uncertainty regarding the size of the original crater. The presence of subrounded pebbles displaying shock deformation in conglomerate in the M1 borehole indicates some level of aqueous transport from their source and may ultimately assist in constraining the diameter of the structure. Well-rounded pebbles of melt-sheet rock and highly shocked granite have also been observed at the Kalahari Group unconformity in MWF05 [10] (M. Andreoli, unpublished data).

Although the M1 core contains only a limited basement intersection, the results from both the M1 and M4 cores confirm the internal complexity of the Morokweng structure. The M4 hole lies only 6 km from the M3 hole in which 870 m of impact melt was recovered. M4 may, thus, lie close to the inner edge of an uplifted peak-ring moat that confined the main part of the Morokweng impact melt; however, at this stage the possibility cannot be ruled out that the core intersected a large allochthonous block within a more voluminous impact melt sheet similar to those intersected at the base of MWF05 [13]. If it is a slump block, however, it must have derived from the central uplift region of the crater owing to the evidence of significant shock pressures seen in its rocks. As suevite in the Morokweng structure was previously known from only a single, cm-scale, vein in HKH1 [6, 9], the M4 core provides a valuable addition to the suite of impactites created by the Morokweng impact.

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