THE MOROKWENG IMPACT CRATER, SOUTH AFRICA: A COMPLEX, MULTIRING STRUCTURE WITH A ~130 KM RADIUS EXTERNAL RING AND ASYMMETRIC RADIAL SECTORS.

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Introduction: The ~144 Ma Morokweng impact crater, largely buried beneath shallow Late Cretaceous to Cenozoic Kalahari sediments (Fig. 1-A, [1, 2]), comprises a ~30 km wide and ≥ 870 m deep, magnetically anomalous melt sheet surrounded by a magnetically quiet aureole (D ~ 70 km [1, 3, 4, 5]). The melt sheet is vertically differentiated and contains pristine to partly recrystallized LL-chondrite clasts and disseminated, siderophile-elements rich sulphides in a variety of settings [2, 4, 5, 6]. However, the one aspect that requires clarification is the final rim size, as previous estimates range from ~70 km [7, 8] to ~240 km [3] even up to ~ 320 km [1, 9, 10]. In this abstract we reassess this issue, and provide a new insight for the apparently poor circular symmetry of the crater.

Methods: Due to the virtual absence of outcrops in the core of the crater, its size and structure were assessed by carefully integrating petrographic observations of the available boreholes (Fig. 1a), with images of the national gravity (Fig. 1b) and airborne magnetic fields. We also reinterpret a mosaic of geological maps published by the South African Council for Geoscience.

Results: The careful analysis of the above data sets shows that the Morokweng crater comprises both concentric rings, arcs and radial features (faults, dykes; Figs. 1a, 1b) that cover a significant part of the northwestern sector of the Kaapvaal Craton. A description of these features is presented as follows:

Ring structures. All boreholes drilled within a radius of ~14 km from the centre (Ring I, Fig. 1a; Ring A, Fig. 1b) intersect impact melt rocks, whereas only three boreholes within a radius of ~33 km (Ring II, Fig. 1a; Ring B, Fig 1b) intersect melt rock, shocked breccia and/or suevite [2]). Borehole logs, satellite imagery, surface samples and data from a Vibroseis seismic profile provide evidence that Ring III (radius ~40 km) marks the outer limit of shock metamorphism, major structural disruption and brecciation of the cover rocks. Polymict, suevitic impact breccia and brecciated dolomite were recorded in boreholes HKH-1 and NEV-1 respectively (Fig. 1a, [11]). The ~ 70 km radius Ring IV (Ring C, Fig. 1b) is defined in the SE quadrant of the structure by the arc-shaped contact between Archaean granite and its supracrustal Cover. The extension of this arc in the other quadrants coincides with a high concentration of water boreholes [11], suggesting that Ring IV marks, at least in places, an impact-related fault/breccia zone. Indeed, a Vibroseis seismic profile [12] reveals a post–Permian fault where it intersects Ring IV. PDFs-bearing quartz is largely absent within this ring, having been reported only near Heuningvlei, close to Ring III [9]. Finally, the incomplete

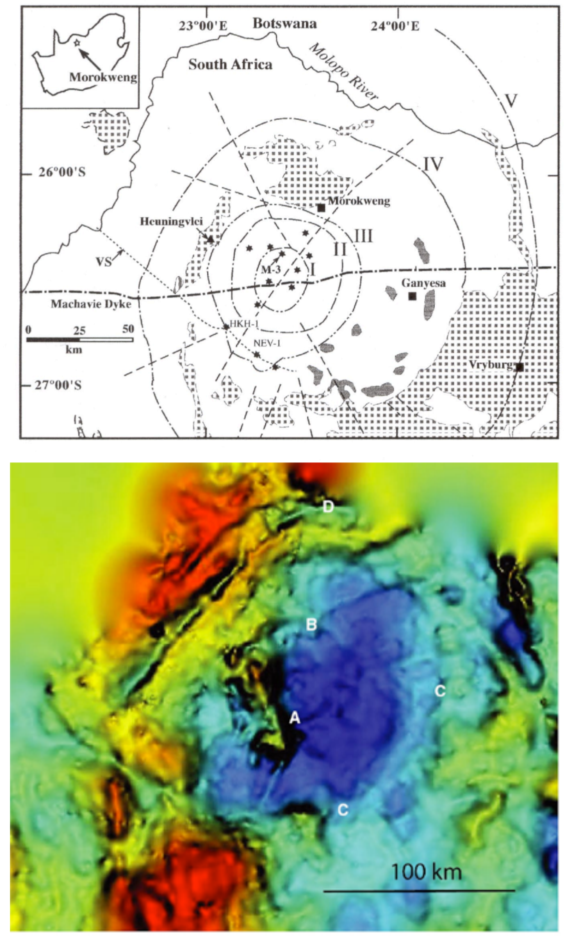

Figure 1. The Morokweng impact crater: a [top]) Generalized geology modified after [5] showing the major structural features - Rings I to V. Archaean granite (dark stippled); supracrustal rocks (light stippled); Kalahari Cenozoic Cover (blank); observed and interpreted faults (broken lines); location of boreholes (stars). VS is the trace of Vibroseis seismic profile [12]; b [bottom]) Edge-enhanced image of the Bouguer gravity of the Morokweng area (gravity data supplied by the Council for Geoscience).

Ring V (R ~ 130 km) is mapped out in the airborne magnetic images [3, 11] and is caused by outcrops of highly magnetic BIFs in the Late Archaean Kraaipan Group.

Radial features. A close examination of Fig. 1a reveals the presence of several radial faults that dissect the Morokweng structure into at least 4 distinct sectors exposing different stratigraphic levels. The Eastern, or Ganyesa Sector is the more deeply eroded as it exposes a large, ~ 100^o arc of poorly exposed granite known as the Ganyesa dome [2]. The overlying early Palaeoproterozoic strata (mainly quartzite and dolomite) dip gently in a southeasterly direction towards a broad synform. The synform runs through the town of Vryburg (Fig. 1a) and is broadly concentric to the Morokweng structure (radius ~130 km). The Western, or Heuningvlei Sector consists of younger Palaeoproterozoic BIFs and is the most asymmetric when compared to the Ganyesa Sector. The Northern, or Morokweng Sector and the Southern Sector represent intermediate levels of erosion (Fig. 1a). The most important radial fault extends in a SSE direction up to a distance of ~200 km from the center of the structure and is accompanied by a ~100 km long dolerite dyke (Fig. 1a).

Discussion: Until recently, little consideration has been given to the formal definition of terms such as crater diameter and multiring structure [13]. In the case of the Morokweng crater, the problem of attributing accurate morphometric values is more complex because of the thick Kalahari cover.

Transient crater. No firm evidence for this feature has been found. However, it appears that cover rocks (Palaeoproterozoic quartzite, dolomite and BIFs) have ben obliterated over a radius of at least 66 km (Ring II). This is a minimum value for the transient cavity, if allowance is made for erosion in the past ~144 Ma.

C*entral Uplift.* In typical meteorite impact craters this feature approximately coincides with the ~10 GPa isobar that marks the incipient development of shock metamorphism and PDFs in many rock-forming minerals [14]. In the case of Morokweng, the radial distance from the centre of PDFs/shocked carbonate occurrences is ~40 km (Fig. 1a). These findings point to a central uplift diameter of 80 km. This inference is consistent with the occurrence in borehole HKH-1 of a polymict, suevite breccia dyke, a rock only found at the margin of central uplifts [15].

Final rim. Various formulas have been proposed to calculate the diameter of the crater rim from the size of the central uplift. Using the formula proposed by [16], the crater rim diameter could be as large as ~190±10 km, a value close to that of Ring IV in Fig. 1a, and D in Fig. 1b.

External ring. Given the ~190 km diameter for the final rim, Ring V (Fig. 1a) is assumed to represent the external ring of a multiring structure [13] having a diameter of ~260 km.

Conclusions. The Morokweng impact crater stands out in all available geophysical and geological datasets of South Africa as a remarkable set of concentric rings with diameters ranging from ~30 km to ~260 km. Shock deformation features mark the extent of a large central uplift with a diameter of ~ 80 km, and a crater final rim of ~190±10 km. In spite of the uncertainties, these morphometric parameters rank Morokweng among the largest terrestrial craters [13]. Our interpretation is consistent with the exceptional thickness of the Morokweng melt sheet, and the discovery that the latter rests on mafic pyroxene gneisses [5] probably representing uplifted middle crust.

In addition, the disarmonic response of the crust to the impact, resulting in an asymmetric crown of 4 main radial sectors is highly unusual and unexplained, yet reminiscent of the Bethlehem structure in the Hidden Quadrant of the Vredefort impact structure [17].

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