MOROKWENG, SOUTH AFRICA: THE JURASSIC-CRETACEOUS BOUNDARY IMPACT STRUCTURE?

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Introduction and Summary. The existence of a large, almost circular, subsurface structure in the area around Morokweng, South Africa (centered at 23°32' E and 26°31' S), was inferred on the basis of gravity and magnetic investigations [1-3] (Fig. 1). Preliminary geophysical, petrological, and geochemical investigations led to the suggestion that this anomaly may represent an impact structure [1-5]. Detailed geophysical studies [5] showed the presence of a circular positive magnetic anomaly (up to 350 nT above regional background). This anomaly (the 'Ganyesa Dome') is a central 30-km-diameter near-circular area, and is surrounded by a concentric, magnetically quiet zone that is 20 km wide, representing the Morokweng Ring Structure (MRS; Fig. 1). Further processing of the gravity and aeromagnetic data revealed the presence of a much larger circular structure with a diameter of about 340 km (Fig. 2; [5]). Three drill cores were obtained from near the center of the structure. Preliminary data were reported by [2, 4] and indicated the presence of melt rocks with high contents of siderophile elements. Our detailed petrographical and geochemical studies proved the presence of a thick layer of impact melt rocks with high abundances of Cr, Ni, Co, and the platinum group elements (PGEs). The PGEs and other siderophile elements are rather homogeneously distributed and the enrichments are consistent with up to 5 % of a meteoritic (chondritic) component being incorporated in the impact melt [6]. To determine the age of the structure, we extracted zircons from the impact melt. SHRIMP ion probe dating of these zircons yielded an age of 146.2±1.5 Ma, which is indistinguishable from that of the Jurassic-Cretaceous boundary [6].

Petrology and Geochemistry: Samples from three boreholes (MWF03, core depth 130.3 m; MWF04, 189.3 m; MWF05, 271.3 m) were used in the present study. A top layer of calcrete is underlain by a thick layer of melt rock [6]. Except for the uppermost part, the melt rock is reasonably fresh and appears homogeneous, but carries a large amount of lithic inclusions at variable proportions. The clast population is dominated by gabbro- and granitoid-derived clasts. Besides mafic lithic clasts, numerous platy, sometimes poikilitic, pyroxene clasts, are also significant [6]. SEM and microprobe studies show the presence of low-Ca pyroxenes with a corroded appearance and an overgrowth of amphibole (with high Ni contents) (Fig. 2a). All pyroxene crystals analyzed contain significant amounts of Ni (about 0.2 wt% NiO). The matrix, which comprises >90 vol%, is dominated by lathy or bladed plagioclase crystals, set between generally smaller, short-prismatic orthopyroxene (average composition: Wo3.6, En 58.2, Fs38.2) and ubiquitous, but in its abundance variable, granophyric intergrowths of plagioclase, alkali feldspar, and quartz. Opaque minerals are relatively abundant in the Morokweng melt rock and include various types of magnetite, spinel (Cr-, Ni- rich), ilmenite and rutile (often intergrown), monazite, ChalcociteCu_2S, and trevorite (containing about 25 wt% NiO). We commonly observed skeletal magnetite (with high contents of either Cr or Ni) within irregularly shaped pyroxene, which is intimately intergrown in the matrix (Fig. 2b). Large spinels show a lamellar internal structure, consisting of Ni-rich zones (25 wt% NiO), Ni-poor zones, and rutile exsolution lamellae (Fig. 2c). Zircon and baddeleyite are also common, the latter being further evidence for the high-temperature origin of the melt rock. The majority of the felsic clasts is completely recrystallized, but some unannealed relics with unequivocal remnants of PDFs are present. Other quartz or quartz-bearing clasts contain densely-spaced planar trails of micro-inclusions, which most likely are remnants of PDFs. Detailed geochemical studies were made of 60 drill core samples. The impact melt rock samples have a remarkably uniform composition, and all have high siderophile element contents, mainly Cr, Co, Ni, and the PGEs. After correction for the indigenous siderophile element contents, a near-chondritic abundance range remains. This is especially obvious when studying the abundances of the PGEs, which yielded a flat, near-chondritic pattern (Fig. 3). Depending on the normalization, about 2-5% of a chondritic component is present in the melt rocks. In contrast to melts from most other impact structures, the meteoritic component is high and uniformly distributed in the Morokweng impact melt rocks.

Age Determinations: Zircons were extracted from a composite sample of several relatively coarse-grained drill core sections from drill core MWF 04. Petrographic evidence indicates that the zircons have grown in the melt rock. The zircons were analyzed for their U-Th-Pb isotopic compositions on the ion microprobe SHRIMP I at the Research School of Earth Sciences (RSES), ANU. Of the separate zircons analyzed, all but two conform to a single population. From those a $^{206}Pb/^{238}U$ age of 146.2 ± 1.5 Ma can be calculated [6]. In addition, an independent $^{208}Pb/^{232}Th$ age of 144.7 ± 1.9 Ma can be calculated from this data set [6]. Our preliminary Rb-Sr isochron studies on mineral separates from the melt rock agree with this result. This age is indistinguishable from the age of the Jurassic-Cretaceous (J-K) boundary, which is placed at the base of the Berriasian Stage at 145 Ma. Thus, Chicxulub does not seem to be the only large impact structure with an age that is identical to that of a major geological boundary.

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References: [1] B. Corner, *Abstr. Proterozoic Crustal and Metallogenic Evolution Conf.* (Windhoek, Namibia), p. 9 (1994). [2] M.A.G. Andreoli et al. *Abstr. Centennial Geocongress*, Johannesburg, 541 (1995). [3] B. Corner, W.U. Reimold, D. Brandt, and C. Koeberl, *Lunar Planet. Sci.* **XXVII**, 257 (1996). [4] M.A.G. Andreoli, L.D. Ashwal, R.J. Hart, and M. Tredoux, *Lunar Planet. Sci.* **XXVII**, 29 (1996). [5] B. Corner, W.U. Reimold, D. Brandt, and C. Koeberl, *Earth Planet. Sci. Lett.* **146**, 351 (1997). [6] C. Koeberl, R.A. Armstrong, and W.U. Reimold, in review (1997).

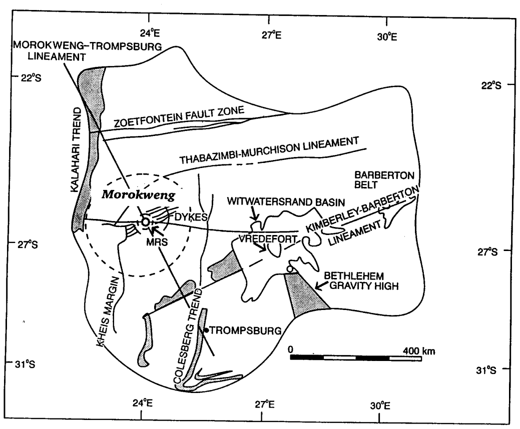

Fig.1

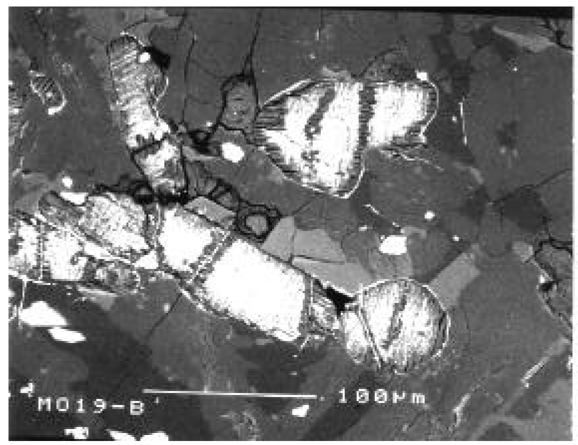

Fig. 2a

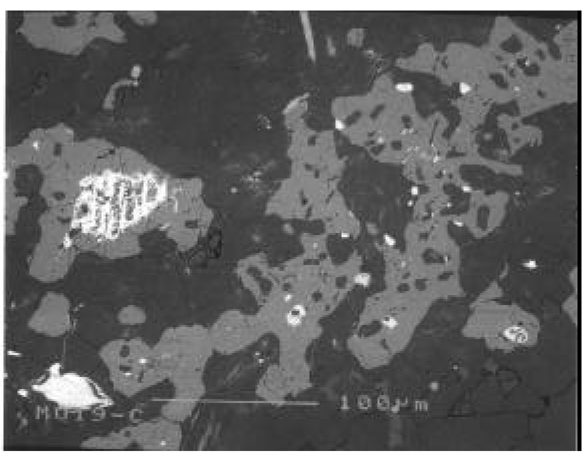

Fig. 2b

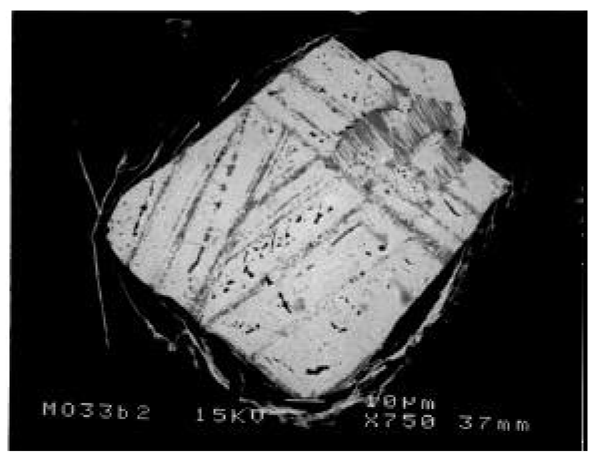

Fig. 2c

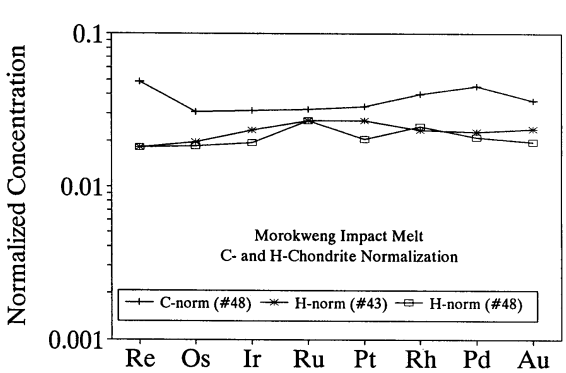

Fig. 3

Fig. 1. The Morokweng impact structure as outlined by gravity and magnetic anomalies (dashed line, about 340 km diameter); after [5].

Fig. 2. SEM-BSE microphotographs of Morokweng impact melt rock. a) Ca-poor pyroxene (light gray), with a rim of amphibole, set in a typical matrix of quartz, plagioclase, and alkali feldspar, with Ni-rich spinel (white). b) Irregular pyroxene (light gray) with skeletal (exsolved?) spinel (white), set in matrix (dark gray). c) Spinel with Ni-rich (light gray) and Ni-poor lamellae and rutile intergrowth (both darker gray).

Fig. 3. PGE contents in Morokweng impact melt rock samples, normalized to average chondritic meteorite compositions, showing the presence of about 2 to 5% of a (H?) chondritic component.