METEORITIC COMPONENT IN IMPACT MELT ROCKS FROM THE MOROKWENG, SOUTH AFRICA, IMPACT STRUCTURE: AN OS ISOTOPIC STUDY. Christian Koeberl[1], Bernhard Peucker-Ehrenbrink[2], and Wolf Uwe Reimold[3]. [1]Institute of Geochemistry, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria (christian.koeberl@univie.ac.at); [2]Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole 02543-1541, U.S.A. (behrenbrink@whoi.edu); [3]Impact Cratering Research Group, Department of Geology, University of the Witwatersrand, Johannesburg 2050, South Africa (065wur@cosmos.wits.ac.za).

Introduction. The Morokweng impact structure is centered at 23°32' E and 26°20' S, close to the border with Botswana in the Northwest Province of South Africa. The structure was recognized as a circular positive magnetic anomaly of up to 350 nT above regional background. This anomaly forms a central 30-km-diameter near-circular area, which is surrounded by a concentric, magnetically quiet zone that is 20 km wide. Refined processing of the gravity and aeromagnetic data revealed the possible presence of a larger circular structure (see [1]). The discovery of impact characteristic shock metamorphic effects in rocks from the Morokweng area (e.g., [1,2]) confirmed the presence of a large meteorite impact structure. The size of the Morokweng impact structure is still debated, but new evidence [3] seems to favor a minimum diameter of about 80 km. Three boreholes in the south-central area of the aeromagnetic anomaly (MWF03, core depth 130.3 m; MWF04, 189.3 m; MWF05, 271.3 m) were sampled [2]. All three boreholes went through a top layer of Tertiary to Holocene Kalahari Group calcrete, which is directly underlain by a dark-brown melt rock, with a thickness of about 125 m in borehole MWF05. Only in borehole MWF05 was the lower contact of the melt rock intersected, when granitic rocks were reached at 225 m depth, whereas the other holes bottomed in the melt rock unit. The melt rock appears fresh and homogeneous, except for a large number of lithic clasts. The clast population is dominated by gabbro fragments, but microscopic studies reveal that felsic, clearly granitoid-derived, clasts are also abundant. The granites drilled below the melt body in core MWF05 are locally brecciated and pervasively recrystallized. Some primary minerals are preserved and display shock deformation in the form of PDFs in quartz, plagioclase, alkali feldspar, and K-feldspar [2]. Some thin (<10 cm wide) breccia veins occur in the granitoids of drill core MWF05. These breccias could be injections of melt or in part recrystallized, locally produced, cataclastic material. It is not clear yet whether granitoid basement has been reached at the bottom of drill core MWF05, but it is well possible that a (mega?)breccia zone below the melt rock and above the basement was intersected. SHRIMP ion probe dating of zircons from the melt rock yielded an age of 146.2±1.5 Ma, which is indistinguishable from that of the Jurassic-Cretaceous boundary [2,4].

Geochemistry of Melt Rock. With the exception of a few obviously altered melt rock samples, the Morokweng melt body is extremely homogeneous in composition. Variations for major elements do not exceed 2-5 rel%. The Morokweng melt rock contains relatively high proportions of CaO (on average, 3.41 wt%), MgO (3.70 wt%), and Fe_2O_3 (5.87 wt%), and an average SiO_2 content of 65.75 wt%. Siderophile elements are consistently enriched (the variation between samples is less than a factor of 2) in the melt rock samples in comparison with rocks of such major element composition (granodioritic to dioritic), with average values for Cr of 440 ppm, of 50 ppm for Co, 780 ppm for Ni, and 32 ppb for Ir. No variation with depth and no differences between drill cores was found [2,4]. It was suggested that mafic to ultramafic country rocks, or other mantle-derived sources, were responsible for these high siderophile and Ir concentrations [2]. Abundances of the platinum group elements showed near-chondritic patterns [2]. 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. The presence of an extraterrestrial component was confirmed by a recent Cr-isotopic study [4], in which two impact melt rock samples (MO-15 and MO-48) were analyzed. This study indicated that about half of the Cr present in the melt rock has an extraterrestrial source. Also, it was concluded that the projectile was similar to L-chondrites in composition [5].

Os Isotopic Investigations. To further constrain the presence of an extraterrestrial component, and to compare the results of PGE analyses and of the Cr and Os isotopic methods, we analyzed the Os isotopic composition and the Os content of 12 samples. This included 4 impact melt rocks (MO-15, MO-20, M=-37a, and MO-48), 3 breccia samples (MO-63A, MO-69B, MO-70), one granitic clast (MO-65), and one gabbroic clast (MO-35CL); all these samples were from the drillcores at the center of the structure. To constrain the contribution from mafic country rock, we analyzed three mafic intrusion samples from the deep drill hole 40 km from the center of the structure (from 1006, 1536, and 2617 m depth), which is described in more detail by Reimold et al. [3]. The Os isotopic method is a particularly sensitive technique for the search for an extraterrestrial component. Details have been described elsewhere (e.g., [6]). In principle, target rocks (old crustal rocks) commonly have high $^{187}Os/^{188}Os$ ratios, whereas meteorites have very low ratios. The target rock and meteorite values define the endmembers in a mixing relation, with impact breccias and melt rocks commonly plotting between the endmember values (if all endmember compositions were analyzed). Due to the very low crustal Os abundances (usually <0.02 ppb), even a small meteoritic component in a breccia or melt rock will completely reset the bulk Os isotopic value. The analyses for the present study were done with a new technique, which involves sparging Os as OsO_4 into a magnetic-sector ICP-MS instrument [7]. This technique allows the rapid determination of the Os content and Os isotopic ratio, and the remainder of the sample can be measured for PGE abundances. Precision is very good, mostly much less than 1 rel% (2σ) for both Os abundance and isotope ratio.

Our results show high Os contents of up to about 9 ppb in the impact melt rock samples, with correspondingly low isotopic ratios, with $^{187}Os/^{188}Os$ at 0.1316 to 0.1341. The melt rocks were remarkably uniform in their isotopic ratio. The breccias show a much wider variation in both isotope ratio and Os abundance, with one low abundance sample obviously being dominated by a meteoritic component. This sample is now confirmed as an injection of impact melt into the crater floor. The mafic rock samples from the deep drill core, which represent the mafic contribution to the Morokweng impact melt rocks, have very low Os abundances (9.8 to 42 ppt) and high isotope ratios (up to a $^{187}Os/^{188}Os$ ratio of 12!). This result clearly indicates that the mafic target rocks of the area did not contribute measurably to the high siderophile element abundances observed in the melt rocks, and that the presence of a meteoritic component in these melt rocks has been independently verified.

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Fig. 1. Plot of Os isotopic ratio versus Os abundance for 12 samples from the Morokweng impact structure, South Africa. The target rocks (including those from the deep drill core outside the structure) define a low Os abundance, high isotopic ratio field, whereas the impact melt rocks have a clear meteoritic component.