NEW RESULTS FROM THE DEEP BOREHOLE AT MOROKWENG, NORTH WEST PROVINCE, SOUTH AFRICA: CONSTRAINTS ON THE SIZE OF THIS J/K BOUNDARY AGE IMPACT STRUCTURE. W.U. Reimold[1], R.A. Armstrong[2], and C. Koeberl[3], [1]Impact Cratering Research Group, Department of Geology, University of the Witwatersrand, Private Bag 3, P.O. Wits 2050, Johannesburg, South Africa, 065wur@cosmos.wits.ac.za, [2]Research School of Earth Sciences, The Australian National University, Canberra 0200, A.C.T., Australia, prise.armstrong@anu.edu.au, [3]Institute of Geochemistry, University of Vienna, Althanstr. 14, A-1090 Vienna, Austria, christian.koeberl@univie.ac.at

Introduction: The Morokweng Structure, centered on the Ganyesa Dome in the North West Province of South Africa, has been confirmed as an impact structure, due to the presence of well documented shock metamorphic effects in minerals from clasts in granophyric melt rock and basement granitoids from the central part of this structure [1-3]. In addition, a meteoritic component was detected in the melt rock [4], which, thus, was confirmed as impact melt rock (known as the Morokweng Granophyre). The age of this impact structure is extremely well constrained at 145±2 Ma, which corresponds to the currently accepted age for the Jurassic-Cretaceous boundary, which is marked by some minor extinctions [2,3]. For this reason, the Morokweng impact event and its possible environmental effects have been widely debated, especially with regard to the likely original size of this impact structure (i.e., magnitude of the impact catastrophe), for which values as high as >340 km have been proposed [e.g., 1,3]. In 1999, it was possible to sample and study the 3.4 km long KHK-1 drillcore obtained by Anglogold Limited on the farm Kelso 351 (appr. 23°12'E/26°40'S), about 38-40 km southwest of the presumed center of the impact structure. Here, we report on the drillcore stratigraphy and results of chemical and chronological analysis of drillcore samples. Preliminary stratigraphic results were presented by Reimold and Koeberl [5].

Borehole Stratigraphy: The top 599.15 m represent (not recovered) dolomite and chert of the 2.25-2.5 Ga Transvaal Supergroup. This package continues until 889.1 m, where the contact with a gabbroic intrusion (to 1083 m) is formed by a 10-cm-wide layer containing shocked quartz clasts, which has been classified as polymict fragmental impact breccia. Some dolomite follows, above a package of arenitic metasediments (to 1200 m). A series of mafic volcanic flows was intersected to a depth of 1417.8 m, where a 1.2 m thick cataclastic breccia (no shock deformation) was observed, above more metasediment, including some diamictite (also no sign of shock deformation). Felsic volcanics and a felsic granophyre follow to the depth of 1784.2 m, and, then, more metasediment, including two thin diamictite bands. Below this depth, a thick package of felsic granophyre was intersected to the depth of 2669.4 m, where it is terminated by a gabbroic intrusion. *Contrary to the report by [5], this felsic granophyre does not contain quartz clasts with PDFs.* A thick gabbro intrusion follows till 3012 m depth, where locally pegmatoidal, but mostly micropegmatoidal granitoids were encountered and continue to the final depth of the borehole (3420 m). Whilst no evidence of shock metamorphism could be detected in any of the granophyric rocks of the drillcore, there is ample evidence that at least some of the granophyric material is of secondary origin, formed from melting of a granitoid precursor.

Chemical Results: The granophyric lithologies of this drillcore texturally closely resemble the Morokweng Granophyre (impact melt). However, the KHK-1 granophyric rocks are much more felsic than the impact melt rock. To further investigate the nature of the drillcore lithologies, a detailed major and trace element study (XRF and INAA analysis) of the volcanic and plutonic drillcore rocks was carried out. The results can be summarised, in comparison with chemical data for drillcore samples from the center of the Morokweng Structure (Ganyesa Dome), as follows: Granitoids from the Ganyesa Dome and KHK-1 drillcore have similar compositions. The Morokweng Granophyre (impact melt) is rather homogeneous in contrast to the felsic granophyres of the drillcore that show a wide range of compositions (e.g., MgO 1.5-5 wt% and Na_2O 2-7.5 wt%). The impact melt has less SiO_2 (60-67.5 vs. 66-75 wt%) than the felsic granophyres, more Fe_2O_3 (4.7-9 vs. 1.2-8 wt%), similar MgO (1.7-4.9 vs. 1.5-5 wt%), more CaO (2.6-5.5 vs. 0.4-1.3 wt%), and similar Na_2O (3.3-5 vs. 2-7.5 wt%). With regard to siderophile elements, there is no evidence for the presence of a meteoritic component in the felsic granophyres of the drillcore – in contrast to the quite strong meteoritic signature of the impact melt rock. In addition, and also in contrast to the impact melt rock, the felsic drillcore lithologies do not give any indication of possible admixture of mafic lithologies.

SHRIMP Zircon Dating: No chemical or direct textural evidence could be obtained that would point towards an origin as impact melt rock for the granophyric rocks of the drillcore. However, the question whether they are coeval with the impact event must be addressed, as it could be proposed that large-scale melting of crustal material could be triggered within a very large impact structure, possibly producing melt rocks of widely different composition, and not all containing a contribution from the meteoritic projectile. Thus, seven samples were selected for zircon extraction, prior to SHRIMP U-Pb single zircon dating: felsic granophyre specimens taken at 1680.3, 1781.9, 2289.5, 2419.8, and 2524.9 m depths, as well as a coarse-grained gabbro from 3237.2 and a basement granitoid from 3406.15 m depth. Quite complex and sometimes very limited zircon fractions were obtained. The majority of crystals extracted also turned out to be strongly metamict and altered. Only the samples from 2289.5 m and 3406.15 m depths yielded well-defined results: The 2289.5 m granophyre data scatter along a discordia with an upper intercept at 2736±29 Ma. For the most concordant analyses a weighted mean $^{207}Pb/^{206}Pb$ age of 2689±5Ma was calculated, which is interpreted as a *minimum* age for this lithology. Basement granitoid 3406.15m also showed severe discordance for many analysed grains, but a group of data plots onto the concordia and gives a weighted mean $^{207}Pb/^{206}Pb$ age of 2878±8 Ma. Two analyses on a single grain give a younger concordant age of 2690±16 Ma. Another 18 analyses from zircon in the samples 1781.9. 1680,3, 2524.9, and 2419.8 produced very variable results, with mostly very to extremely discordant data. These data seem to fall along a poorly-defined discordia trend with an upper intercept between 2750 and 2900 Ma. The lower intercept ages indicated appear to fall between 1300 and 950 Ma, i.e. they can be related to the Namaqua-Kibaran regional tectono-magmatic phase.

Similar results have been obtained by several other chronological investigations on this wider region: e.g., Grobler [6] obtained a ca. 2784 Ma age for the Gaborone granite intrusion in Botswana [cf. also 7]; Anhaeusser and Walraven [8] reported Pb evaporation ages for a number of granitoids in the Kraaipan region (to the east of our study area) between 2880 and 2749 (as well as early Archean ages), and the Kanye Formation; Robb et al. [9] have discussed Kibaran/Namaquan tectonomagmatic events; and one of us (RAA) has unpublished SHRIMP results for surface samples from this northwestern part of South Africa that appear similar to our data for the drillcore samples.

Conclusions: Texturally the granophyric drillcore lithologies resemble the Morokweng Granophyre. However, mineralogical and chemical data illustrate that the Morokweng impact melt rock is different from the felsic drillcore formations, which may, however, be closely related to the volcanics intersected in KHK-1. The SHRIMP dating has proven unequivocally that the granitoids (granophyres and basement granites) are of late Archean age and that their formation is not related to the impact event. The scarcity of impact breccia in the drillcore and general lack of possibly impact-related deformation is a strong indication that this borehole was sunk outside of the original rim of the impact structure. Together with geophysical information (e.g., [10]), this finding constrains the maximum diameter of the Morokweng impact structure to approximately 75-80 kilometers. At this size, it must be considered unlikely that this impact event triggered a global environmental catastrophe that would have led to a major (global) mass extinction, and would have been capable of having a major influence on the plate tectonic development of Gondwana, at that time, as discussed by [2-4].

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