DISCUSSION OF THE CRITERIA FOR RECOGNITION OF MULTIRING IMPACT BASINS -- WITH REFERENCE TO THE SIMPSON DESERT DEPRESSION AND THE VREDEFORT DOME.

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Multiring impact basins (MRIBs) have been shown to be important surface structures on all terrestrial planets (e.g., 1-3). With regard to Mars it has been said that MRIBs define the fundamental tectonic framework, onto which geologic and geophysical processes are later superimposed (1). While this argument is certainly supported by the evidence from Mars and Moon, the persistent geological activity on Earth has created a less unequivocal picture. Nevertheless, various workers in recent years discussed (e.g., 4,5) the implications that formation of numerous MRIBs during the Archean/early Proterozoic would have had for the geological evolution of this planet. There can be no doubt that the current status of the impact cratering record indicates that, throughout time, impact cratering was a most effective, if not originally the most important geological process on Earth's surface. Several terrestrial structures have been discussed in the recent past as remnants of potential MRIBs, such as the Sudbury structure (6), the Simpson Desert Depression (SDD, 7-9), and also the still controversial Vredefort dome (VD). Others, e.g. (10), have speculated on the existence of many other large circular structures on Earth. Should the three structures named indeed fall into the MRIB category, doubtlessly many of their original characteristics have been destroyed since their formation ca. 2 Ga ago. Erosion of such large (and old) structures is naturally favored by their high diameter/depth ratios (1) and extended geological activity over 2 or more Ga. Therefore, in the light of the recent ample literature on MRIBs, both on Earth and on other planets (11), and particularly as new potential basin candidates have been introduced (e.g. the SDD, or the Can-Am structure (12)), it appears timely to discuss the available recognition criteria for such large structures.

As French (13) summarised, generally accepted recognition criteria for impact structures are either morphological characteristics (e.g. circularity), macrodeformation (e.g. brecciation, breccia bodies), or a range of petrographic indicators (high-P polymorphs, shock metamorphic effects). However, most of these criteria can only be applied to "fresh", i.e.relatively young, and small crater structures, while the record for large/old MRIBs is different: circular structures, generally with a central uplift surrounded by faulted annuli (ring structures), with radial and peripheral or tangential lineament trends, as well as significant associated volcanic activity. This conforms largely with the Orientale-type of MRIBs (here thought most important because of its size range at +/- 1000 km), but some workers have pointed out that many of the larger basins on Mars (e.g. Argyre, Hellas, Chryse) differ morphologically and structurally from the Orientale type of smaller diameter (14,15). It is thought that one reason for formation of different structural styles could be variability in the constitution of the crust, e.g. variable lithospheric thickness; the formation of Orientale-type basins may be favored by thick and strong lithosphere in cases of transient cavity depths less than the thickness of the lithosphere. The implication for terrestrial MRIBs is that at times prior to ca. 2 Ga the lithosphere , at least on parts of the Canadian Shield, was relatively thin and geothermal gradients very high (16). Generally it will be impossible to trace ejecta from such old structures (it is difficult for Martian basins, too (1)). Therefore only remote sensing, morphological and geophysical features as possible indicators for ancient MRIBs can be considered. It has been pointed out (17) that large impact structures, such as Manicouagan, commonly feature an aeromagnetic anomaly pattern consisting of a central high and annular rings. The gravity signature of an impact structure is primarily a low (due to brecciation) (18). Finally, the structurally strongly disturbed rim zones may have been geologically active for extended times.

What is the respective record for the SDD and the VD? 1. SDD: a near-circular depression associated with large volumes of volcanics covering some 37000 km^2; the region has been a basinal feature since early Proterozoic; regarding the aeromagnetic pattern, a detailed regional survey is currently being undertaken, but a strong MAGSAT gradient over the region was noted earlier (7); comparing Fig.1 (7) and Fig.4B (11), the gravity profiles across the SDD and Manicouagan, resp., a very strong similarity between these two profiles is obvious; (8,9) pointed out the strong circular, radial, and annular or tangential lineament geometry in the region.
2. VD: Recent gravity modelling (19) suggested a 100 km width for the basement uplift, a figure pointing towards a 300-350 km structural diameter if scaled against other uplift/crater diameter ratios. The regional geological evolution has been recorded for a period of at least 3 Ga. The crust-on-edge geology of the core as well as reflection seismic and stratigraphic data suggest a crustal thickness in the region of at least 35 km, which may be different from other cratonic regions in N. America or Australia at the time. With regard to our list of criteria - the structure has a near-circular uplift and is surrounded by a semicircular (or tangential?) synclinorium in the north, but such structure has not been described from the south. This is explained by some workers (20) by tilting of the crust northwards later than 2 Ga ago and subsequent preferential erosion of the southern sector; ejecta deposits are not known, but it has been suggested to investigate the 1.9 Ga Waterberg Group metasediments. The regional aeromagnetic anomaly pattern (Fig.3, (21)) is dominated by central negative anomalies on the dome itself, and a semi-annular or tangential ridge to the northwest (Rand Anticline) that features prominantly as a negative anomaly due to strongly magnetic West Rand Group shales. The gravity image (Fig.2, (21)) shows the structure located in an area of elevated gravity, surrounded by negative anomalies.

In conclusion, while certain similarities between the suggested MRIB signatures and the SDD structure could be described, in addition to the other geological and geophysical characteristics emphasised earlier (7-9), the region of the Vredefort structure does not so readily conform. As pointed out, this may be due to abnormal thickness of the Proterozoic lithosphere or due to the extreme erosion depth at Vredefort. Also the extensive tectonic activity in the western portion of the Kaapvaal craton since 2 Ga could have largely obscured the original features. It is clearly demanded to further evaluate the recognition criteria for MRIBs, as set out here, by comparison with other large impact structures (e.g. Popigai (100km), Puchezh-Katunki (80km), Siljan (52km)) and other suggested terrestrial MRIBs (e.g.those suggested by (10)).

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