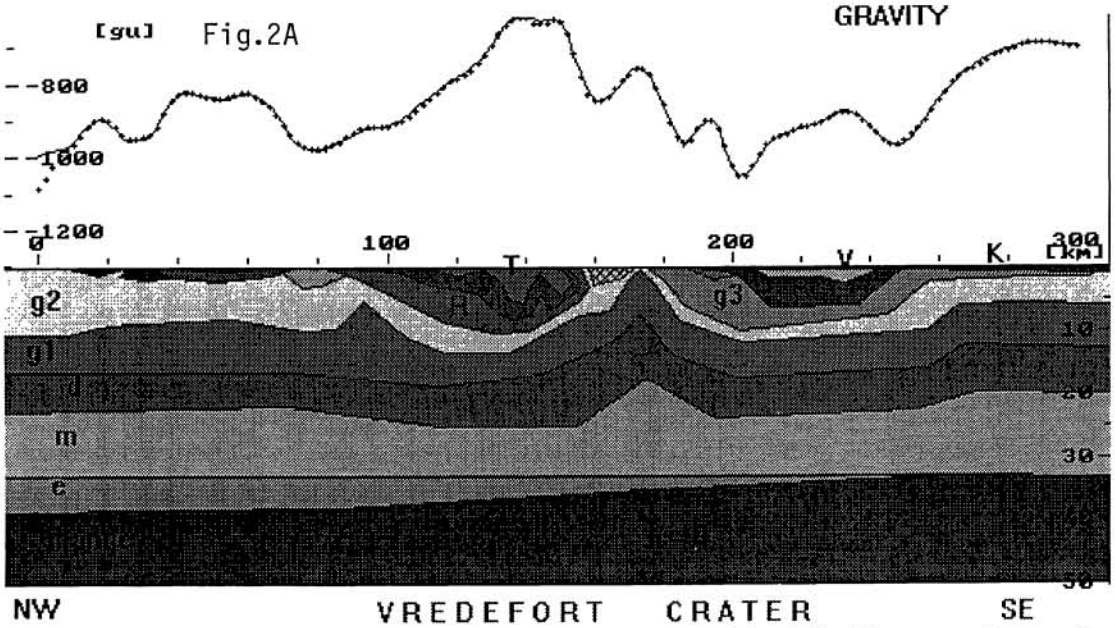
INTEGRATED GEOPHYSICAL MODELLING OF THE VREDEFORT IMPACT STRUCTURE, WITWATERSRAND BASIN, SOUTH AFRICA; **H.Henkel**(1) and **W.U.Reimold**(2), (1)Department of Geodesy and Photogrammetry, Royal Institute of Technology, S-100 44 Stockholm, Sweden, e-mail: herbert@l.kth.se, (2)Department of Geology, University of the Witwatersrand, Private Bag 3, P.O. Wits 2050, Johannesburg, R.S.A., e-mail: 065wur@cosmos.wits.ac.za.

Summary: Detailed integrated modelling has been performed of gravity and magnetic data, aided by a large seismic and petrophysical data base, along two near-perpendicular traverses across the Vredefort impact structure, which includes the Witwatersrand Basin. As a result, the impact related basin has a diameter of 250 km, preserved in the present SW-NE extension, and depths ranging from 7 km in the SE to 12 km in the NW and N. The remaining structural uplift in the centre is 12 km. Vast volumes of material, appr. $6 \cdot 10^4$ km^3, have been ejected by the impact and similar amounts were injected into the crater surroundings. Post-impact deformation includes tilting, being responsible for the present asymmetric shape of the central rise, and NW-SE shortening of the impact basin by as much as 85 km. The magnetic model explains the extension of impact related thermal overprinting of the central upper part of the impact struture.

Background: The origin of the Vredefort Structure by either impact of an extraterrestrial projectile or by internal processes has long been controversial. Only since 1994, unambiguous data in favor of an impact origin 2 Ga ago have been obtained (1,2). Therriault et al. (3) estimated the original size of the Vredefort impact structure to at least 300 km diameter. The most conspiciuous feature of the present surface geology is the occurrence of a 40 km diameter crystalline basement rise. Its location in the center of the economically important Witwatersrand Basin, which is now believed to be a major part of the impact structure, and the need to improve the general understanding of large impact basins were the reasons to attempt comprehensive gravity and magnetic modelling of the present impact structure. As appropriate data were available, two near-perpendicular NW-SE and SW-NE traverses were modelled across the Witwatersrand Basin, Fig. 1.

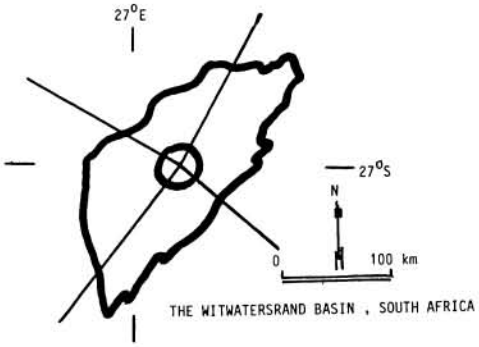
Procedure: The lithospheric velocity model of the South African craton (4), as derived from refraction seismic data, was used as the background model. The p-wave velocities were converted to densities using the empirical relation applied for a similar study in the Baltic Shield (5). Interactive 2.5-d forward modelling of the observed gravity anomaly (6) resulted in the density configuration (gravity model) shown in Fig. 2A. The known surface geology and the corresponding densities (7,8) were used as constraints. The onset of crustal deformation of the Vredefort impact event is seen in the refraction seismic section across the NW part of the Witwatersrand Basin (9) and was used to constrain the region of crustal perturbation. Further structural detail could then be added by similar 2.5-d magnetic modelling of the aeromagnetic anomaly (6) using measured magnetic properties of surface rocks (10) as constraints. The magnetic model for the central rise region is shown in Fig. 2B.

Results: The extension of the *impact related basin* is 165 km in the NW-SE direction and appr. 250 km in the SW-NE direction. The NW-SE shortening is ascribed to post-impact processes: inward thrusting in the NW sector and a 4 km rise of deeper crustal units in the eastern part of the basin along a SSW-NNE trending flexure. The ring basin deepens towards the central rise, having its maximum depth at about 47 km NW of the centre. The shape of the *crystalline central rise* structure is hyperbolic with a diameter of 70 km at its base, 35 km midways, and 40 km at the present erosion surface. The impact related present structural uplift is 12 km, as seen on an upper crustal interface. The amplitude of the central uplift is about 15 km. The upper-lower crustal interface rises 9 km and occurs now at 16 km depth. The crust-mantle interface is only slightly involved with a potential rise of about 4 km. The whole crust is, thus, not on-edge, and there is no connection between observed mafic rocks at the surface and the present mantle. The *pre-impact cover rocks*, with an estimated pre-impact thickness of about 10 km, are overturned around the crystalline central rise except in the SE sector. This difference is attributed to tilting prior to erosion. The huge impact event has also *perturbed the thermal conditions* of the crust: first by the rise of deeper crustal material and second by the formation of impact melt bodies. Such melt bodies may have covered the central rise region and its surroundings. A remaining effect of this thermal overprinting is the remagnetization of all rocks occurring in the vicinity of the melt body and is today seen as a remanent magnetized zone in the sedimentary collar and in the crystalline core rocks of the top of the central rise. The direction of this remanence was determined by Jackson (10) to incl. 56° and decl. 25°, and Hart et al. (11) suggested its origin to be impact related. The modelling shows that this remagnetization reaches deeper in the NW part of the central rise - also as a result of tilting. The *impact melt body,* remnants of which are represented by the 2.8 Mgm^{-3} density granophyre dykes, would have been in contact with the lower part of the upper crust, but not the



K Karoo, T Transvaal, V Ventersdorp, R Rand, g1-3 granitic, d dioritic, m mafic, e eclogitic

Fig.1. Location map.



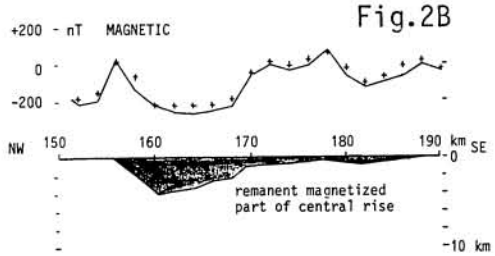


Fig. 2. Geophysical models. Measured anomalies are denoted with + symbols, calculated with full line. **A.** NW-SE gravity model. **B.** NW-SE magnetic model over central rise region.

lower crust. From the gravity modelling and the seismic constraints, the following *approximate impact crater dimensions* can be estimated: Transient crater diameter was 120-150 km and its depth 30-35 km. Potential depth of impact melting is up to 30 km. Extension of shock induced plastic deformation reaches out to 65 km. Following the discussions in Melosh (12), the following approximate quantities can be derived using the previous estimates: Lateral extension of injecta reaches out to 100 km. The thickness of melt and ejecta cover prior to erosion may have been up to 5 km. The amount of ejecta is estimated at $6 \cdot 10^4$ km^3, and a similar volume of material would have been injected into the crater basement.

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References: (1) Leroux, H. et al., 1994, Tectonophysics, 230, 23-239; (2) Kamo, S. et al., 1995, Geocongress '95, Geol. Soc. S. Afr., 1, 577-580; (3) Therriault, A.M. et al., 1995, Meteoritics, 30/5, 586-587; (4) Durrheim, R.J., and Green, R.W.E., 1992, Geophys. J. Int., 108, 812-832; (5) Henkel, H., et al.1990, EGS-EGT Integrative Studies, 1-47; (6) Data compiled by Luc Antoine, Dept.of Geophysics, Univ.Wits., (7) Smit, P.J., and Maree, B.D., 1966, Geol. South Africa Bull., 48, 37p; (8) Stepto, D., 1979, PhD thesis, Univ. Wits, 378p; (9) Durrheim R.J., et al., 1991, Geodynamics, 22, 213-224. (10) Jackson, G.M., BSc. diss. Univ. Wits; (11) Hart, R.J., 1995, Geology, 23, 277-280. (12) Melosh, H.J., 1989, Oxford Mon.Geol.Geoph., 11, 245p.