MAGNETIC IMAGING OF THE VREDEFORT DOME: IMPLICATIONS FOR THE SIZE AND GEOMETRY OF THE VREDEFORT CRATER. A. Galdeano[1], M. A. G. Andreoli[2,3], R. J. Hart[4] [1]Institute de Physique du Globe, Equipe de Géomagnétisme, 75252 Paris Cedex 05 France. [2]Necsa, P. O. Box 582, Pretoria 0001, South Africa, [3] School of Geosciences, University of the Witwatersrand, P. O. Box 3, Wits 2050, South Africa, [4]iThemba Labs P. Bag 11 Wits 2050 Johannesburg, South Africa. Hart@tlabs.ac.za.

Introduction: Models which predict the original size of the Vredefort impact crater vary considerably between 200 and 300 km [e.g. 1,2,3,4]. This is largely due to the fact that so little of the original crater is visible to view to constrain modelling procedures. Most of the 2.0 Ga Vredefort crater has been eroded away and all that remains are the remanents of the central uplift, that is, the Vredefort dome [2]. This problem is further exacerbated by the fact that the southeast half of the dome is largely hidden from view by younger sediments (Fig 1b), which makes it difficult to fully visualize the structure and size of the dome in its entirety. In this study we combine geological observation with magnetic and gravity imaging across the dome and beyond in an attempt to visualize what the Vredefort crater may have looked like shortly after the ~2.0 Ga impact event.

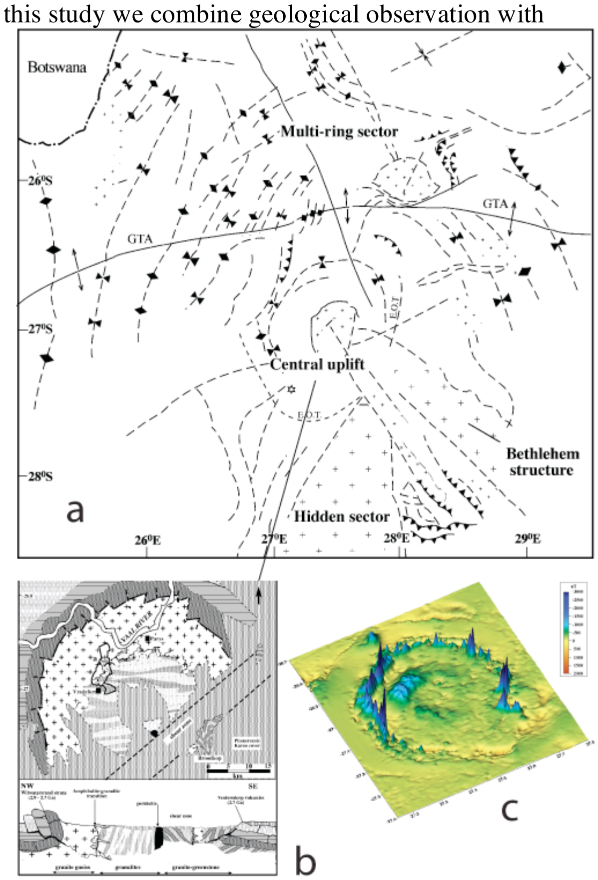

Figure 1. a) Geologic map of the Vredefort crater showing the central uplift, the multiring sector in the north and the hidden sector in the south. b) Geological map of the Vredefort dome and a northwest-southeast section across it. Vertical scale exaggerated. c) Inverted 3- D perspective image of the airborne magnetic image across the Vredefort dome. The outer negative anomaly (shown as positive peaks in blue) corresponds to the iron-rich shales of the Witwatersrand basin.

The Vredefort impact crater in a sketch: The eroded remnant of the grand Vredefort crater is subdivided in three broad, clearly distinct geological domains (Fig. 1a): the Central Uplift, the (north-western) Multiring Sector, and the (south-eastern) Hidden Quadrant. Current literature on the Vredefort impact crater is heavily biased on the Central Uplift. Conversely, much less has been written of the Multiring Sector where the position of the final rim is still uncertain, and virtually nothing on Vredefort-related features in the Hidden Sector.

The Central Uplift: Our modelling of the Central uplift of the Vredefort crater is largely based on the crust-on edge-model and the key observation that depleted upper mantle rocks are exposed near the centre of the crater. The model simply states that the northern half of the dome (Fig. 1b) consists of a 36 km wide arc of near vertical Mesoarchean and Neoarchean stratified rocks: a traverse across this sequence essentially corresponds to a traverse through the earths crust, culminating in depleted upper mantle near the centre of the dome [see 5,6, as well as counter arguments by 7].

The southeastern half of the Vredefort dome. The problem faced by all workers on Vredefort is that most of the southeast part of the dome is hidden from view by younger sediments (Fig. 1b). The few observations that we can make, all suggest that the lithology metamorphic grade and structure of the southeast side of the dome are very different from what is observed in the crustal section exposed in the north-west and most workers [8,9] believe that the northwest and southeast segments of the dome must be separated by a fault or shear zone. A km wide northeast trending zone of intense shearing at the locality Broodkop (see Fig.1a) provides the evidence for shearing. Previous workers [8,9] speculate that the shear zone may be part of an Achaean fault (circa 3.1 Ga) that has been rotated into its current sub-vertical orientation during central peak formation. However, to date, no definitive radiometric dating has been done on the Broodkop shear zone. Most of the arguments put forward by previous workers hinge around observations that are thought to suggest that the shearing observed at Broodkop has not affected the collar strata of the Witwatersrand supergroup. In contrast, our enhanced magnetic imaging suggest that the shearing in the south-east can be extended into the collar strata and has effected the entire Southeast sector of the dome, indicating collapse of the central uplift, shortly after the 2.0 Ga impact event.

Magnetic imaging. A 3-D perspective of the magnetic fields across the dome (Fig. 1c) clearly shows that the northwest and southeast sides of the dome are very different. Most notably, the prominent magnetic anomalies that are caused by ferruginous shales in the stratified rim in the northwest are largely missing in the southeast. It is also clear that the eastern and western limbs of the anomalies associated with the amphibolites-granulite transition are truncated across the centre of the dome (Fig. 1c), which strongly suggests the presence of a northeast trending structural discontinuity at this locality. An extension of this line into the eastern and western limbs of the stratified rocks also shows that the magnetic shales are significantly rotated and truncated both on the eastern and western sides of the dome (Fig. 1c). The few geological observations that have been made on the isolated outcrops that are found along the southeast flanks of the dome show that the attitude of the stratified rocks are chaotic having both overturned and normal dips [9].

The Multiring Sector. With this name we refer to the broad arc that encompasses the whole of the Witwatersrand basin in a series of concentric anticlines and synclines with the centre on the Vredefort structure (see Fig. 1a). This model has often been quoted as the basis to assign a diameter of up to ~350 km to the impact crater [1, 10]. More recent modelling of the Vredefort crater points to a rim-to-rim diameter of ~120-200 km [3]. On this basis the fold axes at radial distances >160 ± 40 km would be considered ‘external rings’, hence diagnostic of a true multiring impact crater [3]. More recently, however, slates and phyllites of the Transvaal Supergroup on the northern and western side of the Johannesburg dome yielded $^{40}Ar/^{39}Ar$ ages of ~2150.Ma and ~2043 Ma [1,12,13]. These ages coincide, within error, with the SHRIMP U-Pb ages of monazite and xenotime yielded by rocks and gold-bearing reefs within the Witwatersrand basin [14]. Significantly, no evidence of resetting was found by [11, 14] of resetting at 2023 Ma, the age of Vredefort [15]. The new ages for post-Transvaal deformation and metamorphism in the Witwatersrand Basin [14] and its hinterland [11] have an important bearing with regard to the Vredefort structure. Firstly, the data cast doubt on the hypothesis that the Vredefort impact caused the localized (small-scale), but region-wide remobilization of autigenic gold [16]. Secondly the new ages imply that the target of the Vredefort impactor was not represented by subhorizontal Transvaal Supergroup strata [17] but of rocks already deformed by the intracratonic “Transvaalide thrust and fold” belt [11].

The Hidden Sector: Practically all recent maps of the Vredefort structure show no geological structures past the edge of the Wits Basin southeast of Vredefort, in a an area where the basement is covered by a substantial Karoo cover. However, a robust linear element extending from Vredefort to the SSE is clearly visible in the regional Bouguer gravity image, This radial features, previously referred to as the Vredefort axis [18] was the object of detailed investigations by a number of mining companies, especially close to the town of Bethlehem. A combination of geophysical forward modeling, drilling and Vibroseis seismic profiles conducted over that area clearly reveal what has been referred to, in unpublished company reports, as the “Bethlehem structure”. The latter consists of a very complex swarm of horst (suboutcrop granite), grabens (suboutcrops of Wits basin) and tangential thrusts fanning out from the core of Vredefort, past Bethlehem, up to a radial distance of ~170 km from the crater centre (see Fig. 1a). The Bethlehem Structure is difficult to explain with the current knowledge of how large craters form. However, the Bethlehem structure suggests impact–related deformation was still very robust at a distance of 170 km from the centre.

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