REMOTE SENSING AND GIS ANALYSES FOR DETERMINING SIZE, MORPHOLOGY AND LITHOLOGICAL MAPPING OF THE VREDEFORT IMPACT STRUCTURE, SOUTH AFRICA

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Introduction:
The overall geometry and size of the Vredefort Impact Structure are still unresolved. Some workers have used modelling based on cratering processes or geophysics to show that the original diameter could have been at least 250-300km or more [1]. Also, previous studies of the Vredefort Structure have indicated that a number of circular or semi-circular features, at varying radial distances, could be rings related to the original Vredefort event [1-5].

Methods and Results:
Landsat TM and ASTER data were used for three interrelated project analyses of the structure over the period 1999-2005, and four fieldwork visits between 1998-2007. Landsat TM uses 6 bands of 30m spatial resolution in the visible and infrared wavelengths, with 1 band of 120m in the thermal infrared [6,7]. ASTER has superior spatial and spectral resolution with 3 visible bands at 15m, 6 infrared bands at 30m and 5 thermal infrared bands at 90m spatial resolutions [8]. These were the first detailed studies of the Vredefort Structure by Remote Sensing methods.landsat TM was particularly useful for recognising features for the first time, such as radial faults to the north of the Ring Collar (Fig. 1), arcuate drainage patterns and a likely ring feature at a radial distance of 125km, suggesting an overall size =>250km [6,7].

Figure 1. Radial faults in the Foch Thrust Zone (FTZ)

Figure 1 shows the Foch Thrust Zone region north of the Vredefort Ring Collar, with a known thrust fault in yellow, normal faults in white, and a dyke in red. Newly recognised radial faults from these studies [6,7] are shown in black; the large magenta structure in the lower central region is the Losberg Complex. Many of these findings supported work by geophysical methods [1]. Spectral profiling with ASTER data was applied to selected regions where either vegetation cover was low, or where other image processing methods highlighted differences in lithologies, or for impact structure morphologies. An area was investigated at Witkop, matching the spectral library profile of gneiss (Fig. 2) [8].

Figure 2. Spectral Profile of gneiss found at Witkop.

In this comparison of observed spectra with library spectra, characteristic absorption features were detected at 0.65µm (band 2, visible green), 2.20µm (band 7, mid-infrared) and 2.35µm (band 9, mid-infrared) [8]. ASTER data was then used successfully for spectral unmixing of specific geological regions and for delineating lithologies [8]. Additionally, Principal Components Analysis (PCA) was used to study Koedoesfontein, a region of quartzites/conglomerates. Two different geological units were observed. The upper half of the sequence belongs to the Turffontein, the lower exposures were discriminated as Johannesburg subgroups of the Central Rand Group, important for gold deposits in the region. Figure 3(a) shows a PCA RGB 123 image of this area. At Dwarsberg, a Dolerite ridge was mapped with PCA, where the ridge was highlighted in strips of magenta and dark blue with a n.east-s.west trend, as displayed in Figure 3(b) [8].

Figure 3(a). PCA RGB123 image of Koedoesfontein. (b). PCA RGB123 image of the Dwarsberg area.
GIS and Digital Elevation Model (DEM) mapping was applied to the Vredefort Impact Structure for the first time [9], resulting in more detailed mapping and recognition of other previously unseen and unreported structures. The DEM revealed a previously unreported raised, circular to lobate-like structure in the central Vredefort core, with height ~30m above the local terrain, and diameter ~25km [9]. Estimation of fault and scarp morphologies were visualised in 3D, one example of which is shown in Figure 5.

Figure 5. Perspective view of the FTZ, looking NE [9].

Fig.5 is a perspective view of the Foch Thrust Zone (FTZ), looking along strike towards the NE, with a Landsat TM RGB 641 [6] draped over a 30m DEM, made from digitised contours of 12 x 1:50,000 topographic maps [9]. Vertical exaggeration is x2, area ~10km. A prominent outward-facing scarp morphology is seen, with gentle back slopes and steep faces. This matches the morphology of ring scarps in a multi-ring basin [10]. The DEM was also used to extrapolate radial faults [9] which intersected at the centre of the structure, confirming the radial orientation [8]; and was also applied to an ‘inverted cone’ model for reconstructing the crater’s original size, by extrapolation of the structure at the FTZ and at the Ensels Thrust Zone. This suggests that Vredefort is a multi-ridged structure with at least two rings at diameters 146km and 186km [9]. The model was applied to the third outer ring structure giving a final original structural extent of 281km diameter, in good agreement with other results [3,12]. Figures 6 and 7 show a profile and cross-section covering ~45km out from the Inner Ring Collar.

Conclusion: 3D morphological modelling, combined with recognition of arcuate structures, add to the determination of size, structure and multiple rings at Vredefort. Many of these findings [7,9,11] are in agreement with workers using other multi-disciplinary methods [1-3]. Multi-ring Basins on Earth are difficult to confirm, however, [10,13] and further multi-disciplinary studies integrated with other digital data within a GIS still need to be done.