POTENTIAL OF RADAR IMAGING AND SOUNDING METHODS IN MAPPING HEAVILY ERODED IMPACT CRATERS: MAPPING SOME STRUCTURAL ELEMENTS OF THE HICO CRATER, TX.

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Abstract: Shuttle Radar Topography Mission (SRTM) and Ground Penetrating Radar (GPR) data collected over an area north of the town of Hico, central Texas, have been used to map disturbances in the surface topography and subsurface stratigraphy. The Radar topography results confirm the presence of multiple rings suggestive of an impact crater. Correlation between the orbital SRTM and on-the-ground GPR field data are affected by different biases related to variations in terrain and vegetation cover. Nevertheless, the correspondence of the two data sets supports the earlier conclusions that a complex, multiple ring impact structure is reflected in the topography of this area. The SRTM data reveal three previously unrecognized rings; with the outermost ring some 5-6 km in diameter. The crater appears to be significantly larger than the size (2.5 km diameter) previously inferred on the basis of aerial images [1, 2]. In addition, the GPR data suggest the presence of subsurface faulting that spatially coincides with the two inner rings of the crater. This suggests that the topographic rings are structurally controlled by faulting.

Introduction: The Hico crater is located N 32.03° and W 98.33°, 3 km North of the town of Hico, Central Texas, and some 90 km southwest of Fort Worth. A structurally disturbed area of 3 km diameter bounded by a ring, a graben and includes a stratigraphically uplifted core, approximately 1 km in diameter. These structures in an otherwise flat-laying, undisturbed sequence of Cretaceous sediments and the discovery of shatter cones identify this disturbance as an impact crater. The age of the structure is unknown, other then post-Cretaceous. It was also not known previously whether the structurally disturbed zone, manifested predominantly by folding rather than faulting, defines the crater in its entirety or whether the actual crater diameter is somewhat larger, possibly as large as 9 km [1], [2]. Aerial images of the Hico crater (see figure 1, bottom), suggests that the crater size is around 2.5 km. Erosion and vegetation have changed significantly the surface topography making very difficult to map the original global shape of the crater. Efficient subsurface prospections were required in order to accomplish this task and get more precise information about the crater form and dimensions as key information to any further studies.

Radar surface and subsurface mapping: Radar sounding and imaging techniques are able to probe the subsurface down from few tenths of centimeter to several meters depending on the frequency, the ground geometry (slop and surface roughness) and dielectric properties [3].

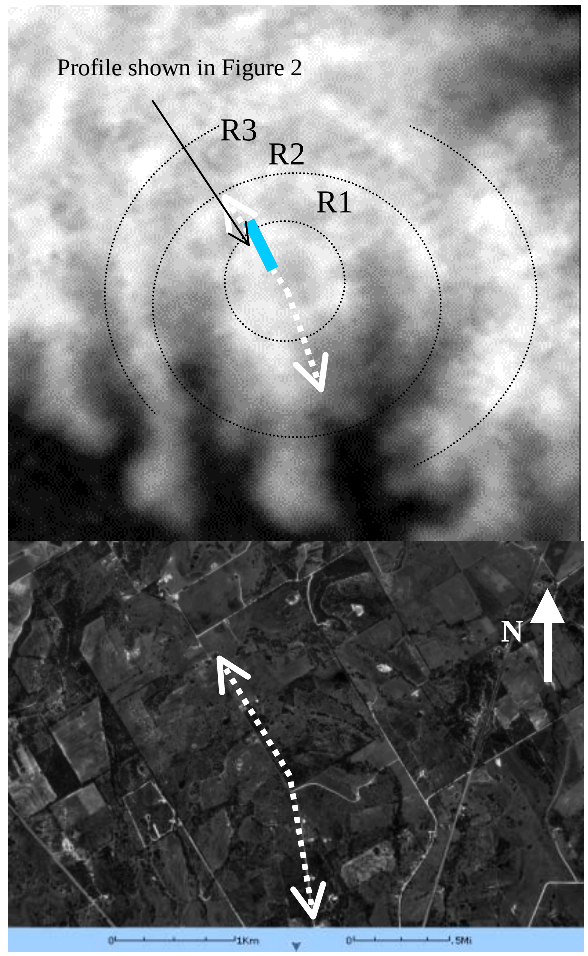

Figure 1: Bottom; an aerial image of the Hico crater. Upper; the 30 m resolution SRTM radar topographic image of the same region. The dotted line indicates the path on which the GPR survey has been carried out. (USGS/JPL images).

Geophysical investigations of the Hico structure have been carried out using the 30 m and 90 m resolution SRTM data to map the outer crater concentric rings, and ground penetrating radar data in order to map the surface topography and the subsurface anomalies an investigate the correlation between both radar tomographies data set.

SRTM surface mapping: The Hico area is covered with the 30 meter resolution, corresponding to the interfermometric Digital Elevation Model (DEM) obtained from the C-band frequency with a vertical resolution of 15 meters [4]. The upper part of figure 1 shows the radar topographic image acquired in February 2000 centered at the location of the Hico crater. We can clearly identify three rings noted R1, R2 and R3, and a central depression. These structures suggest that the crater is 5 km in diameter and that it is heavily eroded in its southern part, as previously recognized from field observations [1,2]. These ring structures differ diagnostically from their surroundings and seem unique for the general region. In order to confirm that the concentric circular rings observed are due to the presence of subsurface geological structures (and not produced by surface large scale roughness effects) we performed shallow subsurface mapping using GPR.

GPR investigation: Ground Penetrating Radar investigations have been carried out using a 200 MHz bistatic antenna along two radial profiles as shown in figure 1; GPR mapping is thus limited to the 2 inner rings. The choice of the frequency was made to get reasonable penetration depth and sufficient resolution to map possible subsurface structures at depths ranging from 10 to 20 m depending on the soil dielectric properties. Specifically we attempted to discriminate whether faulting or folding of the subsurface dominates and whether there is a relationship of subsurface structure and topographic rings. Reflections patterns from the GPR are very sensitive to the geometrical properties of the near subsurface: faulting and folding have different backscattered tomography on the GPR profiles. Folding would give a continuous layered tomography while in the faulting case hyperbolic reflection will appear in the tomography as a result of signal scattering in the faults [5]. The perturbed structure is mainly dominated by the presence of the upper homogeneous layer of limestones (20 to 30 m thick) overlaying sandstones. Both rocks type have relatively low dielectric constant when dry which should lead to a deeper radar investigation depth. We initially expected to get penetration in the order of 35-40 m with the high power bistatic configuration. Unfortunately moisture and possible thin clay layers reduced our penetrations depth to 15 to 20 m due the dielectric losses. GPR results show (cf. figure 2) the presence of hyperbolic signatures on the radar tomography that correlate to the surface anomalies producing ridges and rings observed on the disturbed area. Data analysis does not show significant continuous layering along the surveyed profile.

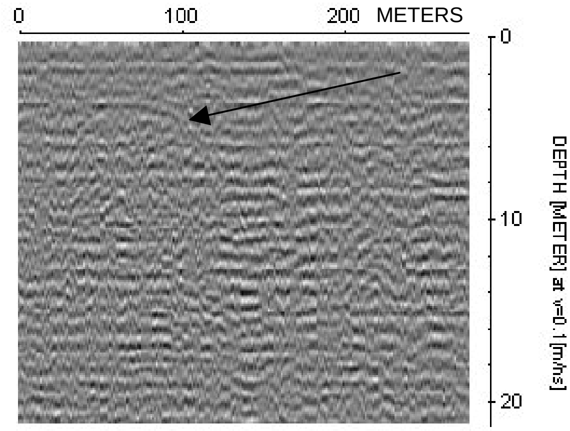

Figure 2: Part of the GPR tomography collected across the first ring R1 showing hyperbolic scattering indicated by the arrow suggesting the presence of faults in the limestone layer.

This is attributed to the geometrical discontinuities caused by the faulting of the subsurface and to the limitation of the penetration depth. Shallow GPR sounding performed in the central uplift area showed the near subsurface to be chaotic and non stratified.

Implications for planetary exploration: One of the interesting aspects of the Hico crater is that it is a good example showing the potential of radar remote sensing techniques for planetary exploration. These methods revealed a much improved topographic representation of the Hico structure, leading to the recognition of 3 concentric ring structures. It was also possible to demonstrate via GPR that these rings are structurally controlled and associated with faults. The latter seem to dominate the gross-structure of the crater, relegating the extensive folding mapped by [1,2] to the accommodation of relatively local stresses and mass-movements during the collapse of the crater's transient cavity. Simultaneous faulting and folding is observed in a fair number of other impact structures [6].

Conclusions and perspectives: SRTM data combined with a GPR field survey suggest that the Hico crater is an impact structure with a minimum diameter around 5 km, and that its concentric rings are structurally controlled by faults.

References: [1] Wiberg, L. (1981) *MS Thesis*, Texas Christian University, Dallas, 74 p. [2] Wiberg-Milton, L. (1987) *Research in Terrestrial Impact Structures*, Braunschweig, Germany, [3] Elachi, 1983, *Colwell RN Manuel of Remote Sensing 2nd edition*, Vol1, Falls Church, VA, [4] Gupta R. V. (2003) *Remote sensing and Geology Springer*. [5] Ulaby (1981), Vol.1, *Microwave remote sensing fundamentals and radiometry*, Ad-Wisely. [6] Kenkmann, T. (2002), *Geology*, 30, 231-234.