THREE DIMENSIONAL GRAVITY FIELD MODELLING OF THE CHICXULUB IMPACT CRATER.
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Introduction: The structure of the Chicxulub crater has been actively investigated by potential field modeling, seismic reflection and refraction surveys, and drilling during the decade since its recognition as the crater responsible for mass extinction which terminated the Cretaceous Period. Given the data sets that are now available to delineate crater structure a surprisingly diverse number of structural models remain proposed. For example, crater diameters ranging from the originally proposed 180 km to ~300 km are still current in the literature, and collapsed disruption cavity sizes (the observable parameter which leads to assessment of the impact's environmental perturbation) range from ~85 km to >120 km. We feel that the available data provide enough constraints to remove most of the variability in published sizes for the structural elements of Chicxulub. We have undertaken 3D modeling of the gravity field over the crater to refine our working structural model [e.g. 2, 3], and to compare our results with those of another 3D modeling effort [4]. The 3D gravity model also establishes an interesting target for scientific drilling.

3D Gravity Modelling: The 3D gravity modeling method employed is that of [1]. In this forward modeling procedure body geometry is specified using horizontally oriented polygons at arbitrary depths. The calculated field is integrated exactly in x and y, and then integrated across the third dimension, depth (z). The grid size was limited to 50 by 50 stations for computational practicality.

Gravity data: The gravity data compilation used (Figure 1) is based on land data collected five decades ago by Pemex (we have digitized unpublished Pemex maps filling in data gaps), results of an airbourne gravity survey conducted for Pemex which fills a data gap west of the crater, several recent land surveys (which have more than doubled available station coverage over the crater), and a shipbourne survey (which has filled in data gaps over the submarine portion of the crater). We have found that recently acquired density constraints have led to substantial revision of our 2D gravity models, and have been guided by those of [2], but anticipate additional progress in improving the validity of gravity models with additional constraints. The Bouguer gravity anomaly expression of Chicxulub has a magnitude of up to ~30 mGals, but still suffers substantial interference from regional anomalies unrelated to the crater; we have removed the regional anomalies guided in part by the regional crustal magnetic anomalies.

Model Results: The 3D modelling results (Figure 2) are particularly informative for the central structures of the crater. The central uplift (Figure 3) is revealed as a twin peaked structural high with vergence towards the southwest as previously indicated by 2D models [2] and consistent with seismic refraction results [5]. A "tongue" of the central uplift extends towards the northeast, in contrast to the steep gradients that bound it to the southwest. The width of the uplift at 4 km depth is ~45 km broadening to ~60 km at 5 km depth consistent with previous 2D modeling. The twin tops of the central uplift rise through the melt sheet to ~2 km depth for the density contrasts chosen. Choosing larger densities for the central uplift will allow for deeper tops to satisfy the central gravity high, but plausible limits still result in a relatively shallow depth for this feature, making it an achievable target for scientific drilling. This is in contrast to the results of [4] where a central uplift top of ~4 km was obtained. More variability would be permitted in the model, but the independent constraint on the width of the central uplift from seismic refraction work [5, 6] removes greater widths as possibilities. The twin peaked central gravity anomaly had first been recognized by Pemex 5 decades ago (the northerly anomaly was called the Progreso Maximo; the southerly, the Chicxulub Maximo), but the recent surveys have allowed clearer delineation of these features.

The twin peaks of the central uplift have an axis of symmetry oriented SW-NE, and we interpret this as indicative of the direction of a slightly oblique impact. The impact direction was towards the northeast based on the asymmetries preserved in various of Chicxulub's structural elements in addition to the vergence observed in the central uplift: compressional structures outside the crater rim, the rim uplift, compressional deformation preserved in the slumped blocks, morphology of the peak ring, off center position of the central uplift in the collapsed disruption cavity (CDC), elongated CDC, and initiation of slumping of Cretaceous stratigraphy off the Yucatan platform. This postulated oblique impact is at a much steeper angle and at right angles to that proposed by [7].

The shape of the modeled central uplift is radically different from that advocated by [8] who proposed a cup shaped central uplift (concave top) with a top at ~3 km depth, but of similar width. That interpretation was apparently based on extrapolating discrete inferred high velocity anomalies in the area of the central uplift [9] into an annular ring. Possibly two of these velocity features result from detecting the twin tops of the central uplift, but if the other features are real it would require substantial departure from density–velocity relations in the rocks of the central uplift, and we doubt that the central uplift has an annular top.

The filling of the CDC, which we interpret as melt, is revealed as a body slightly elongated in a NE-SW sense (Figure 3) with a size consistent with previous 2D model results. With the density contrast from samples from the top of the melt sheet a depth of the melt of ~4 km is obtained consistent with the result of [4]. This depth is dependent upon the density contrast used (-0.15 g/cc), however, and all the mass deficiency need not be melt. We note that seismic refraction detects a melt sheet contrast for only 1 km thickness [5]. The derived melt volume is 1.5 X 10^4 km^3, only slightly smaller than that of [4] and in good agreement with melt sheet volumes estimated by a variety of methods [10].

Figure 1: Gravity anomaly compilation over the Chicxulub crater; Bouguer gravity anomaly over land and free air anomaly offshore. Cool colours are lows, warm colours are highs; the coastline is indicated by a white line. (See text for additional detail

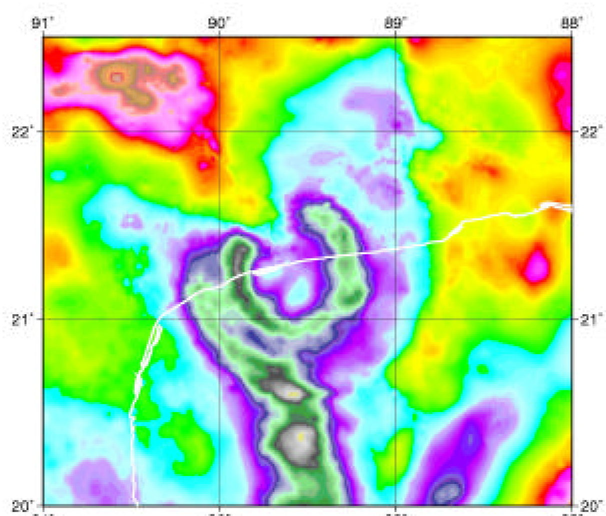

Figure 2: Results of 3D model calculation with same colour convention.

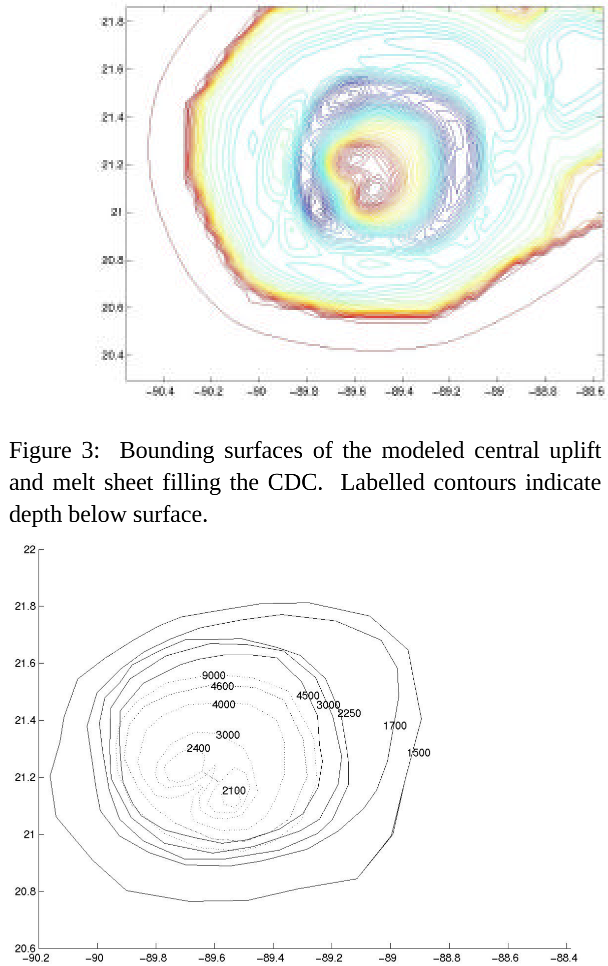

Figure 3: Bounding surfaces of the modeled central uplift and melt sheet filling the CDC. Labelled contours indicate depth below surface.

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