A GRAVITY SURVEY OF THE KENTLAND CRATER FORMATION.

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Introduction: The first comprehensive gravity survey since 1971 [1] of the Kentland Crater area in northern Indiana was conducted during the summer of 2022. Improved constraints on the density structure of the crater are provided.

The Kentland Crater structure is particularly advantageous for a geophysical study, as it provides a nearly flat, horizontal cross-section of a ~12 km diameter crater. Most of the surface material was eroded off due to glaciation processes during the most recent ice age. Therefore, Kentland Crater is an ideal location for gravity measurements, as topographic corrections are minimal. This unique geographic advantage allowed for a survey of the total extent of the crater.

We acquired gravity data throughout the region, including inside the Rogers Group Quarry that excavates the crater's central uplift. This vantage point is particularly unique for planetary science, as it allows us to probe an already heavily weathered complex crater even more deeply thanks to anthropologic intervention.

Methods: For this survey, we employed a Scintrex CG-6 gravimeter which typically provides 1-3 microGal accuracy, allowing us to provide the most accurate, updated gravity data for the area. The CG-6 gravimeter was used in tandem with a real-time kinematic GNSS system for quick cm-accuracy positioning. The gravity survey consisted of 2-mile to 0.5-mileresolution points taken on public roadsides throughout the Newton County and Benton County area (Figure 1). A cluster of points was taken in and around the Rogers Group Quarry located south of SR 24 and west of Kentland, IN. This area was of particular interest because it lies on and around the central peak of the crater and the quarry allows for measurement within the subsurface of the central peak (quarry bottom).

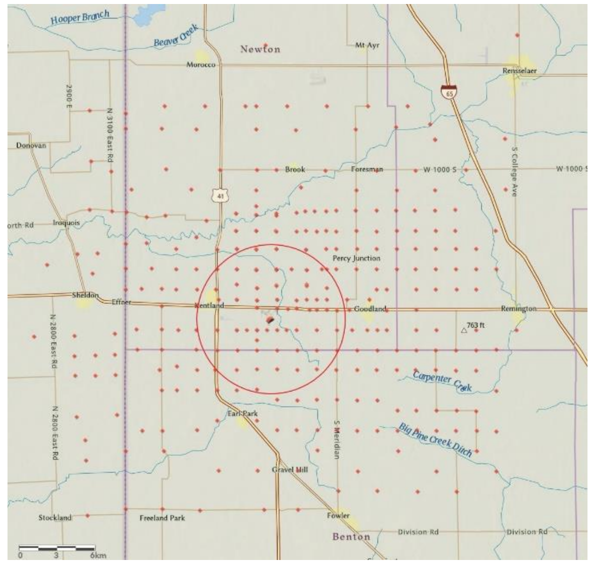


Figure 1. All gravity survey locations, indicated by red points. The cluster of points in the center indicates the Rogers Group Quarry and are located at the center of the crater structure. The expected crater rim (6-6.5 km radius [1]) is roughly outlined by a red circle.

Results: Our survey indicates a significant gravity high that correlates with the center of the crater structure (Figure 2). A subtle annular gravity trough is present surrounding the central peak within the expected crater rim. The central peak anomaly is found to be ~3 mGal (Figure 3), which is in agreement with the results found in [1]. However, there is no distinct discontinuity located within the radius range of the expected crater rim. We conclude that the exact crater rim location is not distinguishable with gravity measurements alone, and the conclusions reached by [1] could have been the result of a local gravity anomaly unrelated to the Kentland crater structure. Therefore, the Kentland crater's assumed diameter of 12 km is open to revision. However, there is a subtle discontinuity between 6.5 and 7.5 km from the crater center, which could be indicative of a rim structure.

Given ~600 meters of structural uplift, the 3 mGal gravity anomaly found in our survey indicates a difference in bulk density ($\Delta\rho$) of ~120 kg/m^3 between the central uplift and the surrounding bedrock. The expected density difference between solid limestone (central uplift composition) and shale (surrounding bedrock) is between 200-300 kg/m^3. The disagreement between the expected value and our survey results is likely due to porosity from impact fracturing. If we correct for low-density glacial till that blankets the region and thickens away from the central uplift (up to 100 m thick [2]), the central gravity anomaly further decreases and allows for greater concentration of porosity at the center of the crater.

Figure 2. Interpolated Bouguer gravity anomaly map. The 6 km expected crater radius [1] is indicated by the large black circle. Small black circles indicate survey locations. Gravity values have been corrected for free air anomalies, the gravitational attraction of the terrain, latitudinal variations, and have been plane-corrected for the slight topographic regional slope.

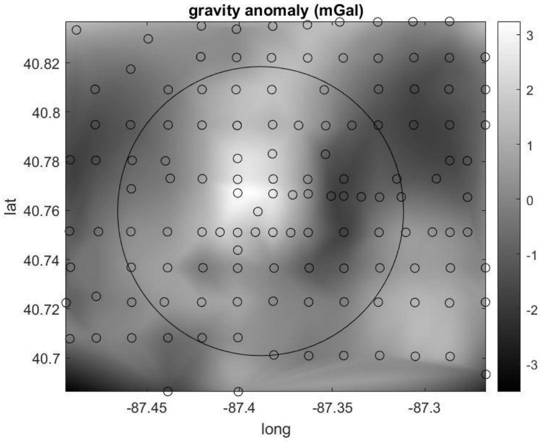
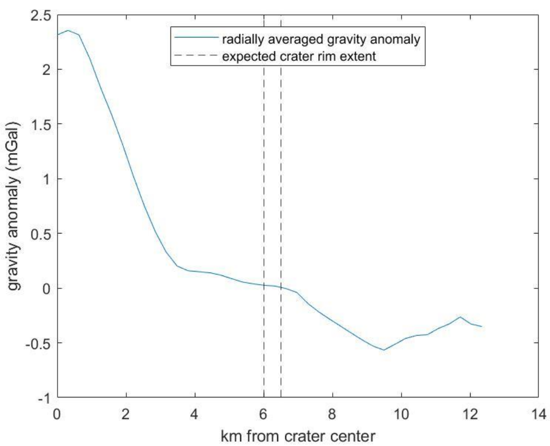


Figure 3. The radially averaged gravity anomaly, centered at the central uplift. Dashed black lines indicate the expected rim location minimum and maximum (6 km and 6.5 km respectively) [1]. Note the drop in gravity at the very center of the crater structure due to the absence of quarried rock from the Rogers Group Quarry.



Future Work: In order to further improve our understanding of the Kentland crater structure, supplemental geophysical investigation must be done. A comprehensive seismic study would illuminate any structural discontinuities not detected by gravity alone. A rim structure could be indicated by a low-to-high density transition outside of the annular trough found in this survey, indicating the edge of the impact fracture zone. Terraced faults surrounding the central uplift could also potentially be identified seismically. Terracing is likely to occur within a complex crater, but the significant erosion of this particular crater structure could make these faults more difficult to detect.

To further constrain the density of the central uplift, near-surface geophysical work is the next step. Passive seismic data could give a profile of glacial till thickness throughout the area. Understanding how the low-density blanket of glacial till changes throughout the survey area would allow for a more accurate density model, and in turn would provide a more accurate gravity anomaly value. This would allow us to further constrain the density difference between the uplifted limestone and the surrounding bedrock.

While the glacial till in the area is highly saturated, a GPR study could give essential insights into the exact density of the glacial till, a technique recently used to find an estimate of the bulk density of the lunar regolith [2]. Further, a GPR survey within the walls of the Rogers Group Quarry would provide a subsurface profile where seismic surveys are difficult to conduct. This data would elucidate the properties of the bedrock within the central peak and allow for a more accurate estimate of the porosity of the uplifted rock.

Once the geologic profile of the area is better understood, a reasonable estimate for the density and porosity within the crater structure could be attained. These values will give valuable insight into complex-crater formation processes.

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References:

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