A GRAVITY GRADIENT METHOD FOR CALCULATING BULK DENSITY IN TOPOGRAPHICALLY COMPLEX AREAS,
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Introduction: In the summer of 2022, a gravity survey was conducted to map the Kentland crater formation. During this survey, this team was granted access to the Rogers Group Quarry, located on and around the central peak of the crater.

The exact density and porosity of the material within complex crater structures is of particular interest to planetary science. These values can give valuable insights into the crater formation process.

In this abstract, we introduce a new method to extract absolute density from gravity measurements within topographically complex structures. It is notoriously difficult to glean useful information from gravity surveys in these types of areas due to highly varying surrounding terrain, which is not accounted for in commonly-used free air and Bouguer anomaly corrections. These correction methods are ideal due to their simplicity, but they are less and less useful on their own in increasingly varying terrain settings.

Gravity gradients are a commonly used technique in planetary science to probe density differences within the subsurface (a primary focus for the GRAIL mission). However, these measurements provide only the relative density of an area on a given planet. We propose to use highly varying topography as a tool for extracting exact density of topography in areas with both surface and satellite gravity measurements.

Methods: For areas with little to no topographic variation, the free air correction equation is linear (constant slope). However, significant surrounding topography can alter the gravity gradient at a given location. For instance, a tall rock face nearby would result in a gravity gradient lower than the free air correction gradient, rendering the free air correction insufficient. However, if the density of the nearby rock face is well-known, the gravity perturbation due to the excess of mass nearby is calculable, and can be incorporated into an additional correction.

For this method, we take advantage of this concept and propose that one can calculate the absolute density of the nearby terrain using the first derivative of the gravity gradient with distance from the topographic anomaly. The rate of change of the gravity gradient is determined by the density of the material nearby. Therefore, from gravity gradient measurements, one could infer the density of the terrain that caused the perturbation.

Surface gravity data has been used previously to determine the relative density of terrain surrounding the Apollo 17 landing site [1].

For this study, we use gravity gradients taken at various distances from the base of a rockface within the Rogers Group Quarry. The density of rock quarried from this location is well-known, and can be used to verify the results of this method.

We used a Scintrex CG-6 gravimeter, which provides 1-3 microGal accuracy, in tandem with a real-time kinematic GNSS system for quick cm-accuracy positioning. Figure 1 shows the quarry survey locations, and the red circle indicates the values used for this particular abstract.

Figure 1. (top) Topographic relief map of the entire Rogers Group Quarry complex. Red square indicates the location depicted in below image. (*bottom)* Green diamonds indicate survey locations within the quarry and the locations within the red circle make up the subset used for this study.

Results: Our gravity gradient measurements follow the expected shape (decreasing with distance from the cliff face). The gradient values do not approach the free-air gradient, possibly because of the influence of other quarry walls.

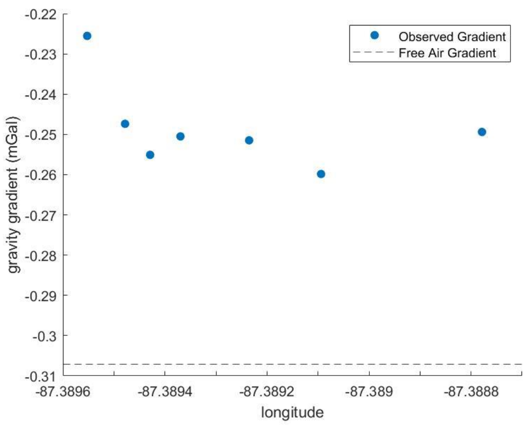

Figure 2. Gravity gradients with distance from cliff face pictured in Figure 1 (bottom). The accepted slope for the free air gradient correction on Earth is indicated by the dashed line.

Future Work: More corrections must be made to our gravity data before we can confidently estimate a bulk density value for the rock which makes up the cliff. It is assumed that the cliff face to the north significantly lowers the gravity gradient as well, and incorporating this topography in our corrections will result in gravity gradients that more closely resemble the expected exponential decrease that tends toward the free air slope of -0.3071. To this end, one challenge will be to accurately represent the precise shape of the terrain. This is non-trivial because the quarry is being actively excavated and the terrain model shown in Figure 1 is subtly different from the terrain that we encountered in our survey. We will incorporate more recent aerial photography as well as GNSS measurements of the cliff face in order to quantify these recent topographic changes.

One useful application for this method would be to use the absolute density values provided by this novel method in tandem with previously determined relative density values to obtain a map of absolute densities for a given area.

Surface gravity data has been used previously to determine the relative density of terrain surrounding the Apollo 17 landing site [1]. If we employ the method proposed in this project, absolute bulk densities of the Apollo 17 landing site region can be obtained.

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References:

[1] Urbancic N. et al. (2017) *JGR: Planets, 122(6),* 1181-1194.