A Gravity Survey of Barringer Crater: Data Reduction and Preliminary Analysis. C. D. Mitchell[1] and P. B. James[1], [1]Baylor University, One Bear Place #97354, Waco, TX 76798-7354

Overview: This work presents the results of a February 2019 gravity survey of Barringer Crater (colloquially known as "Meteor Crater") near Winslow, AZ. We have completed several analyses in an effort to combine previous survey data with our own survey to generate an updated Residual Bouguer Anomaly (RBA) map for Meteor Crater. The addition of this modernized survey—including crucial gravity measurements on the crater wall—yields a robust model that can be utilized for advanced crater modelling and future Meteor Crater research.

Methodology: In our previous abstract [1], we recreated and digitized the data sets from a previous gravity survey at Meteor Crater by Regan & Hinze [2] and performed terrain corrections using modern computational techniques for Meteor Crater. We also outlined the process of establishing a center to the Regan & Hinze gravity data in UTM coordinates, and the analyses that we performed as a preliminary action to surveying the crater. We determined the position of the survey's crater center to be 111.02274º West and 35.02772º North and concluded that the RBA may have been overestimated in Regan & Hinze's paper by as much as 0.15 mGals, suggesting the porosity under the crater is less than previously assumed. We have now completed a gravity survey over Meteor Crater, shown overlain with the prior survey data in hill-shade relief in relation to the data collected in Fig. 1. The addition of modern gravity data to the previous survey increases the coverage of the survey to areas thought previously to be unreachable, namely along crater walls where no data had been collected before. The survey was completed with 10m spacing intervals in these challenging areas, increasing our ability to detect near-surface variations in density as well as increasing the data density along crater walls. The only areas that we were unable to survey were the vertical cliffs present on three of our four radial transects. In these cases, we collected measurements immediately above and immediately below the cliffs. Lastly, this survey took advantage of real-time kinematic GPS equipment, and the gravity station's locations and elevations can be easily utilized to find precise positions of notable Meteor Crater features (crater center, crater rim, crater walls, etc.).

Gravity Data Reduction: Before beginning our analysis of the gravity anomalies in the area, we consider the assumed density of Meteor Crater. Using Nettleton's method and the results of our survey, we calculate the best-fit density for Meteor Crater's walls to be approximately 2300 kg/m^3, consistent with the assumption of the previous reference survey [2], shown in Fig. 2. To seamlessly splice our data with that of the previous work, we also consider different methods of applying the terrain correction to our data. We use a technique called multi-level discretization, outlined in our previous work. Multi-level discretization creates many bins of varying sizes from which the terrain correction can then be calculated from while retaining the higher resolution of our DEM and reducing computation times, utilizing a gravity-from-prism equation [3]. This equation can then be adapted to smooth the terrain in areas where small discrepancies exist between the DEM data and GPS data collected in the gravity survey, where the reported GPS height does not match the DEM. We adjust the DEM to the GPS height for the station to better calculate the terrain correction. We generated a new regional gravity gradient for the area and applied it to both datasets. Lastly, tares are applied where necessary to aid our interpretation when joining the two datasets.

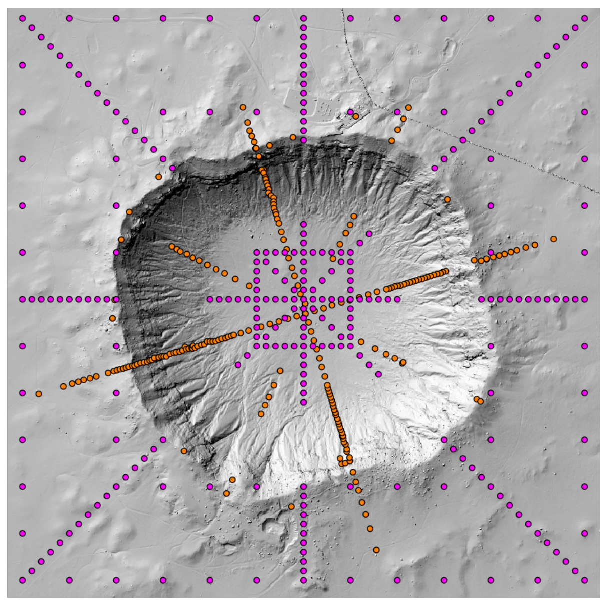

Fig. 1. Regan and Hinze gravity stations (purple) along with station locations of our new survey (orange). Hill-shade relief adapted from Palucis and McEnulty [4].

Results: The residual free-air anomaly (i.e., what remains after the regional trend has been removed) is plotted in Fig. 3. This map splices data from the previous survey by Regan & Hinze with our own data set. The combined map reveals that the free-air anomaly has values close to zero outside of the crater, increases by a few mGal at the crater rim, and plunges to a value as low as –15 mGal in the crater center. This makes sense: the free-air anomaly is generally correlated with topography at kilometer length scales, since high topography corresponds to an increase in mass.

In order to remove the influence of topography from the free air anomaly, we perform a correction that takes into account the local terrain. This yields the RBA, which we can splice with that of Regan & Hinze's work, as shown in Fig. 4.

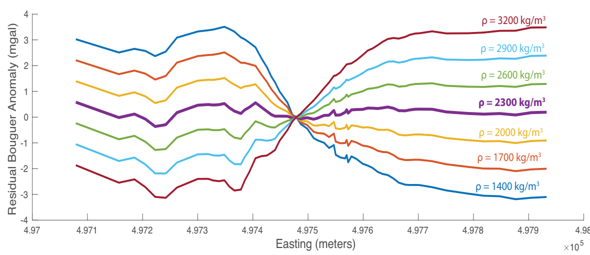

Fig. 2. Nettleton's Method applied to Meteor Crater Gravity data collected by authors. This plot shows the best-fit density for Meteor Crater is 2300 kg/m^3.

The more complete transects provided by our survey reveal a set of concentric RBAs. The crater rim features a RBA of approximately –0.8 mGal, suggesting there is some porosity of these areas that are not accounted for in our assumption of a uniform bulk density of 2300 kg/m^3. Additionally, our results show that several areas beyond the crater rim also show more negative residuals than previously suggested. This is likely due to variations of the near-surface lithology of the crater, namely the presence of a thick, loosely consolidated ejecta sheet. There is a negative RBA at the very center of the crater, and the edge of this negative anomaly coincides with the extent of the "playa", i.e., the lake sediments present on the basin floor. Consequently, this gravity feature should not be interpreted in terms of impact fracturing without more careful modeling.

Conclusion: Further modeling with this data set will offer new insight to cratering on Earth. This study identifies a strongly negative RBA associated with crater walls. This suggests that impact cratering generated more fracturing than previously assumed in the area, where the bedrock composing the crater walls now shows evidence of being less dense and highly fractured. Further analysis of these data will be completed for constraining the changes in density along the crater wall by application of Nettleton's method across the distinct lithologies on the crater wall. The data used to construct these figures has been made available at: 10.5281/zenodo.3600593, for future research.

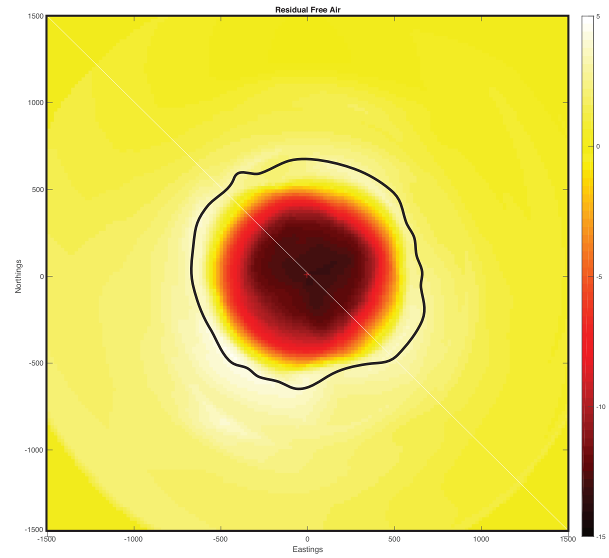

Fig. 3. Residual Free-Air Anomaly of Meteor Crater, combined data from Regan and Hinze and author data.

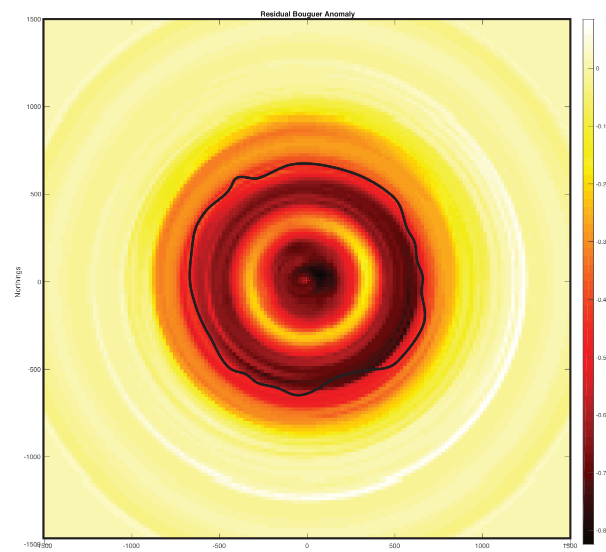

Fig. 4. Residual Bouguer Anomaly at Meter Crater, combined Regan and Hinze and author data.

Acknowledgements: This survey was aided by Dr. David Kring (LPI) and Tyler Leggett (Baylor). We would also like to than the Barringer family for permitting access to the crater floor.

References: [1] Mitchell C. D. and James P. B. (2019) *LPS L,* Abstract #2132. [2] Regan R. D. and Hinze W. J. (1975) *JGR, 80, No. 5.* [3] Banerjee B. and Das Gupta S. P. (1977) *GEOPHYSICS, v. 42, p. 1053–1055*. [4] Palucis M. and McEnulty T. (2010) *NCALM Mapping Project Report: Meteor Crater, Az.*