Lunar Surface Gravimetry at the Gruithuisen Dome for Density Estimates of Extreme Volcanics: A. Braun[1], K. A. Carroll[2], B. L. Joliff[3] and the Mons Explorer Team[3], [1]Queen's University, Dept. of Geological Sciences and Geological Engineering, 36 Union St, Kingston, ON, K7L 3N6, Canada, braun@queensu.ca, [2]Canadensys Aerospace Corporation, 10 Parr Blvd, Bolton, ON, L7E 4G9, Canada, [3]Washington University in St. Louis, McDonnell Center for the Space Sciences, Washington University, One Brookings Drive, St. Louis, MO 63130-4899, USA

Introduction: Gravity observations on the lunar surface have not been attempted since the Apollo 17 mission in 1972 [1]. The recent lunar orbital gravity mission GRAIL has provided gravity data with a limited spatial resolution of 9-15 km [2, 3]. However, gravimetry is a technique which is able to constrain the density of lunar materials, a fundamental parameter needed towards better understanding of processes leading to the formation of the lunar surface. Herein, we present a modelling study of lunar surface gravimetry to constrain the bulk density of a prominent lunar feature, the Gruithuisen Domes in the Oceanus Procellarum KREEP Terrane [4]. The domes have been proposed as alkali feldspar and silica rich volcanic materials in strong contrast with the surrounding mare basalts, which make up most of the lunar volcanic units [5]. The processes leading to these extreme volcanic features are still under debate, and one of the illuminating parameters towards improved understanding is to estimate the bulk density of the dome material from surface gravimetry. This study is in direct support of the proposed Mons Explorer Prism-2 Mission.

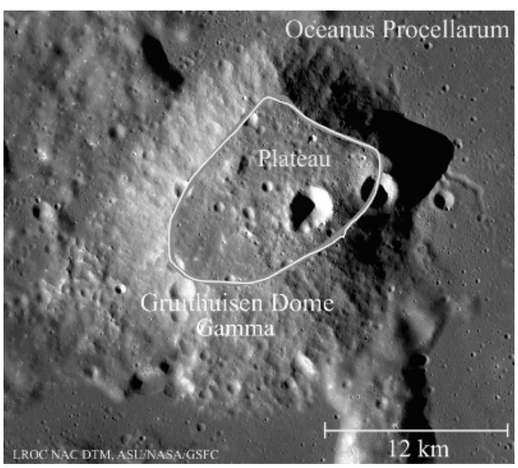

FIGURE 1: Gruithuisen Dome Gamma topography from the NAC DTM [11]. The Plateau shows the area of potential landing sites for gravity surveys.

Lunar gravimetry forward modelling: The density contrast between mare and silicic materials as expected for the Gruithuisen domes ranges in value between -900 and -300 kg/m^3 [6, 7], but nothing can be confirmed without an in-situ observation of gravity. Even if the geometry of the silicic lithologies cannot be determined from a few gravimetry observations, the density can be estimated to a higher accuracy than the current uncertainty. Such gravity forward models have been presented for survey planning [8] or to investigate the potential to resolve resolve lunar lava tubes [9]. Herein, we employ the IGMAS+ modelling suite [10], which calculates 3D models of density distribution to estimate gravity and gravity gradients at specified measurement stations. The input parameters of the models include the subsurface density distribution and the topography (e.g. from SLDEM and NAC Digital Terrain Model [11]. Gravity stations or observation points are distributed on the terrain surface, e.g. where a rover-based gravimeter would conduct its measurements. The output includes vertical gravity and gravity gradients, the latter provide more spatial detail, but are more difficult to obtain, despite that a second gravimeter is proposed at the landing site. The model parameters consist of the NAC DTM with a subsampled resolution of 20m, the dome material density and the mare density. From a gravity station grid with a station spacing of 50m, we interpolate 500m long rover traverses to simulate a realistic surface gravity survey.

Space Gravimeter VEGA: The proposed gravimeter to be deployed on a lunar rover is VEGA. It comprises a single accelerometer, mounted inside a two-axis gimbal [12, 13]. VEGA does not require levelling and outputs absolute gravity observations, i.e., zero bias. No field calibration or tie into reference points is needed. For an integration time of 10 minutes, VEGA can achieve a RMS accuracy of approximately 0.3 mGal (3 μg) on the Moon with improving sensitivity with increasing observation time.

Results: Based on constraints posed by the mission and the rover capabilities, we estimate the gravity data and the density for a rover traverse of 500m. The traverse length and orientation are critical for the accuracy of the density estimate, with the best traverse being

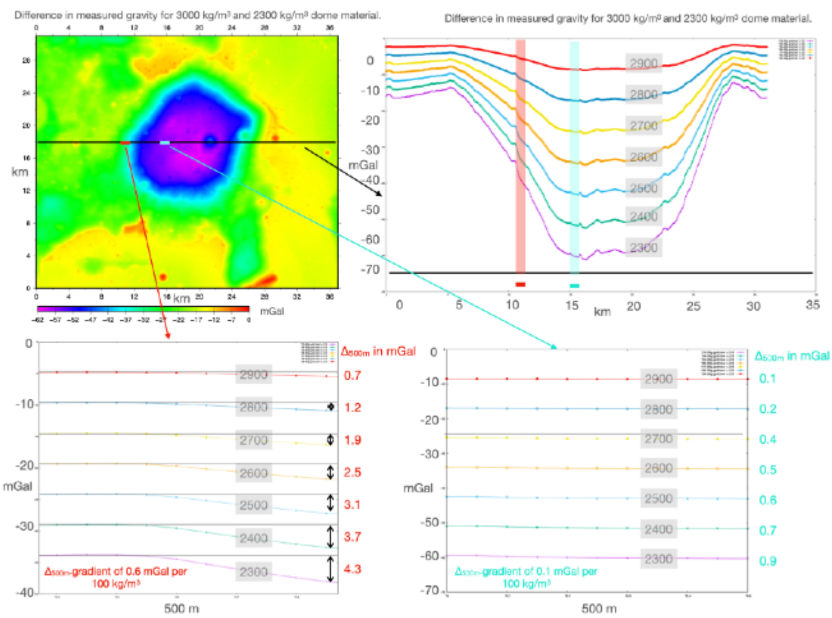

FIGURE 2: Gravity forward model of Gruithuisen dome structure underlain by mare basalt (3000 kg/m³). Top left: Difference in measured gravity at surface between a dome with density of 3000 kg/m³ and 2300 kg/m³. Black, red and cyan lines indicate traverse locations for the other panels. Top right: Gravity difference for different dome densities. Shaded regions show 500 m traverses in an area of high gradient (red) and low gradient (cyan). Bottom panels: 500 m traverses and their gravity difference from start to end of the traverse (Δ500 m) for different densities. The gravity gradient varies between 0.1 mGal per 100 kg/m³ and 0.6 mGal per 100 kg/m³. Considering a VEGA sensitivity of 0.3 mGal, the bulk density of the dome could be estimated with an uncertainty of 50-300 kg/m³.

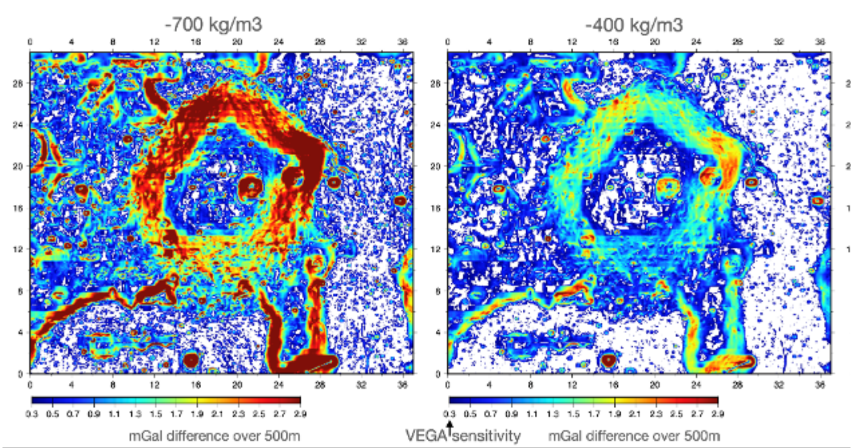

FIGURE 3: The panels show the difference in gravity between the start and the end of 500m long traverses for two different density contrasts between the dome and mare materials. With a VEGA sensitivity of 0.3 mGal, the estimate of the dome bulk density would be possible in any colored area.

along the steepest gradient of the gravity field. For the dome's plateau with a diameter of 12km and an elevation of 1500m above the mare basalt plains, we model any 500m traverse in 50m increments. The expected density contrast between mare volcanic material and the dome's silicic volcanic material ranges from -300 to -900 kg/m³ [7]. Figure 2 shows forward modelled gravity differences for three traverses. The accuracy of the estimate is clearly a function of the location, the orientation and the terrain variability. Figure 3 shows the locations for which density estimates can be achieved assuming 0.3 mGal sensitivity and a density difference between mare and dome of -700 and -400 kg/m³.

Conclusions: 500m long rover-based gravity surveys using a VEGA gravimeter could provide estimates of the bulk density of the dome structure accurate to 50-300 kg/m³, depending on the landing site and its local terrain. The bulk density can further constrain the geological and geochemical observations in the proposed Mons Explorer Mission.

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