Application of the Wedge-Pentahedra Method (WPM) to the Apollo 17 Landing Site and Comparison to the Traverse Gravimeter Experiment Measurements. M. Noeker[1,2] (matthias.noeker@observatory.be) and E. Tasev[1] and B. Ritter[1] and Ö. Karatekin[1], [1]Royal Observatory of Belgium (Avenue Circulaire 3, 1180 Uccle, Belgium,), [2]Université catholique de Louvain (Place de l'Université 1, 1348 Ottignies-Louvain-la-Neuve, Belgium).

Introduction: Surface gravimetry is a well-established geophysical technique on Earth [1]. The number of extraterrestrial applications, however, is still very limited. The Apollo 17 mission carried the Lunar Surface Gravimeter (LSG) which malfunctioned [2], and the Traverse Gravimeter Experiment (TGE) which returned surface gravity measurements, not only at the Lunar Module (LM), but likewise at different stations along the Lunar Roving Vehicle (LRV) traverse [3]. Gravimetric data recorded by the Curiosity rover accelerometers allowed to infer subsurface material properties on Mars [4]. Currently, the GRAvimeter for small Solar System bodies (GRASS) is being developed [5] as part of the ESA Hera mission to record surface gravity on the asteroid satellite Dimorphos [6].

While the GRAIL mission measured the Lunar gravity field from orbit [7], localized geophysical studies demand surface gravimetry. Using a surface gravimetric survey, lava tubes can be detected and located [8]. Rover-based gravity surveys have been proposed using differential gravimetry, measuring inside and on top of an underground lava tube, allowing to infer information of the lava tube roof material [9]. In this context, we apply the new Wedge-Pentahedra Method (WPM) [10] to the Apollo 17 (A17) TGE data set for topographic correction. These measurements were analyzed initially by [3] and later by [11], revealing a subsurface density anomaly in the Taurus-Littrow Valley. However, both studies used flat-topped prisms for topographic corrections, creating a discontinuous surface. The WPM allows to assess the topographic gravitational influence at variable resolution, with a continuous surface in the surrounding of the A17 landing site (LS), removing the approximation error on the surface.

In this work, we apply the WPM topographic correction to the TGE measurement locations. As a first step of the ongoing work, we present results of the gravitation analysis only considering *homogeneous density* in the Bouguer plate and topography.

Topographic Data and Measurement Locations: We have obtained the topographic data from JMARS [12] taking the *Blended LRO/LOLA and SELENE/Kaguya DEM* data set[1]. The spherical coordinates of the measurement stations reported in [3] are obtained from [13] and we convert them by simple transformation into Cartesian coordinates. The measurement stations and the relative gravity difference is presented in Table 1. Note that Station 2A is not reported in [13] and therefore excluded in this study to avoid inconsistencies in the evaluation location.

Table 1: *TGE measurement stations, relative gravity* Δg *measurement [3], and locations reported by [13].*

Station	Δg [mGal]	Lon. [°E]	Lat. [°N]	Radius [m]
LM	0	30.77168	20.19091	1,734,774
Station 1	-4.6	30.78653	20.15690	1,734,765
Station 2	-50.8	30.53033	20.09916	1,734,953
Station 2A	-40.5			
Station 3	-16.5	30.56556	20.17402	1,734,901
Station 4	-4.5	30.62427	20.21532	1,734,854
Station 5	-10.6	30.72611	20.18572	1,734,809
Station 6	-36	30.79997	20.28993	1,734,835
Station 8	-31.6	30.87753	20.27663	1,734,777
Station 8	-32.5	30.87753	20.27663	1,734,777
Station 9	-12.7	30.83264	20.23141	1,734,749
Station 9	-12.9	30.83264	20.23141	1,734,749

We rotated the local surrounding of the LS using the original LS surface vector. Here, we investigated a local surrounding of 40×40 km², centered at the LS (Figure 1), including the neighbouring massifs.

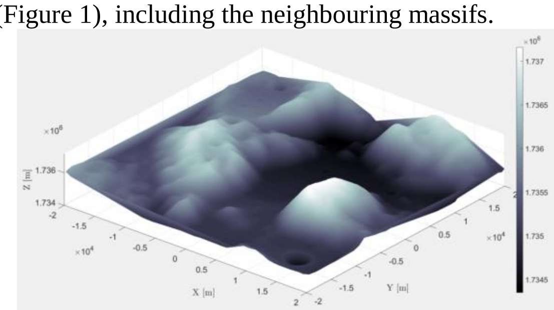

Figure 1: *Imported A17-LS-surrounding rotated surface, with reduced resolution of every 20th point and a total area of (40 km)². Note that here the Y-axis aligns with the Taurus-Littrow Valley, the North Massif is on the –X and the South Massif on the +X side.*

WPM Surface Solidification: With the surface in place and rotated, the WPM solidifies the local surrounding in preparation of the topographic reduction. This is shown in Figure 2, together with the gravity evaluation points corresponding to the points listed in Table 1. Clearly visible, the measurements took place in the Taurus-Littrow Valley, between the South massive (closest to station 2, +X-direction) and the North massif (closest to station 8, −X-direction) [3].

WPM Gravitation Results: In a first step, we compute the gravitation considering the Bouguer anomaly, consisting of free-air gradient, Bouguer correction (plate) and topographic correction (here:

[1]https://astrogeology.usgs.gov/search/details/Moon/LRO/LOLA/Lunar_LRO_, accessed on 17.12.2021.

WPM), being the most relevant for a relative comparison. For this, we consider initially a homogeneous density for both terrain and Bouguer plate of ρ = 2,000 kg/m³ [3]. The resulting *relative* gravitation signal is shown in Figure 3 (top).

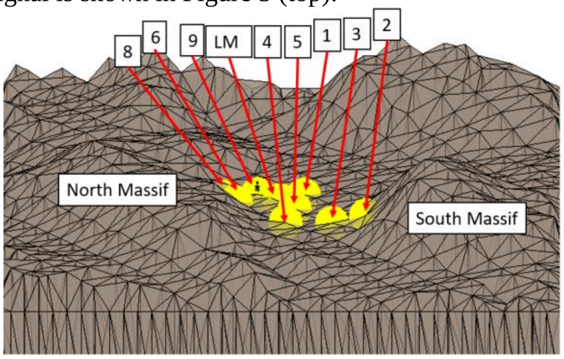

Figure 2: *WPM volume from solidified surface, with measurement stations (yellow). Cf. Figure 1 for different view.*

Note that for this comparison, we only consider the relative difference, and we therefore present the TGE data relative to the LM site and remove the difference in TGE and WPM means from the WPM. Considering a constant density for terrain and Bouguer plate, we minimized the difference using a least-square approach, iterating from 0 to 4,500 kg/m³ in steps of 50 kg/m³, limited by the computation time. While the sum of the absolute difference for all 11 stations was 150.9 mGal for 2,000 kg/m³, the best fit was found for constant densities of 750 kg/m³ with 145.1 mGal (Figure 3 (bottom)). This residual misfit is still too large (145.1 mGal / 11 Stations = 13.2 mGal), and from a geophysical perspective, this best fitting density value is too small, demanding an extension of the model to account for subsurface density variation. Especially at LM site and Stations 4/5/1, the resulting *relative* signal was lower than the measured, supporting the concept of a (denser) subsurface anomaly [3, 11].

Future work: As the constant density does not provide a good agreement with the ground-truth data for all densities, we will extend the WPM to add a subsurface anomaly, top-bound by the real Lunar surface. This will extend the space to analyze various further test cases, not only varying the density (this work), but also density contrast Δρ, depth and geometry (e.g. by extending it into the side-valley (+X-direction)) of the subsurface anomaly. Like this, we will find the best fit of this new simulation method and the TGE data, possibly revealing more detail on the local subsurface.

Conclusion: We have adapted the WPM [10] to the Moon and applied it to the A17 LS, allowing to consider the continuous lunar surface in the topographic reduction. We compared our modelled gravitation to the TGE data and varied the subsurface and topography density. Here, the best agreement was found for 750 kg/m³, while this low value and the remaining misfit demands a more complex analysis in the future, e.g. assessing a possible subsurface anomaly [3, 11] of complex shape. Applying the WPM is of specific interest in the case of surface gravimetry where the local topography cannot be neglected nor approximated.

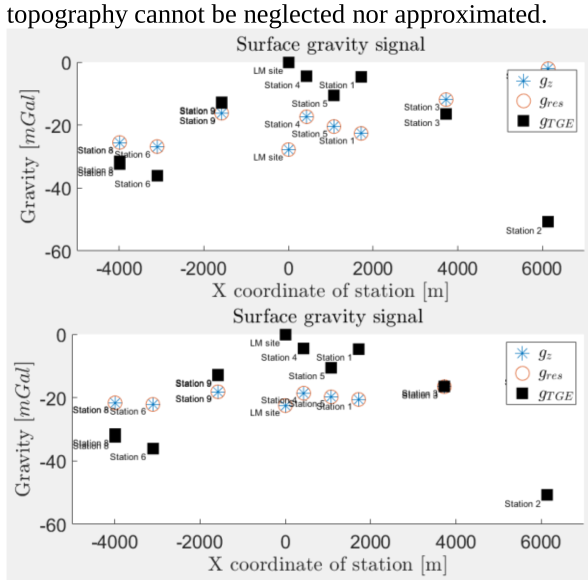

Figure 3: *Simulated relative gravitation results for constant density 2,000 kg/m³ (top), and for best fitting value of 750 kg/m³ (bottom) w.r.t. LM site measurement. TGE denotes A17 data, g_{res} and g_z resulting and vertical gravitation, respectively.*

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