Distribution of Shida number over the Moon based on virtual deformation signature. K. Karimi[1], G. Kletetschka[1,2], [1]Charles University, Albertov 6, Prague, 12843, Czechia, kurosh.karimi@natur.cuni.cz, [2]University of Alaska-Fairbanks, 903 N Koyukuk Drive, AK, USA, gkletetschka@alaska.edu. for second author

Introduction: The dichotomy of the Moon is a prominent visual quality of this celestial body. This characteristic is manifested in many physical properties of the near side and far side- gravity anomalies, thickness, brightness, elevation, crater density, mineral composition etc.- are all examples of these properties [1]. This dichotomous feature prompted us to examine the relative horizontal elasticity (Shida number) of the lunar crust based on the craters' virtual deformation, distributed almost all over the crust. Although the crater density is less on the near side than the far side, it can still meet our goal, and could be informative in the scope of this work. We apply concept of Virtual Deformation (VD) [2]. It is the crustal deformation of a planet in response to its gravitational field. To analyze the VD of the lunar crust, we used GRGM1200A gravity model [3]. This model reaches the degree and order (d/o) of 1200, but we truncated it at d/o=600, which was recommended by the authors of the model. The grid resolution of GRGM1200A at d/o = 600 is about 10 km on the ground with precession of around 10 mGal. Because of the available grid resolution, the craters with diameter of about 60 km and higher are considered in this study.

Impact process: Whenever a projectile (impactor) approaches the surface of a planet, a great deal of kinetic and thermal Energy is released in the form of an explosion. This energy expands in as spherical wave, that is why the planar shape of the impact craters on the planetary surfaces are circular. The diameter range of the formed crater is an order of magnitude larger than the projectile dimensions. This is because of the high velocity (momentum) at the time of the impact result in kinetic to heat energy transfer that convert the impactor into the liquid and vapor phase with tremendous expansion potential that results in explosion. The projectile conversion generates an excavation in the target material with an order of magnitude larger diameter [4, 5]. The impact event has four phases - (1) contact and compression, (2) excavation (3), post impact and modification [5]: 1.The impactor (meteorite) approaches the target (Moon), and the two bodies come into contact and the explosion occurs. 2.Because of the high velocity of the impactor (40 000 ± 20 000 m/s) during the contact, it turns to a scalding mass of expanding gas (the temperature change in this process is about 5000 °C), and a part of the surface and most of the impactor are vaporized. 3.The gravity field of the planet acts as a key agent to modify the morphology of the crater which is dependent on the characteristics of both the target and impactor.

Topography and megabasins: Pre-Nectarian system is the first geological period of the lunar crust. It starts from the solidification of the crust and ends with Nectaris basin impact [1]**.** The outstanding features of this period is formation of three megabasins that changed the shape of the Moon (Figure 1); one of them, Near Side Megabasin (NSM) is the source of the Moon's dichotomy. Firstly, a giant impactor struck the near side of the Moon and the NSM formed. Because of this collision, the near side was thinned; a part of the ejecta dissipated into the space and the remaining ejecta was dispersed and accumulated on the far side, thickening the crust and forming a far side bulge [1]. Two impacts that formed the other megabasins were Chaplygin-Mandel'shtam megabasin (CM), and South Pole Aitken megabasin (SPA). After the NSM impactor, the CM and SPA impactors landed on the far side bulge and modified its shape. Yet, the dichotomy of the Moon was preserved (Figure 1). The ejecta, aggregated on the far side, may be more porous than the near side. Therefore, the plasticity and/or elasticity of the far side may be different than on the near side.

Virtual Deformation (VD) and Shida number: The lack of mass due to the generated cavity in the impact area, and extra mass, accumulated as the rim, both disturb the equipotential surface (geoid) of the Moon in that district, which in turn give rise to the deflection of vertical and VD. As a result of this deflection, the gravitational field of the Moon creates a tidal type force, exerting on its own crust and causing horizontal displacement of any surficial elements. Because of this VD, a horizontal unit circle on the crust is deformed. The total dilatation of this deformation is [2]:

$$c = -\frac{l_s R_M}{g_n}\left(T_{xx} + T_{yy}\right) = -\frac{l_s R_M}{g_n}\left(\nabla . \mathbf{T_H}\right) \qquad (1)$$

Where l_s, is Shida number (the horizontal elasticity coefficient), R_M and g_n are the radius and the normal gravity of the Moon, in the order. T_H and T_{ij} are, respectively, the horizontal components of the gravity disturbance and second horizontal derivatives of the disturbing potential.

$$\mathbf{T_H} = \begin{pmatrix} T_x \\ T_y \end{pmatrix}, \quad and\ T_{ij} = \frac{\partial}{\partial i}\frac{\partial T}{\partial j}$$

The impact-related VD depends on five variables: 1. The material of the substrate (horizontal elasticity), 2. Size of the impactor, 3. The impactor's velocity magnitude, and 4. Its velocity direction, 5. Material of the impactor. If the lunar craters are classified as some size groups (60-80 km, 80-100 km 100-120km, 120-140km, 140-160km, and 160-180km), and each group is consid-

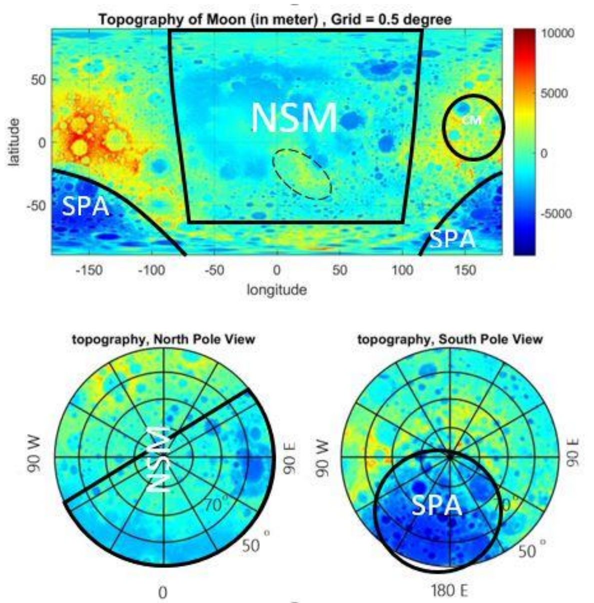

Figure 1. Topography of the Moon along with the NSM, SPA, and CM megabasins.

ered separately, the effect of "size" could be partly adjusted. Inasmuch as we deal with a statistical problem, an average response examination of all the datapoints of each crater may adjust the effect of velocity orientation to some extent. Though not much could be done in recognition of the velocity magnitude, consideration of the craters with diameter above 60 km may decline a large number of secondary craters, causing error in the attained solutions. Provided we ignore all the variables related to the impactor, the final VD of the craters depends on the target material (horizontal elasticity). In this condition, we suppose that the average VD of all the craters from the same group should be equal; from this assumption we can achieve the horizontal elasticity distribution (Shida number) of the crust in the respective craters' locations. If we have $c_{ave\,1} = c_{ave\,2} = c_{ave\,3} = \cdots = c_{ave\,n}$ for all the datapoints of a specific group of craters (n is the number of the group members) , considering equation (1), and the fact that $(\nabla.\mathbf{T_H})$ for each crater is different, i.e.,

$$(\nabla.\mathbf{T_H})_1 \neq (\nabla.\mathbf{T_H})_2 \neq (\nabla.\mathbf{T_H})_3 \neq \cdots \neq (\nabla.\mathbf{T_H})_n \qquad (2)$$

we can infer the distribution of Shida number over the lunar crust (Figure 2). According to equations (1) and (2), the variations of l_s and $(\nabla.\mathbf{T_H})$ are opposite.

Results, discussion and conclusion: The Normalized Shida number distribution of the lunar crust for all examined groups of crater is shown in Figure 2. Each crater (colorful square) represents its own relative Shida number. The darkest color scale signifies an absolute plastic state ($l_s=0$), and the lightest yellow color indicates the most elastic state ($l_s=1$). The Shida number at each category of the craters follow a similar behavior over the crust, that is, the l_s over the highlands is small and over the lowlands is bigger.

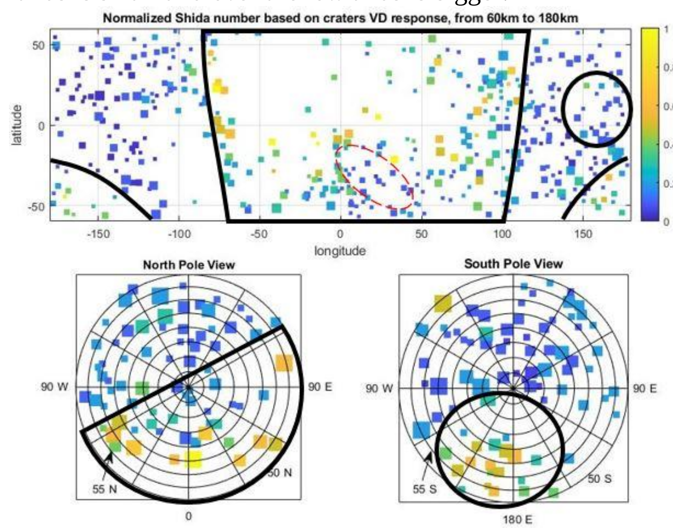

Figure 2. distribution of the Shida number over the lunar crust

The Shida number, specifically, has the greatest values in several zones inside the NSM. As with NSM, the l_s distribution over SPA is of greater values relative to the elevated surrounding sections. In the NSM (except for the encircled highlands) in figure 2, or inside SPA, there are a number of squares with a variety of sizes, representing Shida number of their respective craters, with green and yellow colors. Even though the l_s is not exactly analogous in each of these megabasins, its variance is between 0.4 (green) and 1 (pale yellow), distinguishing NSM and SPA horizontal elasticity from the elevated districts. The l_s over the highlands, in opposite, does not exceed 0.2.

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