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A quantitative geometric model of relief-forming potential in terrestrial planets

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Abstract

One of the most interesting results of the comparative planetology is realization of a fact that relief ranges of terrestrial planets increase with the solar distance. If tides play a leading role in surface disturbance then one should expect an inverse tendency: the closest to Sun planets must have rougher surface reliefs. But recent MESSENGER data confirm that Mercury is much smoother than Mars. What makes the outer terrestrial planets have larger relief ranges than these of the inner planets? The wave planetology [1-5 & others] has its own answer to this question and, moreover, a quantitative answer in form of a visible geometric model.

The wave planetology' third theorem [1-5] states that "Celestial bodies are granular". This tectonic granulation in any celestial body is a result of their movements in keplerian non-circular orbits with periodically changing accelerations. These endless cyclic changes (+ speeding and – braking) evoke in the bodies standing warping waves propagating in rotating bodies (but they all rotate!) in four ortho- and diagonal directions. An interference of these waves produces uplifting (+), subsiding (-) and neutral (0) regularly disposed tectonic blocks. Their sizes depend on warping wavelengths. The fundamental wave 1 produces ubiquitous tectonic dichotomy - segmentation (Theorem 1), the first overtone wave 2 produces tectonic sectoring (Theorem 2). On these most pronounced warping forms are superimposed tectonic granules (Theorem 3) size of which is inversely proportional to bodies orbital frequencies: higher frequency – smaller granules, lower frequency – larger granules (Fig. 1). There is the following row of granule sizes equal to a half wavelength (it includes the solar photosphere at one end and asteroids at the other). Photosphere $\pi R/60$, Mercury $\pi R/16$, Venus $\pi R/6$, Earth $\pi R/4$, Mars $\pi R/2$, asteroids $\pi R/1$ (R – a body's radius). All these sizes are tectonically expressed. For examples, the long known solar supergranulation with diameters of supergranules 30 to 40 thousands km or the terrestrial superstructures of the Archean cratons with diameters ~5000 km. (Fig. 1, 2).

The above granules inscribed in a great planetary circle (equator) as standing waves (Fig. 1) show the relief ranges increasing with the solar distance. These waves, obviously not tidal, could be called "swing waves". Their amplitudes are expressed by the granules radii.

The geometrical model of Fig. 1- 4 allows measuring a theoretical surface roughness and comparing it with observations. Cosmic experiments of the last several tens of years produced rather detailed maps of many Solar system bodies and one can use estimates of the relief ranges at some of them. In 1995

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when the publication [6] was prepared we knew that relief ranges increase from Venus to Mars from ~14 to ~30 km, Earth being in between with ~20 km. Without adequate topography on Mercury we theoretically assumed that this planet's relief range must be significantly lower (3-6 km) just to not violate the observed sequence (Fig. 5). Recently acquired Messenger's radar measurements (2008) show that the real range indeed does not exceed ~5 km and for widespread lobate scarps just a bit over 1 km [7]. And what is important, this small vertical relief differentiation is physically logically (the angular momentum action) accompanied by small petrologic (density) differentiation expressed by a low albedo range [8] (Fig. 5). This correlation is an illustration of the forth theorem of the planetary wave tectonics – "Angular momenta of different level blocks tend to be equal " [1-5]. With increasing relief ranges density ranges between rocks building lowlands and highlands also increase (Fig. 5).

So, the real relief amplitudes for four terrestrial planets are as follows: Mercury ~5 km, Venus ~14 km, Earth 20 km, Mars ~30 km (the martian relief span can be increased to 35 km if one takes into account collapsed summits of giant volcanoes with caldera radii 40 to 50 km and slope angle 5-6 degrees what makes heights of collapsed cones 4 to 5 km). Comparative to the Earth's span 20 km taken as a unit one has: Mercury 0.25, Venus 0.7, Earth 1.0, Mars 1.5 (1.8). Theoretical ranges taken as tectonic granules radii in planetary spheres reduced to unity for stressing a role of wave numbers are as follows: Mercury $2\pi R/64.08$, Venus $2\pi R/24.34$, Earth $2\pi R/16.44$, Mars $2\pi R/8.8$. Relative to the Earth's range one has: Mercury 0.256, Venus 0.675, Earth 1.0, Mars 1.868. One can see a remarkable coincidence of the real measurements and the theoretical estimates [9]. Now, if one takes the real sizes of planets (Fig. 4) the overall picture slightly changes with smaller ranges for Mercury and Mars but the established important tendency remains.

This tendency can be projected into the asteroid belt where bodies are flattened and curved and thus have greater departure from a sphere and greater relief range between uplifted and subsided segments (hemispheres).

At the other end of the analyzed sequence is the solar photosphere where holes of the solar dark spots produce relief range of the order of ~300 km. Relative to the solar radius (~700 000 km) it is not much and does not spoil a perfect solar sphericity. From our wave point of view a relief range mainly depends on orbiting frequencies and thus on size of supergranulation and should be ~183 km [10]. This figure is not far from the approximate observational data and thus is logical continuation of our wave sequence for solid planets into gaseous media.

One more important confirmation of wave relief-forming potential of celestial bodies of various sizes and physical states very recently came from the icy saturnian satellites [11]. The saturnian system mimics the Solar system but orbital frequencies of its satellites starting from Iapetus are higher than the Mercury's one. So, this satellite sequence is a valid continuation of frequency row from the higher frequency end. Recently published data on limb roughness of saturnian icy

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satellites [11] show that the roughness increases with the increasing distance from the planet, thus, with diminishing orbital frequencies proving the earlier established tendency. It is interesting that two near orbital frequencies, these of rocky Mercury and icy Iapetus (1/88 & 1/79 days) produce similar relief ranges (about 2 to 5 km, Iapetus ‘ roughness is 4.1 km [11]). Thus, the warping waves act in various media and their relative lengths and amplitudes (relief ranges) depend mainly on orbital frequencies.

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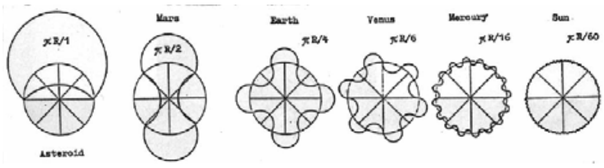

Fig.1: Geometric presentation of warping waves in the planetary system. All bodies are reduced to one size [9].

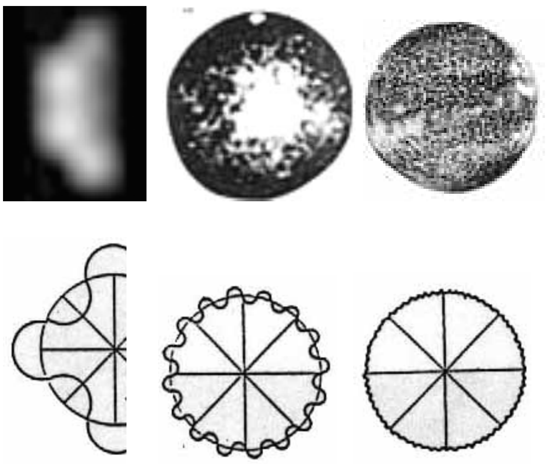

Fig. 2. Observations and geometric models (Fig. 1) of tectonic granulations. From the left to right: Earth, PIA04159, from a distance of 1 170 000 km, MRO, August 2005; Mercury, a radar image from Earth; Sun, supergranulation.

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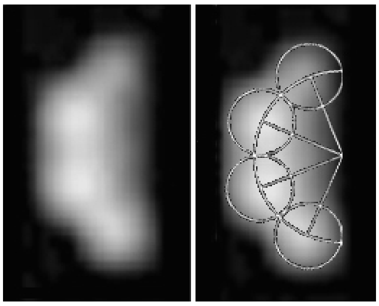

Fig. 3. Earth' granules from a distance of 1170 000 km (Fig. 2) and superposed theoretic granulation.

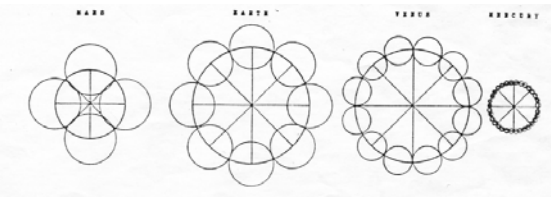

Fig. 4. Geometric presentation of tectonic granulations (warping waves) in terrestrial planets of real sizes.

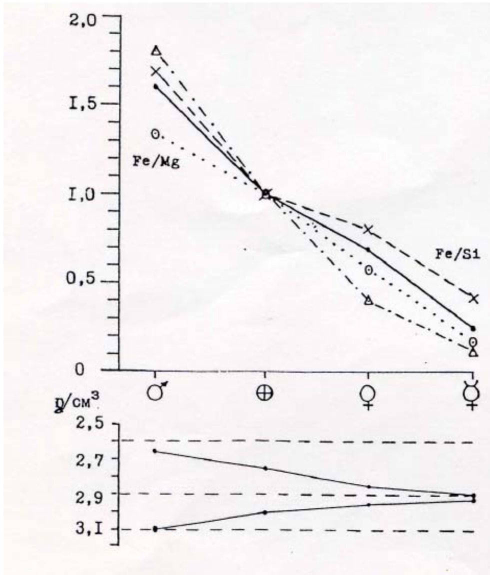

Fig. 5. Ratios of some planetary crust parameters compared to the terrestrial ones taken as 1:solid line – relief, dashed line – Fe/Si, dots – Fe/Mg in basalts of lowlands, dot-dashed line – highland/lowland density contrast. Below: increasing highland/lowland density contrast with increasing solar distance [6].