

**VENUS: THE APPARENT HISTORY OF THE GEOID, M.A. Ivanov<sup>1,2</sup> and J.W. Head<sup>2</sup>, 1-Vernadsky Inst., Moscow, Russia, RAS, mikhail\_ivanov@brown.edu, 2-Brown Univ. Providence, USA.**

**Introduction:** The geoid is the equipotential surface that depends on the large-scale distribution of masses in the interior of a planet and reflects the pattern of mantle convection [e.g., 1]. The configuration of the geoid is built based on the gravity measurements; hence it represents the modern geophysical signal. Attempts were made to reconstruct the evolution of the geoid of Earth based on the documented geological record [2-5]. Here, we outline the possible history of the geoid of Venus analyzing the regional correlation (or lack of it) between the areal distribution of major stratigraphic units [6] and the major features of the geoid of Venus that were calculated from the 120th-degree and -order spherical harmonic gravity model, SHG120 [[http://pds-geosciences.wustl.edu/missions/magellan/shadr\\_topo\\_grav/index.htm](http://pds-geosciences.wustl.edu/missions/magellan/shadr_topo_grav/index.htm)].

**Geological units:** Their areal distribution is shown on the global geological map that extends from 82.5N to 82.5S and covers about 99% of the surface of Venus [6]. The material and structural units everywhere display consistent geologic relationships that help to establish the global stratigraphic column, which is applicable to the entire planet. The column includes the following major units that make up about 94% of the map area. *Tessera* (t, 7.8% of the map) forms areally extensive areas of multiple sets of tectonic structures. *Ridged plains* (pr, 2.2%) form belts of contractional structures, ridges. Tessera and ridged plains are the oldest units that either embayed or cut by the younger materials/structures. *Groove belts* (gb, 8.7%) represent zones of extensional structures, grooves. Groove belts postdate tessera and ridged plains but are largely embayed by shield and regional plains. *Shield plains* (psh, 18.5%) display numerous small volcanic edifices on the surface. *Regional plains* (rp, 42.8%) have morphologically smooth surface with homogeneous radar albedo. Material of regional plains typically embays structures of shield plains [7]. *Lobate plains* (pl, 8.8%) form fields of lava flows that are typically undeformed by tectonic structures. *Rift zones* (rz, 5.3%) are long and broad belts of extensional structures, graben and fractures. Rift zones appear to be contemporaneous with lobate plains and both these units postdate regional plains.

**Correlation of the geological units and geoid:** The geoid of Venus displays three prominent highs thousands of km across (Fig. 1a). The oldest and heavily tectonized units (t, pr, gb) display little correlation with the major features of the geoid (Fig. 1b). Tesserae are seen within both geoid highs and lows and may occur near the largest positive anomalies (Beta) and at the largest negative anomalies (Atalanta) as well. The photogeologic analysis of Beta Regio [8] and the study

of the gravity signatures of the largest tesserae on Venus [9] have showed that tesserae likely represent remnants of the extinct regimes of mantle convection. The linear structural zones of ridged plains and groove belts are not aligned with the major features of the geoid and show no visible correlation with it (Fig. 1b). Similarly, the geoid does not control the areal distribution of shield plains (Fig. 1c).

In contrast to the older units, regional plains are clearly distributed non-randomly relative to the geoid (Fig. 1d). The absolute majority of the plains are concentrated within the geoid lows while the unit is distinctly less abundant within the highs. The youngest units (pl and rz) show the most prominent correlation with the major features of the geoid. These units are almost exclusively concentrated within the geoid highs and are absent within the deepest depressions (Fig. 1e). The strongest visible correlation with the geoid is observed for rift zones that connect the largest positive anomalies within the Beta-Lada and Aphrodite regions (Fig. 1e). The large positive anomaly in the northern portion of the Ishtar-Bell region (Lakshmi Planum), however, has no rifts associated with it, which probably reflects the strongly different mode of formation [10]. Lobate plains tend to occur at the periphery of the geoid highs and a minor amount of the plains associate with the largest anomalies at Beta and Atla. The only exception to this pattern of distribution of lobate plains is the area centered at about 60N, 240E where a large cluster of the occurrences of the plains is within a broad plateau of the geoid (Fig. 1e).

**Discussion:** The comparison of the areal distribution of the units and the geoid shows that the noticeable correlation between them begins to appear after formation of shield plains (Fig. 1c-d). The geoid significantly affected the distribution of regional plains and strongly controlled the distribution of lobate plains and rift zones (Fig. 1e). We interpret the lack of correlation between the units and geoid for the older units and progressive increase of the correlation for the younger units as evidence for the major reorganization of the pattern of mantle convection on Venus. The striking difference in the relationships of shield plains and regional plains with the geoid (Fig. 1c-d) suggest two important conclusions. (1) Careful stratigraphic analysis shows that shield plains predate emplacement of regional plains [7] but the units are indistinguishable by the crater statistics: Although the mean crater density on shield plains is ~20% larger than that on regional plains, the error bars of these estimates almost completely overlap each other. These data suggest that the reorganization of the mantle convection pattern after formation of shield plains occurred during a relatively short time interval. (2) If regional plains indicate times when the current

configuration of the geoid of Venus appeared, we may estimate the model time scale at which the geoid evolved. Regional plains have largest fraction of impact craters the density of which is  $\sim 17\%$  larger than the mean density of craters on entire Venus. The total mean density may correspond to different model ages of the surface, e.g., 750, 500, and 300 Ma [11-14]. These values and the density of craters on regional plains provide the estimates of the mean age of the plains, 879 ( $\pm 126$ ,  $3\sigma$ ), 586 ( $\pm 84$ ,  $3\sigma$ ), and 352 Ma ( $\pm 50$ ,  $3\sigma$ ), respectively. The latter values roughly correspond to the estimates of the age of the major features of the terrestrial geoid, early Mesozoic-late Paleozoic [2,3], but some other researches have estimated the age of the large-scale features of the geoid on Earth to be about 50 Ma [5]. This suggests that since the emplacement of regional plains the configuration of the geoid of Venus was changed at longer (and perhaps, much longer) time scale comparing with the geoid of Earth.

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