EVOLUTION OF VOLCANISM ON VENUS. M.A. Ivanov[1,2] and J.W. Head[2], [1]Vernadsky Institute, RAS, 119991, Kosygin st., Moscow, Russia, mikhail_ivanov@brown.edu, [2]Brown University, box 1846, Providence RI 02912, USA.

Introduction: Manifestations of major internal processes, such as volcanism, are directly related to the loss of internal heat of the planets, which governs the geological histories of the planets to a large extent. This is especially true for Venus where erosional/depositional processes are strongly inhibited [1,2] and impact craters are relatively rare [3,4]. The nature of volcanic landforms revealed on Venus permit the tracing of the history of volcanism, which plays a key role in understanding of the geological evolution of the planet. A recently compiled global geological map of Venus [5] portrays the spatial and temporal distribution of specific units interpreted to be of volcanic origin and permits global assessment of the history and styles of volcanic activity and helps to constrain their relationship to the major episodes of the geological evolution of Venus.

Main volcanic units of Venus: Although the surface of Venus displays a variety of volcanic landforms [6-8], three major volcanic material units are most important: shield plains, psh; regional plains, rp; and lobate plains, pl (Fig. 1). Together they comprise ~96% of all volcanically dominated units and cover ~70% of the surface of Venus. *Shield plains* (~26% of the total surface of the major volcanic units, ~17% of the surface of Venus): Abundant small (2-10 km across) shield-like features (volcanic edifices [6,7,9]) characterize shield plains. In many cases the shields occur close to each other and form clusters. Shield plains are only mildly deformed by wrinkle ridges and sparse fractures/graben. *Regional plains* (both the lower and upper subunits, ~61% of the three major volcanic units, ~40% of the surface of Venus) are composed of morphologically smooth, homogeneous plains the sources of which are not discernible. Networks of wrinkle ridges deform the surface of the plains [10]. *Lobate plains* (~13% of the three major volcanic units, ~8% of the surface of Venus): The surface of lobate plains is occasionally disturbed by graben of rift zones. The most characteristic features of lobate plains are numerous bright and dark flow-like features. The flows can be as long as several hundred kilometers and tens of kilometers wide. The plains are usually associated with the large dome-shaped rises (e.g., Beta, Eistla, Atla Regiones, etc.).

Age relationships among the main volcanic units: In almost all regions of Venus where the main volcanic units occur together they display the same sequence (Fig. 2). Shield plains predate regional plains (exceptions are rare and were mapped as a specific unit of shield clusters) and wrinkle ridges deform both units (Fig. 2). Lobate plains superpose the surface of shield and regional plains (Fig. 2), and embay wrinkle ridges. These relationships strongly suggest that at the global scale shield plains represent the oldest volcanic unit, regional plains are at the middle stratigraphic position, and lobate plains are the youngest. Due to the significant burial of shield plains by regional plains, the abundance of shield plains is underestimated.

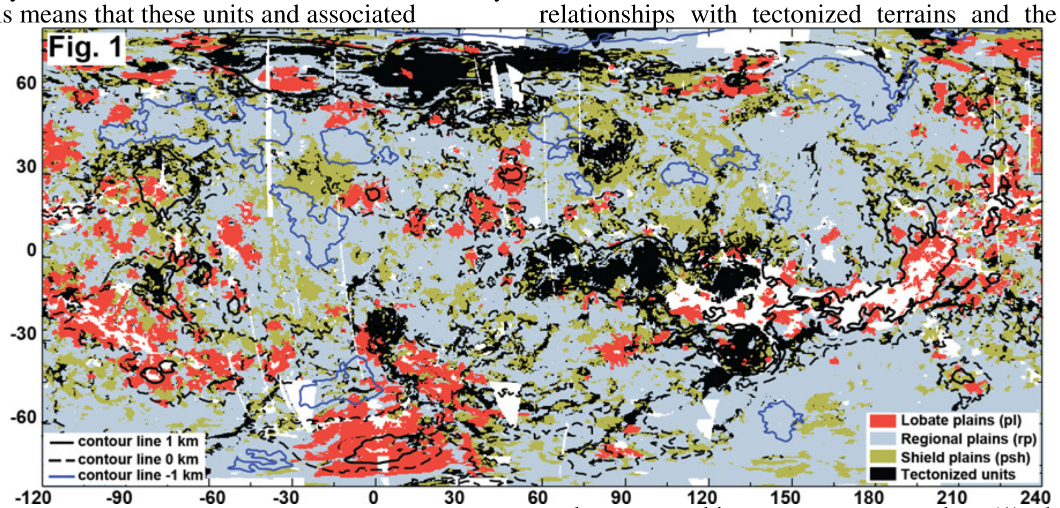
Topographic distribution of main volcanic units: Shield plains often occur in spatial association with large and small exposures of older tectonized units (e.g., tessera) that form either local or regional highs, whereas the largest occurrences of regional plains tend to be associated with regional lowlands (Fig. 1). As a result, the hypsogram of shield plains is shifted to higher elevations relative to regional plains (Fig. 3). Lobate plains are preferentially associated with regional dome-shaped and rifted rises. Due to this, the hypsogram of lobate plains is strongly shifted to higher elevations (Fig. 3).

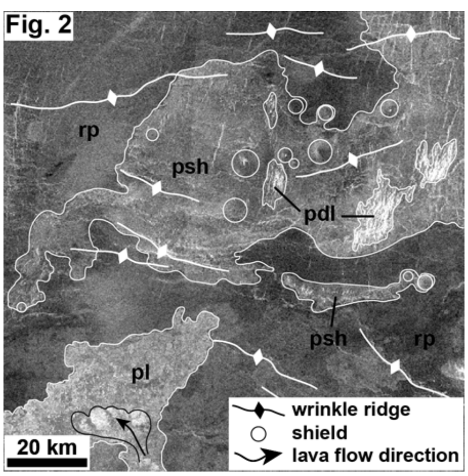
Discussion and conclusions: One of the most obvious relationships of the main volcanic units of Venus is that they embay and bury most of strongly tectonized units/structures (black areas in Fig. 1, see also Fig. 2). These relationships are observed everywhere on Venus [5,11-13] and indicate that a tectonically dominated regime near the beginning of the observable geological record underwent a change to a volcanically-dominated regime that characterizes the geological history of Venus since the time of the emplacement of shield plains. The minimal (exposed) area of the older tectonized units comprises ~21% of the total surface. Formation of these units/structures was probably related to specific patterns of mantle convection and the change from the tectonic- to volcanic dominated regimes may indicate diminishing of mantle convective vigor and enhancement of melt production. Late tectonic activity, which occurred during emplacement of lobate plains (rift zones, white zones in Fig. 1), has affected only a small fraction of the surface of Venus (~5%).

Distinctly different morphologies characterize the main volcanic units (Fig. 2). Small volcanic constructs of psh are consistent with globally distributed volcanism (multiple eruptions from small, shallow, and broadly distributed sources [e.g., 6,14]). Regional plains form very broad and morphologically homogenous surfaces where the sources are not visible at the resolution of Magellan SAR. These characteristics are consistent with voluminous volcanic activity resulting in lava flooding [6,15-17] of a significant portion of the surface of Venus. The lack of sources, however, suggests that individual volcanic eruptions during formation of regional plains did not last long and were not associated with persistent magma supply (flood volcanism). In contrast to regional plains, numerous and very distinctive lava flows characterize pl. Typically, the flows are associated with very prominent but isolated volcanic centers such as large volcanoes [e.g., 8]. The abundance of lava flows and association with distinctive centers of volcanism strongly suggest that lobate plains formed due to long-lived, persistent, and likely deep-seated magmatic centers.

These characteristics of the main volcanic units have been documented in practically all regions of Venus [e.g., 5,18-21]. Thus, specific types of volcanism that were responsible for formation of the units had a global-scale nature. The consistent age relationships of the main volcanic units (from psh through rp to pl) suggest that different volcanic styles have succeeded each other sequentially at a global scale during the later-stage (post tessera) volcanically dominated regime.

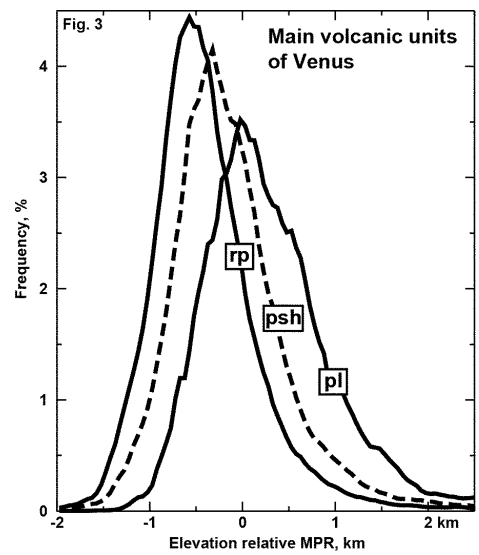
The stratigraphically older shield plains often occur in the vicinity of the elevated tectonized units and embay them. This means that these units and associated topographic highs formed before emplacement of psh. Shield plains extend from the elevated terrains along the regional slopes toward the lowlands (basins) where the plains are embayed and buried by regional plains. In places, however, the stratigraphic windows of shield plains occur near the bottom of the basins. Regional plains are preferentially concentrated within the basins and are less abundant at their elevated edges where shield plains prevail.





This correlation of psh and rp with the long-wavelength topography suggests that the regional- to global-scale topographic pattern controlled the spatial distribution of shield plains to a lesser degree but was an important factor in distribution of regional plains. This suggests that the basins predated emplacement of regional plains and served as sites of preferential accumulation of their material. Thus, the most important features of the long-wavelength topography of Venus, such as the high-standing tessera plateaus and the broad basins, were largely established prior to the emplacement of regional plains. Since that time, the major changes in the global-scale topographic pattern were related to evolution of several dome-shaped rises and rift zones that characterize less than 10% of the surface of the planet.

The characteristics of the main volcanic units and their relationships with tectonized terrains and the global-scale topographic pattern suggest that (1) the major features of the surface of Venus (most of tectonic terrains, the most widespread volcanic units, the principal features of the long-wavelength topography) were established early on in the geological history of the planet and (2) the types and intensity of internal activity on Venus were strongly time-dependent.



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