REGIONAL AND GLOBAL STRATIGRAPHY OF VENUS: A PRELIMINARY ASSESSMENT AND IMPLICATIONS FOR THE GEOLOGIC HISTORY OF VENUS; A. T. Basilevsky[1,2] and J. W. Head[2], [1]Vernadsky Inst., Russian Academy of Sciences, Moscow 117975, Russia, abasilevsky@glas.apc.org; [2]Dept. Geol. Sci., Brown Univ., Providence, RI 02912 USA.

INTRODUCTION. Analysis of the Magellan imagery in numerous representative sample areas of Venus led to establishing the stratigraphic sequence of geologic formations of the planet starting with heavily deformed tessera-forming materials, followed by the suite of plains-forming volcanics, moderately deformed by widespread deformation, which, in turn, are locally overlapped by younger volcanics mostly associated with rifts. This sequence and the resulting scenario of the geologic history of Venus, put constraints on the character and rate of processes in the planet interior. The global high-resolution Magellan coverage of Venus [1] provided a basis for establishing the characteristics of the major geologic units and structures of this planet, for assessing their stratigraphic relations, and for interpreting the geologic history of the planet. Such an endeavor will require many years of intensive mapping and analysis of the data before a detailed picture emerges. Here we report on an initial analysis of widely distributed areas on the planet and a preliminary assessment of regional stratigraphic units into the model of global stratigraphy of Venus. Further detailed studies, especially made through the NASA-sponsored Venus Geologic Mapping Program, are necessary to test the suggested stratigraphy model.

VENUS STRATIGRAPHY MODEL. Using the Magellan C1- and F-MIDRP mosaics both in hard copy and in digital format (and related altimetry and physical property data) we first studied stratigraphic relations in thirty-six 1,000 x 1,000 km areas randomly spaced on Venus [2,3]. This study was followed by photogeologic analysis of several larger regions including western Ishtar Terra, northern Beta Regio, Bell Regio, Lavinia Planitia, Baltis Vallis, and the Venera and Vega landing site regions [4]. The stratigraphic relations among the terrains, features and structures were determined using the traditional principle of superposition as was successfully done by the U.S. Geological Survey in the case of the Moon and Mars [e.g., 5,6,7]. In our earlier studies we identified sixteen terrain units and structures with which we could describe the major characteristics of the geology and stratigraphic relations in any of the widespread areas of our studies [2,3]. Those terrain units and structures represent a natural mixture of material units and deformational episodes. Following confirmation of their validity and utility in our analyses of the previously mentioned larger areas (western Ishtar Terra, etc.), we split them into two different categories: 1) mappable stratigraphic material units and 2) tectonic structures which also are a part of the age sequence [4]. Here we present a preliminary definition and classification of these material geological units and an assessment of the relation of the units and structures in the geologic history of Venus (Fig. 1). Seven rock-stratigraphic units, three related time-stratigraphic units (Systems), and three geologic time subdivisions (Periods) are proposed (Fig. 1) to describe the vast majority of the areas under study. The most ancient geologic unit identified in morphologic records of Magellan is the highly deformed tessera terrain which materials form the Fortuna Group, apparently the result of the global-wide event that destroyed the morphology of preexisting terrain and any superposed craters. Rarity of on-tessera craters deformed by the tessera-forming deformation shows that termination of that deformation was rather fast [8]. Global image data reveal no evidence for extensive terrain dating from the pre-Fortunian time, comprising the first 80-90% of the history of Venus, although rocks dating from this period are almost certainly contained within the tessera. Immediately following the Fortunian an extensive period of plains volcanism began, forming a suite of geologic units composing together the Guinevere Supergroup. During the early part of the Guineverian time the widespread plains of the Sigrun Group were emplaced and deformed by extensive and closely-spaced graben systems. Continued widespread plains emplacement occurred forming the Lavinia Group units, which are then deformed, some into extensive ridge belts, recording a change from distributed extensional deformation to often-focused compressional deformation. Plains of the Rusalka Group are the most widespread currently exposed, and are characterized by extensive development of wrinkle ridges of compressional origin. This three-member suite of plains must have been emplaced and deformed over a relatively short period of time (probably not more than about a hundred million years) because the vast majority of impact craters are superposed on the plains, and the crater retention age of this surface is of the order of 300-500 Ma [9,10]. This extensive plains volcanism then gave way to materials of the late Guineverian Atla Group, represented by the local volcanic edifices and flow units with sources mostly associated with rifts. The uppermost Aurelia Group units, defined by impact craters with dark parabolas, are interpreted to extend from the present back to about 30-50 Ma ago. During Atlian and Aurelian time extensive rifting occurred in several areas of Venus and volcanism has continued at a reduced level relative to the earlier parts of the Guineverian period.

VERIFICATION AND IMPROVEMENT OF THE MODEL. Since the time when the global stratigraphy model was worked out and published [2-4] several new stratigraphic studies have been made thus testing the model. Geologic mapping of 1:10M scale of the area, confined 40-80 N and 140-260 E [11], 1:5M geologic mapping in Beta Regio [12] and Lavinia Planitia [13], stratigraphic studies around Baltis Vallis [14] and Maxwell Montes [15] as well as stratigraphic studies within and around 30 small-sized coronae [16] confirmed the general consistency of the model. Brief reports of the participants of the Venus Geologic Mappers Meeting in Flagstaff, AZ, July 1995, showed that the model is applicable to many of the areas under study. A new stratigraphic unit, shield plains material, first suggested by [17], was found to be widespread. It should be included in the model in between the materials of the Lavinia Group and Rusalka Group. Observations in several areas [e.g., 14] led to conclusion that the Rusalka Group can be split into two subunits: 1) plains with relatively homogeneous low radar backscatter, and 2) overlaying relatively bright subunits with flow-like morphology, both deformed the wrinkle ridges postdated subunit 2. The described stratigraphy model shows that the morphologically recorded part of the geologic history of Venus started with high rates of tectonic deformation and volcanic resurfacing, followed by the period of declining surface activity of endogenic origin which lasts until now. The lack of surface units representing the first 80-90% of the history of Venus is remarkable from the standpoint of its present low level of activity. This contrast, together with the emerging geologic history of the last 10% of the lifetime of Venus, suggests that catastrophic and/or episodic global processes may have characterized Venus in its earlier history.

QUESTIONS TO ANSWER. The Venus geologic history scenario described above should be tested and compared to specific geophysical models. Some important questions include: 1) If the formation of the Fortuna Group tessera terrain as well as the emplacement and deformation of the Sigrun, Lavinia, and Rusalka Group materials indeed occurred over a short period of time, then changes in the regional and global stress regime from compressional (Fortunian time) to extensional (late Fortunian-Sigrunian) and back to compressional (Lavinian-Rusalkan) may put some constraints on heat generation and loss rates and styles during this part of the thermal evolution of Venus. What geophysical models are consistent with these observations? 2) If the observed part of the geologic history of Venus indeed started with global catastrophic deformation and resurfacing, this should inevitably disturb the upper mantle in Fortunian time, thus changing patterns of mantle circulation, including modifying the penetration of hot spot plumes from the deeper interior of the planet. However, in the subsequent (Sigrunian) period we see evidence of corona-forming probable hot spot activity (COdf unit); this could be interpreted to mean that hot spot activity began or was restored immediately following this significant mantle disturbance, or perhaps even associated with it. What mantle convection models are consistent with the spatial and temporal distribution of these features? 3) If the Atla Group volcanic activity closely related to the rift zones is the result of heating up of the downwelled previously cold and dense upper mantle material then it puts constraints on the time which is necessary to heat the material enough to produce rift-forming extensional stresses and to generate the Atla Group magmatic melts. What time duration is consistent with these observations? Our observations show that from place to place the geology of the planet is strikingly uniform. In most regions we see practically the same terrains and features representing the same rock-stratigraphic units and the same age sequence. In general, uniformity dominates over variability, and only occasionally we observe unusual landforms such as canali or steep-sided volcanic domes. In this respect, Venus is more similar to the Moon and Mercury, where impact cratering and volcanism form the major surface units, and differs significantly from Mars and especially the Earth, where atmospheric and hydrospheric processes add considerable diversity and complexity to the geological record.

REFERENCES. 1) Saunders R.S. *et al.*, *JGR*, *97*, 13067, 1992; 2) Basilevsky A.T. & Head J.W., *LPSC 25*, 65, 1994; 3) Basilevsky A.T. & Head J.W., *EMP*, *66*, 285, 1995; 4) Basilevsky A.T. & Head J.W., *PSS*, *43*, 1523, 1995; 5) Wilhelms D.E., *USGS Interagency Report: Astrogeology 55*, 1972; 6) Wilhelms D.E., In *Planetary Mapping*, Cambridge University Press, 208-260, 1990; 7) Scott D.H. & Tanaka K.L., *USGS Map I-802-A*, 1986; 8) Ivanov M.A. & Basilevsky A.T.,*GRL*, *20*, 2579, 1993; 9) Phillips R. *et al.*, *JGR*, *97*, 15923, 1992; 10) Strom R *et al.*, *JGR*, *99*, 10899, 1994; 11) Kryuchkov V.P. *LPSC 27*; 1996; 12) Basilevsky A.T. L*PSC 27*, 1996; 13) Ivanov M.A.& Head J.W., *LPSC 27*, 1996; 14) Basilevsky A.T. & Head J.W., *LPSC 26*, 81, 1995; 15) Basilevsky A.T., *LPSC 26*, 79, 1995;16) Pronin A.A., *Vernadsky/Brown Microsymposium 22*, 82, 1995;17) Aubele J., *LPSC 26*, 59, 1995.

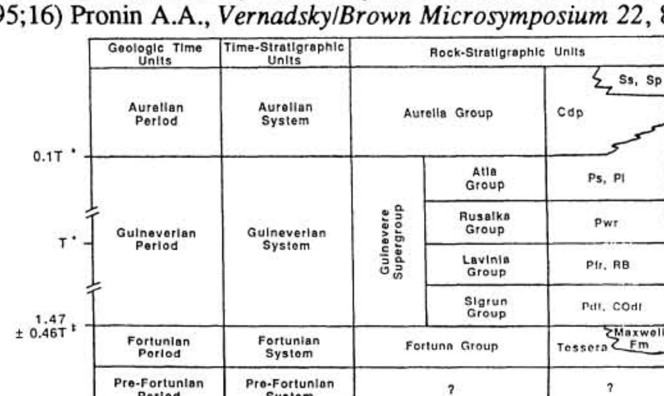

Figure 1. Proposed Venus regional and global rock-stratigraphic, time-stratigraphic, and geological time units. References are: (*)Basilevsky, 1993; Strom, 1993. (+) T is crater retention age of the surface of Venus.