SEQUENCE OF TECTONIC DEFORMATION IN THE HISTORY OF VENUS: EVIDENCE FROM GLOBAL STRATIGRAPHIC RELATIONS; James W. Head[1] and Alexander T. Basilevsky[2], [1]Dept. Geological Sci., Brown Univ., Providence, RI USA 02912, [2]Vernadsky Institute, Moscow, Russia.

INTRODUCTION. Analysis of local and regional stratigraphic relationships has permitted the assessment of the nature of tectonic structures and their distribution throughout the observed history of Venus. We find that regional shortening characteristic of the tessera gives way to widespread distributed extension, followed by compression (peaking during and just following the emplacement of the majority of the volcanic plains), which wanes in significance with time (ridge belts ->wrinkle ridges). Focused extensional deformation (rift systems and fracture belts) dominates the later stages of geologic history. These trends appear well-established from a stratigraphic point of view and provide guidelines and constraints on models for Venus geologic history.

BACKGROUND & APPROACH. We analyzed 36 1000 x 1000 km areas and several larger regions in order to define local stratigraphic units and determine their sequence [1]. On the basis of these analyses, we studied the structural deformation that was characteristic in the definition of some units and the deformation that occurred independently of these units. We asked the following questions: What is the origin of the observed structure in terms of sense of deformation? Is the deformation local, regional or widespread? Is the deformation distributed (e.g., plains with evenly distributed wrinkle ridges) or focused (e.g., a rift zone)? Where does the deformation occur in the stratigraphic record? Here we present the results of our analysis.

STRUCTURAL DEFORMATION & RELATIONSHIP TO GEOLOGIC UNITS. In the defined stratigraphic units and proposed stratigraphic sequence [1] one of the characteristics of the stratigraphic units is the presence (or absence) of deformation which differs from unit to unit in its pattern, abundance and spacing. Although structural fabrics are commonly a factor in the definition of planetary geologic units [2], we took care to distinguish between well-defined stratigraphic units and structural deformation occurring both as part of them and separately. Deformation of certain types can be overprinted both on newly-formed material and on materials formed during previous geological epoch(s) and now sitting adjacent to or beneath the newer material. This fact indicates that caution should be used when structural elements make up a portion of the definition of a unit [2]. Fortunately, in the case of Venus only the oldest of the suggested stratigraphic units, representing the tessera (Fortuna Group) (Fig. 1), have such intensive characteristic tectonic overprinting. It is difficult, if not impossible, to see the nature of the tessera precursor terrain, although there is evidence of volcanic plains precursors in Tellus and Ovda [3]. In spite of very heavy faulting in the densely fractured plains (Pdf, Sigrun Group), it is definitely possible to see that its precursor terrain is plains. For younger stratigraphic units the typical tectonic overprint is much less dense so one can easily distinguish when the broad ridge belts (RB, characteristic of the Lavinia Group) affect primarily undeformed plains, and when they deform densely fractured terrains, which are often included as islands in the fractured and ridged plains or ridge belts. Wrinkle ridging which is typical for the plains with wrinkle ridges (Pwr, Rusalka Group) is also not dense and the precursor plains terrain can easily be seen. The wrinkle ridges may be clearly superposed on primarily undeformed plains and we classify the latter as Rusalkan ones, or wrinkle ridges can be superposed on plains already affected by broad ridges and in this case we classify the plains as part of the Lavinia Group. We have never observed wrinkle ridges superposed on Fortuna Group tessera and only in very rare and unclear cases did we see them superposed on Sigrun Group densely fractured terrains. Obviously, highly fractured materials of the Fortuna Group are likely to consist of large-scale rubble mechanically analogous to the breccias of the lunar highlands, and like these may have physical properties less favorable for warping into wrinkle ridges than the adjacent volcanic plains, as appears to be the case on the Moon [4]. Younger deformation represented by normal faults and fractures (both associated and not associated with rifts) are overprinted on practically all stratigraphic units. In most cases it is possible to see through and to determine the unit(s) they deform [e.g., 5].

TECTONIC DEFORMATION & CORRELATION WITH STRATIGRAPHIC UNITS. On the basis of this analysis, several distinctive structural features and groups of features were mapped in the areas under study and these could be subdivided stratigraphically into several episodes of deformation (Fig. 1). The earliest and most intense is the deformation which determined the observed highly deformed morphology of tessera terrain (Fortuna Group), exposed over about 8% of the surface but probably underlying much more [6]. Tessera is a result of complex patterns of synchronous deformation and intensive multiple deformation patterns; the predominant sense of deformation appears to have changed with time from compression to extension [6, 7]. Following and at least partly contemporaneous with the terminal stages of tessera deformation was extensional faulting now visible as Phase II deformation within the tessera and as remnants of Sigrun Group densely fractured material; together, these units are widespread over Venus. A transition from the dominance of extension to an environment characterized

mostly by compression is seen following the emplacement of the fractured and ridged plains (Pfr) and during formation of the Ridge Belts of the Lavinia Group. Compressional deformation formed broad ridges, fragments of which are now seen in many places on Venus as islands of Lavinia Group material surrounded by younger plains, particularly in Atalanta and Lavinia Planitiae. More broadly distributed compressional deformation continued following the emplacement of the very widespread Rusalkan plains with wrinkle ridges (Pwr). Youngest deformation is observed either in the form of long and relatively narrow rift zones and fracture belts [5, 8] formed in the late Guineverian or Aurelian periods of time (Fig. 1), or in the form of rare, but widely distributed open fractures many of which are interpreted to represent the surface manifestation of shallow dikes [9]. The broad distribution of rift zones implies a further change in deformational environment from moderate compression to moderate extension, often accompanied by volcanism [10].

SUMMARY & CONCLUSIONS. An important characteristic of most of the observed deformation in a general sense is its global distribution. Examination of almost any moderate-sized region of Venus shows islands of tessera, islands of densely fractured terrain and extensive areas of plains with wrinkle ridges. In areas where some of this sequence is not observed, there is usually evidence of younger volcanism which may cover earlier units. Localized deformation is seen either in the form of relatively young (late Guineverian-Aurelian) rift zones (Fig. 1) whose formation postdates wrinkle-ridge emplacement, or in the form of coronae several hundred of which were developed on background terrain during the Guineverian Period. In all cases where we could observe coronae in contact with rift-associated fractures all corona-related materials and structures were cut by rift-associated deformation. We interpret this to mean that formation and evolution of coronae is less significant during late Guineverian and Aurelian time. Although these deformational stages appear to be widespread and global in significance, there is also a regionalization that may provide important clues to mantle processes. Presently exposed tessera terrain is not evenly distributed over the planet [6]. Rift zones/fracture belts are largely outside tessera regions and many of these are correlated with the concentration of volcanic centers seen in the Beta-Atla-Themis (BAT) area making up about 20% of the surface of the planet [11]. These correlations suggest that presently exposed tessera may be the loci of early downwelling and crustal thickening, while the BAT area is the site of latest broad-scale upwelling. Given the relatively short time recorded by Venus surface units (300-500 Ma) [12], these mantle convection patterns may be causally related.

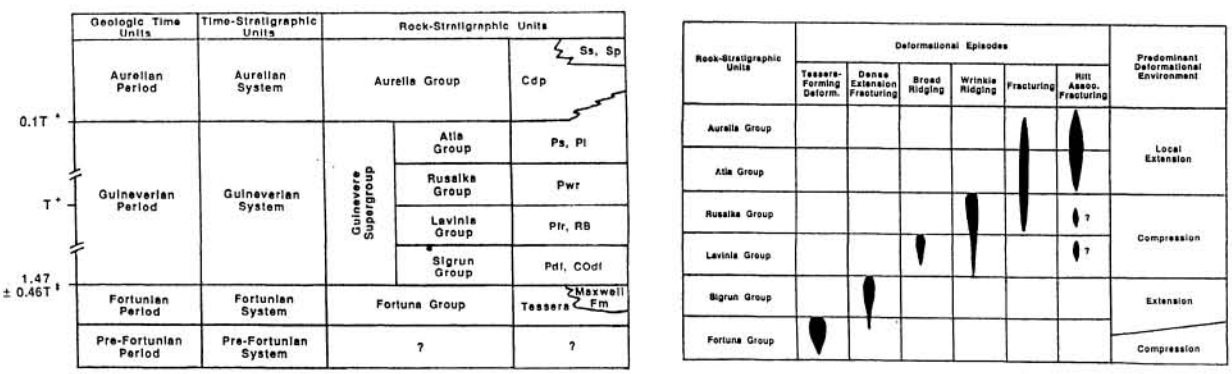

Figure 1: a) Stratigraphic units and global correlations [1] and b) interpreted deformational sequence.

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