RADIAL LINEAMENT SYSTEMS ON VENUS: CONSTRAINING MODELS OF GLOBAL STRESS

Eric B. Grosfils & James W. Head, Dept. Geological Sciences, Brown University, Providence, R.I. 02912

Overview: The stress dependent geometries of 163 giant radiating graben-fissure-fracture systems identified on Venus can be used to test existing models for the generation of a global stress field. The stress configuration recorded by these structures across the two-thirds of the planet between 330-210°E (Aphrodite Terra) is best matched by models of isostatic compensation of existing long wavelength topography or coupling between mantle flow and the lithosphere. The configuration across the rest of the planet, centered on the Beta-Atla-Themis region, is correlated with concentrated rifting and volcanism.

Observations: Each system's radial configuration is usually quite pronounced near the center: in 52% of the cases radiating lineaments fan through more than 270°, and 80% exceed 180° of arc. In their distal regions, however, the radiating elements in 72% of the systems continue along a purely radial trend, while distal elements in the remaining 28% curve gradually into unidirectional, sub-parallel geometries. Spatially, the systems as a whole are not randomly distributed across the venusian surface (Figure 1). Of the 163 identified, 79% lie within 40° of the equator, and there is a longitudinal concentration from 190-300°E. Globally, purely radial systems are widespread, but they tend not to occur in lowland and polar regions, and unusual concentrations occur within the Aphrodite Terra highlands, Eistla Regio, and along the Parga and Hecates rift zones. Systems which become unidirectional are also widespread, and avoid the lowland and polar areas, but their global distribution is otherwise different than the purely radial systems. Between longitudes 330-210°E (about two-thirds of the planet) the unidirectional systems principally occupy a broad swath north of Aphrodite Terra that curves around the eastern end of the highland area before terminating south of Atla. Throughout this region the unidirectional lineaments generally align perpendicular to the trend of the long wavelength topography. The remainder of the planet, between longitudes 210-330°E, is dominated by the concentration of rifts and volcanic features of the Beta-Atla-Themis (BAT) region. Unlike the Aphrodite Terra area, the unidirectional radiating structures within BAT do not appear to be geometrically related to the current distribution of long wavelength topography. Instead, these features are associated with the Parga, Hecates, and Devana rift zones, and their distal lineaments align parallel to the observed rift trends.

Discussion: Whether formed predominantly by subsurface dike swarm emplacement or domical uplift, the radiating tensile lineament geometries are stress dependent[1-3]: those radiating systems which remain radial throughout are interpreted to have formed in the presence of a negligible regional differential stress field, while those systems which become more unidirectional were affected by a stronger regional differential stress, causing their distal lineaments to align in the maximum horizontal stress direction. This stress dependency implies that the geometry of the radiating systems observed on Venus can be used to constrain the orientation and relative magnitude of the planetary stress fields, thus providing a useful means of testing and further refining existing models for their generation. These include: 1) isostatic compensation of long wavelength topography[4, 5]; 2) Earth-like plate tectonics[6]; and, 3) coupling between convective mantle flow and the lithosphere, either with[4] or without[7, 8] shear decoupling due to the presence of an asthenosphere. ***Isostatic Compensation***: In considering the temporal evolution of the venusian surface, *Turcotte* [1993] argues that elevated topography on Venus is directly supported by a thick, isostatically compensated lithosphere. Using only long wavelength information, *Banerdt* [1986] calculated the stress field which would result under these conditions. His results predict topography-perpendicular stress orientations that agree quite well with those recorded by the unidirectional radiating systems across the two-thirds of the planet associated with the Aphrodite Terra highlands. The isostatic model, however, also predicts high differential stresses in the highlands and lower ones in the surrounding areas, contrary to the observation that purely radial systems dominate in the highlands while unidirectional ones occupy the adjacent regions. In addition, across the remaining third of the planet (BAT) the unidirectional orientations are only poorly approximated. We thus conclude that, while an isostatic model correctly predicts stress orientations across two-thirds of the planet, implying that the stress field and topography are correlated (this is suggested by wrinkle ridge alignments as well[9]), further refinement is required to account for both the differential stress magnitudes in highland and lowland areas and the observations within BAT. ***Plate Tectonics***: On Earth, the maximum horizontal compressive stress direction at divergent oceanic plate boundaries is generally aligned perpendicular to the rift[10]. While morphologic evidence indicative of plate tectonics on Venus is not widespread[11], *McKenzie et al.* [1992] argue that many areas exhibit a plate tectonic signature like that of Earth.

CONSTRAINING MODELS OF GLOBAL STRESS: E. B. Grosfils & J. W. Head

Around Aphrodite Terra, given the consistency of the unidirectional system behavior, the simplest interpretation requires plates to spread approximately normal to the current highland topography, a situation not supported by existing data[11]. Within BAT, the rift-parallel orientation of the unidirectional systems is also inconsistent with Earth-like plate boundary spreading; however, the geometry is characteristic of intraplate continental rifting on Earth, and may be linked to broad-scale upwelling[12]. ***Mantle-Lithosphere Coupling***: Coupling between mantle convective flow and the lithosphere can generate long wavelength topography and a global system of stress[7]. If an asthenosphere exists to decouple basal shear, the maximum compressive stress configuration expected on Venus is quite similar to that generated by pure isostatic compensation of a thick lithosphere[4]; it therefore accurately predicts the stress orientations recorded about Aphrodite Terra but fails to explain either the relative highland-lowland differential stress magnitudes or the radiating system behavior observed within BAT. In the absence of an asthenosphere, the addition of basal convective shear stress enhances the differential stress magnitude at the surface[7], and may have promoted thermally dependent tectonic resurfacing[8]; however, as in the decoupled shear model the differential stresses should be higher in elevated areas, inconsistent with observations. While detailed predictions about the expected global stress configuration for this situation have not been made, the topography-perpendicular orientation of the systems about Aphrodite Terra suggest that mantle material flowed normal to the highland, a situation consistent with either mantle upwelling or downwelling beneath the currently elevated regions.

References: 1. Anderson, E.M., 206 pp., Oliver.& Boyd: Edin. (1951). 2. Ode, H., *GSAB v.68*, 567-576 (1957). 3. Cyr, K.E. & Melosh, H.J., *Icarus v.102*, 175-184 (1993). 4. Banerdt, W.B., *JGR v.91*, 403-419 (1986). 5. Turcotte, D.L., *JGR v.98*, 17061-17068 (1993). 6. McKenzie, D., *et al.*, *JGR v.97*, 13533-13544 (1992). 7. Phillips, R.J., *JGR v.95*, 1301-1316 (1990). 8. Solomon, S.C., *PhysTod v.46*, 48-55 (1993). 9. Bilotti, F., *et al.*, *LPSC 24*, 107-108 (1993). 10. Forsyth, D.W. & Uyeda, S., *GJRAS v.43*, 163-200 (1975). 11. Solomon, S.C., *et al.*, *JGR v.97*, 13199-13225 (1992). 12. Crumpler *et al.*, *Sci v. 261*, 591-595 (1993).

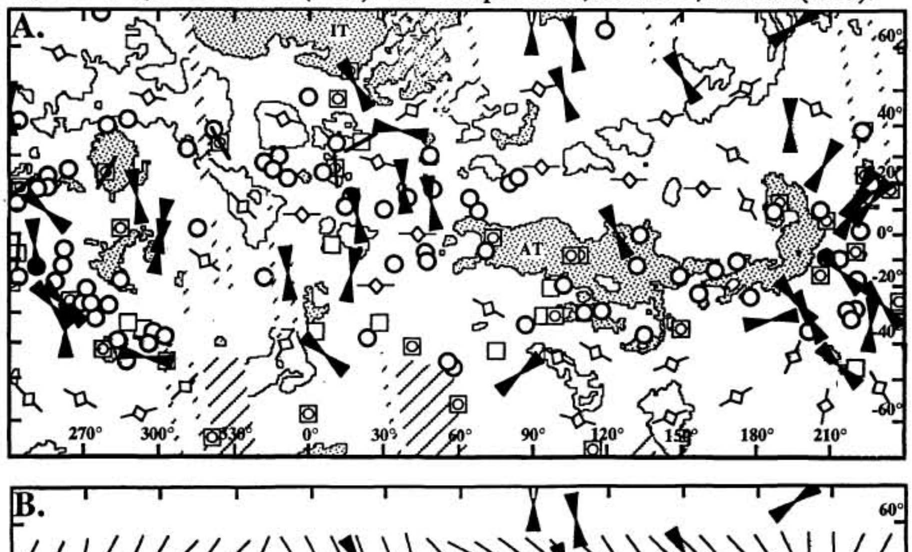

Figure 1: A) Distribution of radial graben-fissure-fracture systems on Venus. Those involving significant dike emplacement are circles (low regional differential stress) and black arrows (high differential stress, aligned with maximum horizontal compression), those dominated by uplift are squares, and those whose dominant contributing mechanism is not known are squares containing circles. Maximum compression directions indicated for the latter two cases are depicted by a solid line. Lines with diamonds show general wrinkle ridge trends[9]. 6051 km contour is shown and elevations above 6053 km are stippled. B) Unidirectional orientations compared with the maximum horizontal compressive stress directions (dashed lines) predicted by Banerdt [1986] for isostatic compensation of a thick lithosphere.