Radiating graben-fissure systems on Venus: A tool for characterizing magmatic events and their age relationships

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Magmatism on Venus: There are several scales of magmatic events on Venus (Ernst and Desnoyers 2004): 1) isolated coronae, volcanoes, flow fields, and radiating graben systems; these range in scale up to 1000 km or more in diameter; 2a) individual and small clusters of volcanoes and coronae associated with topographic swells, geoid highs, and triple junction rifting; these are most clearly indicative of terrestrial-type plumes originating from the deep mantle; 2b) coronae distributed along rifts (chasmata); these are the clearest examples of melt generation associated with rifting; 3) regional concentration of activity in the Beta-Atla-Themis (BAT) region; this is the closest example of a terrestrial plume cluster event, sometimes termed a 'superplume event'; and 4) global volcanic resurfacing of the volcanic plains; no terrestrial analogue is confirmed, although the global burst of terrestrial plume activity in the Neoarchean is a possible analogue. New insights into this record are available from detailed mapping of graben-fissure systems.

Importance of Graben-Fissure Systems: Reconnaissance-scale (225 m/pixel C1-MIDR) Magellan images revealed 163 radiating graben-fissure systems of which 118 were interpreted to be underlain by dykes (Grosfils and Head 1994) as well as linear and circumferential systems. More detailed mapping using full resolution (75 m / pixel) Magellan images is revealing a significantly larger population. A 14 Mkm^2 area (264^o-312^o E, 24^o-60^o N) near Guinevere Planitia (Ernst et al. 2003) contains thirty-four radiating systems, of which 16 have radii greater than 300 km and eight have radii greater than 1000 km. (In this area only 5 radiating systems were identified in the earlier reconnaissance mapping). Furthermore, twenty-six linear (straight) systems with a length greater than 300 km have been distinguished of which six have a length greater than 1000 km, and 19 circumferential systems are mapped and identify coronae. In addition, preliminary detailed mapping in the adjacent area (216^o-264^o E, 24^o-60^o N) has revealed 30 radiating systems of which 9 have radii greater than 300 km and two have radii greater than 1000 km. (In this area only 4 radiating systems were identified in the earlier reconnaissance mapping).

The radiating graben-fissure systems that we catalogue represent a database of tectono-magmatic centres that complements the centres defined using other criteria, e.g. large volcanoes, coronae, and shield fields. Using radiating graben-fissure systems in this way has some distinct advantages (e.g. Ernst et al. 2003), summarized below:

1) The areal extent of most systems greatly exceeds that of the volcano or corona on which they are centred. Thus there is the potential for accessing the relative age of widely separated volcanoes or coronae by the crosscutting relationship between their associated radiating graben-fissure systems.
2) Some radiating systems lack any volcano or corona at their centre, indicating radiating graben systems can identify cryptic mantle plumes / diapirs.

3) Faint closely-spaced lineaments, often in crosscutting sets (“gridded terrain”), can often be traced into unambiguous graben-fissure systems, suggesting that the faint lineament sets can be used to extend the distribution of graben-fissure systems.
4) Graben-fissure systems are especially prominent in fracture belts and densely fractured plains, but some can be traced as more subdued features into adjacent plains. This indicates that fracture belts and densely fractured plains represent ‘basement’ units, which are overlain by plains units. The local thickness of the plains units will determine whether the graben-fissure systems in the ‘basement’ are partially or completely obscured. Therefore, regional variation in the visibility of partially flooded graben systems can potentially be used to determine the variation in thickness of plains lavas.
5) Some radiating graben systems extend a few hundred km before swinging into a common direction that presumably reflects the influence of a regional stress field. Others continue radiating for their full extents. The pattern and age distribution of fully radiating vs. swinging swarms should reflect the regional stress pattern and its variation through time (Grosfils and Head 1994). These results can be compared with those determined from wrinkle ridges which appear to correlated with long-wavelength topography.
6) Since Venus is a one-plate planet with a stagnant lithosphere, individual large volcanoes represent a combination of plume head and subsequent plume tail activity. It is possible that a giant radiating swarm is associated with only the plume head stage and its distribution could help define plume-head vs. plume tail components of the volcanism.

Additional graben-fissure system geometries are important. Circumferential systems are used to map coronae, and it should be possible to establish age relationships with respect to associated radiating systems. Linear systems may be linked with rift zones but may also be the distal portions of larger radiating systems.

<u>Lessons for Earth:</u> On Venus, graben-fissure systems preserve their primary geometry and distribution because of the absence of plate tectonics. This characteristic provides insights into the primary distribution of intraplate magmatism on Earth (including that associated with mantle plumes) where regional relationships are obscured by the uncertainty of plate reconstructions, especially in the Precambrian.

<u>References</u>

Ernst, R.E. & Desnoyers, D.W. 2004, Lessons from Venus for understanding mantle plumes on Earth. Phys. E. Planet. Int., 146: 195-229.

Ernst, R.E., Desnoyers, D.W., Head, J.W., and Grosfils, E.B., 2003, Graben-fissure systems in Guinevere Planitia and Beta Regio (264^{o}-312^{o}E, 24^{o}-60^{o}N), Venus, and implications for regional stratigraphy and mantle plumes. Icarus, 164: 282-316.

Grosfils, E.B. & Head, J.W. 1994, The global distribution of giant radiating dike swarms on Venus: implications for the global stress state. Geophys. Res. Lett. 21: 701-704.