NATURE AND SEQUENCE OF VOLCANIC AND TECTONIC ACTIVITY IN BETA REGIO, VENUS,

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Venus is characterized by a number of deep linear valleys known as chasmata, concentrated in the equatorial region and interpreted as zones of lithospheric extension and rifting (1, 2). One of the most distinctive occurrences of chasmata, Devana, is in Beta Regio, known to be a region of rifting and volcanism (1, 3, 4). Pioneer Venus, Venera 15/16 and Arecibo data have been used to characterize the nature of Beta as a major topographic rise and rift zone on Venus (5). Here, we summarize the nature of volcanic and tectonic activity in Beta, and determine a sequence of geologic events.

Tectonic structures. The Devana trough has a general N–S trend through Beta, with an average depth of over 1 km. The flanking uplift along the rift is generally <1 km, with the highest rift shoulders at Rhea Mons. The faults of the rift zone (as indicated by linear roughness elements and scarps) are distributed over both the trough and the high topography of the dome in central and northern Beta, but are confined to the trough in the vicinity of Rhea Mons (Fig. 1). At Theia Mons, the trough and faults are not visible, and Theia appears to be superimposed on the western boundary fault of the rift zone (profile a, Fig. 1). North of Theia, the trough makes several shifts 20–30 km to the west along strike, and the trough itself is much narrower than the zone of faulting. South of Rhea Mons (profiles d–e, Fig. 1), the trough becomes a broad central low on the dome, losing its distinct profile. At Rhea Mons, flank heights increase and the trough narrows and deepens (profile f, Fig. 1). North of Rhea (profiles g–j, Fig. 1), the trough broadens and becomes shallower as the topography decreases. Arecibo and Venera 15/16 data of northern Beta Regio indicate that the faults of the rift zone are rough scarps generally facing the central depression. The faults have a general N–S trend through central Beta, then splay out as the topography decreases into the plains to the north. The faults are usually spaced 10–20 km apart, but are 5 km apart near Rhea Mons.

Volcanic structures. Plains characterized by moderate roughness and reflectivity compose the majority of the surface of the Beta highland and the surrounding region. Plains units on Venus have been interpreted to be volcanic in origin on the basis of general morphology and Venera lander measurements (6). Abundant domes are seen in the plains surrounding Beta, and are also interpreted to be volcanic in origin (6). The domes are 10–15 km in diameter, some with summit craters, with no observed flow features.

Volcanic shields are closely associated with the rift zone in Beta Regio. Theia Mons, located in southern Beta Regio, is a 5 km topographic high over 350 km in diameter. Theia is surrounded by radial flow-like features that trend down regional slopes. The volcanic shield is superimposed on the western boundary fault of the rift, and appears to postdate major rifting and faulting. Rhea Mons, over 900 km to the north of Theia, is a 4 km topographic high above mean planetary radius, with a maximum width of over 250 km. Rhea is a shield-shaped topographic dome dissected by the trough. The trough dissecting Rhea contains radar-bright faults parallel to the trough walls. Flow-like radar-bright and dark features trending down regional slopes are visible on the flanks, and apparently interrupt major fault trends. The dissection of Rhea by the trough indicates that Rhea predated the major formation of Devana Chasma in Beta, but postdated at least some uplift and faulting.

The tectonic and volcanic structures in Beta Regio allow a number of fundamental questions on the origin and nature of Beta to be addressed.

1. **Is the topography associated with the Beta rift (both the broad topographic rise and the narrower flanks) a result of volcanic construction or uplift?** If the topography were a result of only uplift, faulting may reflect stresses due to doming, and flank heights would not be expected to be higher in the vicinity of volcanic features. If topography were solely the result of volcanic loading, the rift and faults would have formed only as a result of lithospheric stretching or flexural processes associated with loading. The fault patterns associated with the Beta rift zone most resemble theoretical fault patterns produced by doming under regional tension (7, 5). The distribution of volcanic structures and the fault patterns indicate that uplift has been significant in the formation of the overall topography of Beta Regio. At the major volcanic shields, increased flank heights associated with the topography of the volcanoes indicate that volcanism has contributed at least 1 km of topography to the flanks. The evidence for doming and early-stage construction of Rhea Mons indicate that a thermal anomaly may have been significant in the formation of the high topography of Beta Regio.

2. **What is the role of volcanism in Beta Regio?** Volcanism associated with the rift zone is dominated by two large shield volcanoes, Theia and Rhea Mons, with diameters >250 km. Both are accompanied by radar-bright and dark flow-like features that extend for 100's of kilometers down regional slopes. Both volcanoes are characterized by high dielectric materials, which may be associated with relatively young volcanic activity (8). Theia and Rhea are controlled or appear to control structural features. Rhea is dissected by the trough and predates major trough formation. Theia Mons is superimposed on the western boundary fault of the rift zone, and postdates major rifting. Although volcanic shields occur in other tectonic environments on Venus (9), shield volcanoes are closely associated with extensional tectonics in Beta Regio.

3. **What is the sequence of events in Beta Regio?** A sequence of events in Beta has been determined utilizing

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volcanic and tectonic evidence. Flows around Rhea Mons appear to trend down regional slopes of the dome and overlie major fault trends. We interpret this to indicate that domal uplift was accompanied by faulting and lithospheric extension, and then followed by volcanic flooding and formation of Rhea Mons. The formation of the trough, Devana Chasma, postdated the formation of Rhea, with continued rift-related faulting in the trough. The closer spacing of faults at Rhea may be due to simple crustal thinning or differential strength layering in the lithosphere at the time of deformation. Further volcanic activity resulted in the formation of Theia Mons, with the location of Theia on the western boundary fault indicating structural control. Some of the events discussed above may have overlapped in time. The volcanic activity associated with the rift has moved to the south over time, similar to migration of tectonic and volcanic activity at terrestrial rifts (10).

Conclusions. Present data suggest that Beta Regio formed as a result of doming in response to a thermal anomaly, initiating a major shield volcano, Rhea Mons. Trough formation followed, with extensive faulting within the trough. Later volcanism produced a second major shield volcano, Theia Mons, superimposed on the rift zone. The sequence of events at Beta outlined above is similar to reconstructed events at the terrestrial East African rift (11). In Kenya, faulting was accompanied by doming and stretching of the lithosphere, followed by extensive volcanism. Trough formation occurred later, with continued faulting within the trough (11). The similarities between the East African and Beta rift zones will provide further constraints on the nature of the Beta rift zone. The lack of impact craters on the Beta dome indicates a relatively young age for the surface of Beta. The dome itself may be older, with impact craters covered by a thin veneer of volcanic deposits. Chasmata similar to Devana are located in Aphrodite Terra, and are also likely to be sites of major crustal uplift, extension and volcanism. Isolated topographic highs along the Aphrodite chasmata may be shield volcanoes comparable to Rhea and Theia Mons.

References. 1) H. Masursky *et al.*, *JGR, 85*, 8232, 1980. 2) G.G. Schaber, *GRL, 9*, 499, 1982. 3) G.E. McGill *et al.*, *GRL, 8*, 737, 1981. 4) D.B. Campbell *et al.*, *Science, 226*, 167, 1984. 5) E.R. Stofan *et al.*, *LPSC XVII, Suppl.*, 1031, 1986. 6) V.L. Barsukov *et al.*, *JGR, 91*, 378, 1986. 7) M.O. Withjack and C. Scheiner, *AAPG Bull., 66*, 302, 1982. 8) J.W. Head *et al.*, *JGR, 90*, 6873, 1985. 9) E.R. Stofan *et al.*, in press, *Earth, Moon and Plan.*, 1987. 10) J. Illies, *Tectonophys., 29*, 251, 1975. 11) B.H. Baker and J. Wohlenberg, *Nature, 229*, 538, 1971.

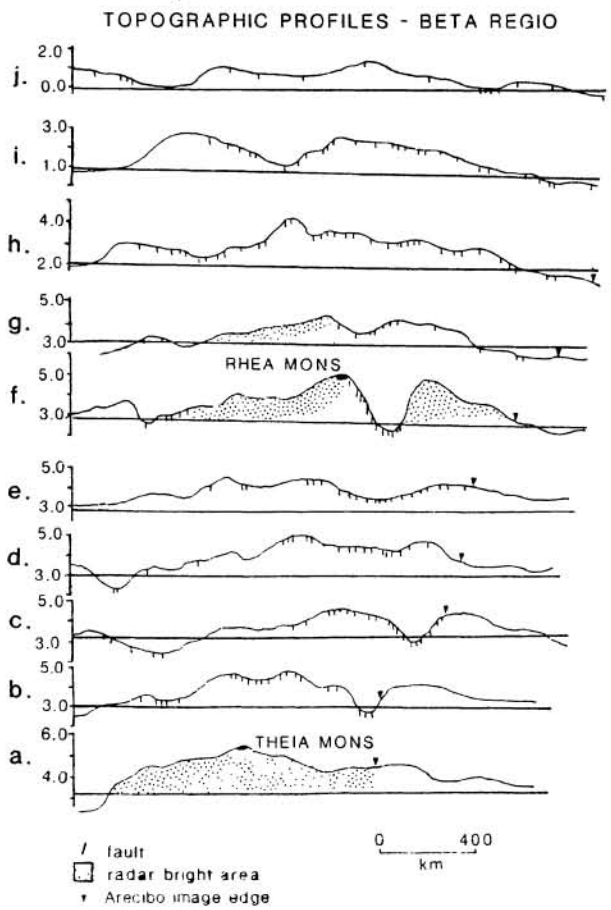

Figure 1. E-W topographic profiles across Beta Regio based on Pioneer Venus altimetry data with superimposed Arecibo radar characteristics. Lines represent location of linear radar-bright features interpreted as zones of roughness (talus) associated with fault scarps, but do not represent exact fault location or fault dip.