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VENUS: PRELIMINARY GEOLOGIC MAPPING OF SOUTHERN BETA REGIO–NORTHERN PHOEBE REGIO.
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New preliminary geologic maps of C1 sheets 15N283 and 00N283 were compiled according to Magellan data (Figs. 1 and 2). The oldest terrains are tesserae that have fragmentlike shapes. Its margins are partly buried by younger plain materials. Volcanic plains are the dominant types of terrains. There are many different volcanic features on plains: radar-bright and -dark flows and spots, shield volcanos, volcanic domes and hills with varied morphology, and coronalike constructions.

Devana Chasma rift crosses the surface between Beta Regio and Phoebe Regio. The rift's normal faults dissect volcanic plains and shield volcanos. The rift valleys are relatively young structures. According to structural analysis of the rift valleys we conclude the rift originated due to 5–10% crustal extension and crustal subsidence. Devana Chasma rift is characterized by shoulder uplifts.

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VENUS: GEOLOGY OF BETA REGIO RIFT SYSTEM.
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Beta Regio is characterized by the existence of rift structures [1,2,3]. We compiled new geologic maps of Beta Regio according to Magellan data (Figs. 1 and 2). There are many large uplifted tesserae on Beta upland. These tesserae are partly buried by younger volcanic cover. We can conclude, using these observations, that Beta upland formed mainly due to lithospheric tectonic uplifting and was only partly constructed by volcanism.

Theia Mons is the center of the Beta rift system. Many rift belts are distributed radially to Theia Mons. Typical widths of rifts are 40–160 km. Rift valleys are structurally represented by crustal grabens or half-grabens. There are symmetrical and asymmetrical rifts. Many rifts have shoulder uplifts up to 0.5–1 km high and 40–60 km wide.

Preliminary analysis for rift valley structural cross sections lead to the conclusion that rifts originated due to 5–10% crustal extension. Many rifts traverse Beta upland and spread to the surrounding lowlands. We can assume because of these data that Beta rift system has an "active-passive" origin. It formed due to regional tectonic lithospheric extension. Rifting was accelerated by upper-mantle hot spot origination under the center of passive extension (under the Beta Regio).

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THE ORIGINS OF RADIAL FRACTURE SYSTEMS AND ASSOCIATED LARGE LAVA FLOWS ON VENUS.
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Magellan images have revealed the existence of systems of radial fractures on Venus that are very similar in form to terrestrial dike swarms such as the Mackenzie swarm in Northern Canada. The association of many of the fracture systems with lava flows, calderas, and volcanic edifices further support the idea of a dike emplacement origin [1]. A global survey of the Magellan images has allowed the location of 300 such fracture systems [1]. The fracture systems vary widely in form but can be broadly divided into two types or classes (Figs. 1 and 2).

Classes of Fracture Systems: Figure 1 shows a fracture system in which fractures radiate away from the outer edge of a caldera 70 km in diameter and feed short, indistinct flows that have built an edifice 700 m high. The form of this feature is very reminiscent of the style of dike emplacement and eruption seen in places like Hawaii and Iceland where emplacement of dikes occurs laterally from magma chambers situated at shallow levels [2–5]. The existence of a caldera in the feature in Fig. 1 is suggestive of localized storage of magma at relatively shallow levels, though the greater diameter of the caldera compared with terrestrial examples may imply deeper storage than is seen in Hawaii or Iceland (where magma storage is centered at a depth of ~3 km below the surface). Thus this first type of radial fracture system has properties consistent with lateral dike emplacement from a magma chamber situated at depths of probably a few kilometers below the surface. By contrast, the feature shown in Fig. 2 has no caldera, but instead is largely contained within a much greater diameter (~200 km) concentric trough. In addition, the radial fractures show a more complex

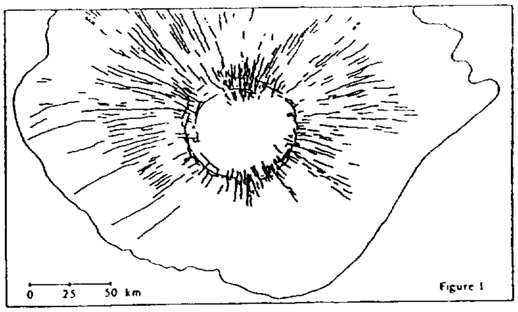

Fig. 1. Map of a radial fracture system located at 38°S 23°.

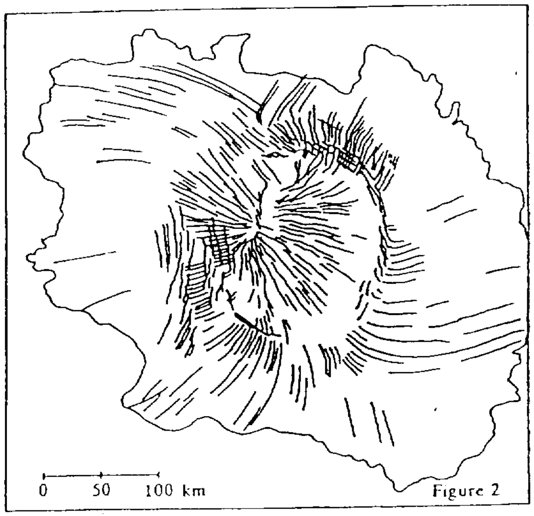

Fig. 2. Map of a radial fracture system located at 15°S 215°.

relationship at the center of the swarm radiating from a central point with some apparently crossing the central region, rather than radiating from it. This pattern seems more consistent with vertical dike emplacement from a deeper source associated with the concentric fracturing and deformation. However, the radial fractures still have a basic radiating form that, like that in the example in Fig. 1, is very suggestive of lateral propapagation. Thus the second type of fracture system (Fig. 2) probably results from growth of dikes from deep levels, possibly from the head of a mantle plume. At depth, propagation would be primarily vertical due to the buoyancy of the magma, but as the dikes propagated to shallower depths, propagation seems to have developed a lateral component, probably due to the reduced density contrast between the magma and crust. Recently it has been shown that dikes within the Mackenzie swarm in Canada show evidence of vertical magma flow close to the center of the swarm and of lateral flow at greater distances from the center [6]. This is consistent with the pattern of dike emplacement discussed above.

Dike Emplacement Modeling: A series of models was developed to simulate the emplacement of dikes on Venus [7]. Observations of fracture lengths and widths were then used to constrain the emplacement conditions [7]. The model results show that the great length and relatively large width of the fractures can only be explained if the dikes that produce them were emplaced in high driving pressure (pressure buffered) conditions. Such conditions imply high rates of melt production, which, particularly in the case of type 2 swarms, is consistent with the melt being derived directly from a plume head.

Associated Volcanism: Approximately 50% of the radial fracture systems found on Venus are associated with lava flows. These flows typically have lengths of tens to hundreds of kilometers and widths of a few kilometers. The thicknesses of the flows are not known, but their lack of expression in the altimetry data suggests that they are <100 m thick and they may well be considerably thinner than this. The lobate or digitate form of such flows suggests that they are cooling-limited, while the fact that the flows from one radial fracture swarm tend to be fairly similar suggests that the flows are emplaced under eruption conditions that vary little through the history of a swarm. Eruption rates for such flows can be estimated using the flow length, width, and thickness. Pinkerton and Wilson [8] developed a relationship between the geometry of a cooling-limited flow and the eruption rate at the vent. If the flow has a length L, a width W, and a thickness D, then the volume eruption rate V is given by

$$V = \frac{300\,L\,W\kappa}{D}$$

where κ is the thermal diffusivity, which for basalt has a value of ~10^{-6} m^2/s. If we take typical dimensions for a flow from a radial fracture system—L = 75 km, W = 10 km, and D = 10 m (the latter is probably a minimum estimate)—an estimate of the typical eruption rate can be calculated and is found to be ~0.08 km^3/hr, implying an emplacement time of ~3 days. This eruption rate is ~2.5 times higher than the maximum eruption rate calculated for the Laki fissure eruption in Iceland [9] and 1/50 of the estimated eruption rates for the most rapidly emplaced Columbia River flows [10].

Eruption Rates Implied by Dike Modeling: We have recently modeled the vertical emplacement of a dike from the top of a mantle plume and calculated the eruptions rates such a dike would produce on reaching the surface. This modeling shows that eruption rates of ~0.1 km^3/hr can readily be generated by such a dike, consistent with the above results. However,the sensitivity of the model to dike width and therefore driving pressure means that eruption rates from dikes emplaced from the base of the crust or the head of a mantle plume could be orders of magnitude higher than this. Clearly, therefore, the model needs to be refined in order to better constrain eruption conditions. However, it is worth noting here that the initial results do show that even for moderate dike widths (<10 m), eruption rates could be at least on the order of those estimated for terrestrial flood basalts. As our modeling of the lengths and widths of fractures ([7] and above) imply dikes of up to 75 m in width, effusion rates could be considerably higher than this. There is no obvious physical limit on how high eruption rates can be, and indeed, given the widths implied for these dikes (and these widths compare remarkably well with those found for terrestrial dike swarms; see, e.g., [6]), it is difficult to avoid having very high eruption rates. Thus dikes propagating to the surface from the head of a mantle plume could give rise to flows emplaced at very high rates which would therefore be expected to form broad sheetlike flows, i.e., flows like those forming the plains areas on Venus [11].

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APPLICATION OF LEFT- AND RIGHT-LOOKING SAR STEREO TO DEPTH MEASUREMENTS OF THE AMMAVARU OUTFLOW CHANNEL, LADA TERRA, VENUS.

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Venusian channels are too narrow to be resolved by Magellan's radar altimeter, so they are not visible in the standard topographic data products. Stereo image data, in addition to their benefit to geologic mapping of Venus structures as a whole [1], are indispensible in measuring the topography across the channels. These measurements can then be used in conjunction with the regional topographic maps based on the altimeter data to produce cross-sectional areas for the channels and estimate the fluid discharge through them.

As an example of the application of the stereo image data to venusian channels, a number of test depth and profile measurements were made of the large outflow channel system in Lada Terra [2,3], centered at 50°S latitude, 21°E longitude (F-MIDR 50S021). These measurements were made by viewing the cycle 1 and 2 digital FMIDRs in stereo on a display monitor, so as to minimize the errors in measuring parallax displacement as much as possible. The MIDRs are produced at a scale of 75 m/pixel. This corresponds to a vertical scale of about 17 m/"pixel," when calculating the height of a feature from its parallax displacement. An error in placement determination of 1 pixel was assumed to characterize the vertical accuracy as ±17 m.

When this technique was applied to the outflow channel, it was noted that the walls of the collapsed terrain source and "trough reach" of the channel are laid over in both the cycle 1 and 2 images (incidence angles around 23°–25° for both right- and left-looking data). This is evident when examining the distance between features