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 $\sim 10^{-6}$ 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. T. J. Parker, California Institute of Technology, Jet Propulsion Laboratory, Pasadena CA 91109, USA.

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

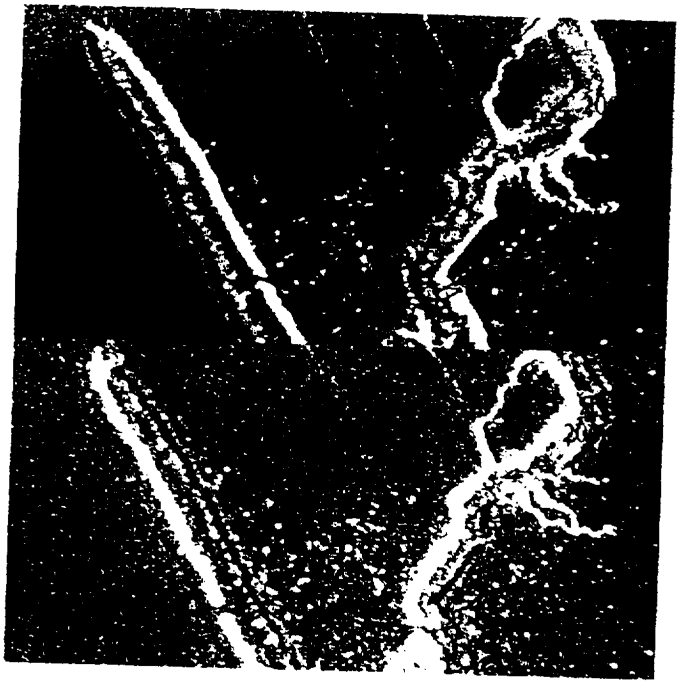

Fig. 1.

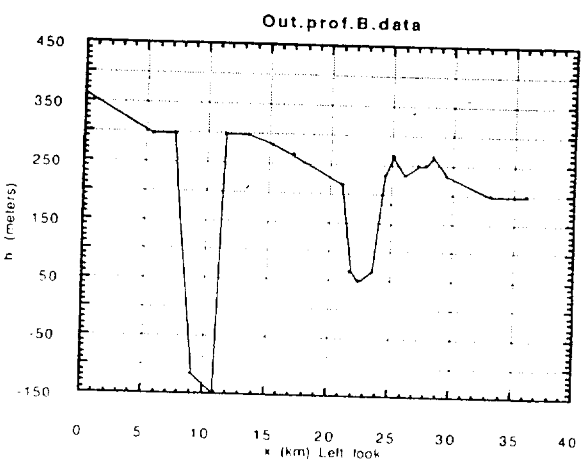

Fig. 2.

on the plateau and the cliff walls in the two images (Fig. 1). The layover "shifts" the features closer to the apparent edge of the wall relative to the oppositely illuminated image. Figure 1 also shows one "single-point" depth measurement, illustrating the large parallax displacement between the left- and right-looking data in areas of moderate relief. At the bottom of each scene is a sample profile trace across the trough and part of the channel connecting the collapsed source with the trough. Figure 2 is a plot of this data using the cycle 1 image sample values for placement on the x axis. Vertical height values are relative values, and are a function of the parallax displacement of features relative to the projection of the two FMIDRs.

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CHEMICAL DIFFERENTIATION OF A CONVECTING PLANETARY INTERIOR: CONSEQUENCES FOR A ONE-PLATE PLANET SUCH AS VENUS.

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Partial melting of the interior of a planet to generate its crust must inevitably leave behind compositionally buoyant residual mantle. This basalt-depleted mantle is chemically less dense than undepleted mantle due to its reduced Fe/Mg and dense Al-bearing minerals such as garnet. The chemical density difference is substantial: for 20% melt extraction the density decrease is as large as that due to a 500°C temperature increase. The melting temperature of this depleted residual mantle is also increased. Deep mantle circulation driven by cold strong sinking lithosphere associated with plate tectonics may mix the depleted mantle back into the mantle. In the absence of plate tectonics, less mixing will allow a buoyant depleted layer to collect at the top of the mantle [1,2].

Chemically depleted mantle forming a buoyant, refractory layer at the top of the mantle can have important implications for the evolution of the interior and surface. On Venus, the large apparent depths of compensation for surface topographic features [3] might be explained if surface topography were supported by variations in the thickness of a 100–200-km thick chemically buoyant mantle layer or by partial melting in the mantle at the base of such a layer. Long volcanic flows seen on the surface [4] may be explained by deep melting that generates low-viscosity MgO-rich magmas. The presence of a shallow refractory mantle layer may also explain the lack of volcanism associated with rifting [5]. As the depleted layer thickens and cools, it becomes denser than the convecting interior and the portion of it that is hot enough to flow can mix with the convecting mantle. Time dependence of the thickness of a depleted layer may create episodic resurfacing events as needed to explain the observed distribution of impact craters on the venusian surface [6].

We consider a planetary structure like that shown in Fig. 1 consisting of a crust, depleted mantle layer, and a thermally and chemically well-mixed convecting mantle. The thermal evolution

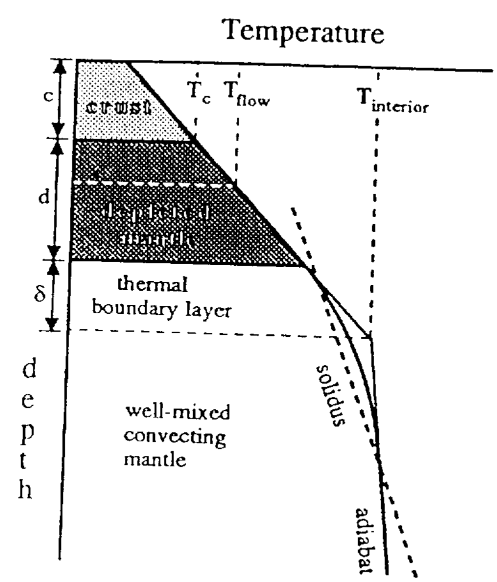

Fig. 1. Planetary structure considered in models of thermal/chemical internal evolution. These models examine the role of a chemically buoyant basalt-depleted mantle layer and crustal recycling on planetary evolution.