

RESIDUAL THERMAL STRESS: A MECHANISM FOR JOINTS IN VENUSIAN LAVA FLOWS; Catherine L. Johnson and David T. Sandwell, Scripps Institution of Oceanography, La Jolla, CA 92093

High resolution synthetic aperture radar (SAR) images collected by the Magellan spacecraft reveal several large areas containing polygonal fracture patterns. Fractures are generally associated with major lava flows (Figure 1) and occur in areas of low relief. Individual fractures do not display horizontal offsets suggesting that they are joints rather than faults. On the Earth, polygonal joints are due to thermal contraction of major flows and sills. We propose a similar origin for the much larger scale (~1 km) polygonal fractures found on Venus.

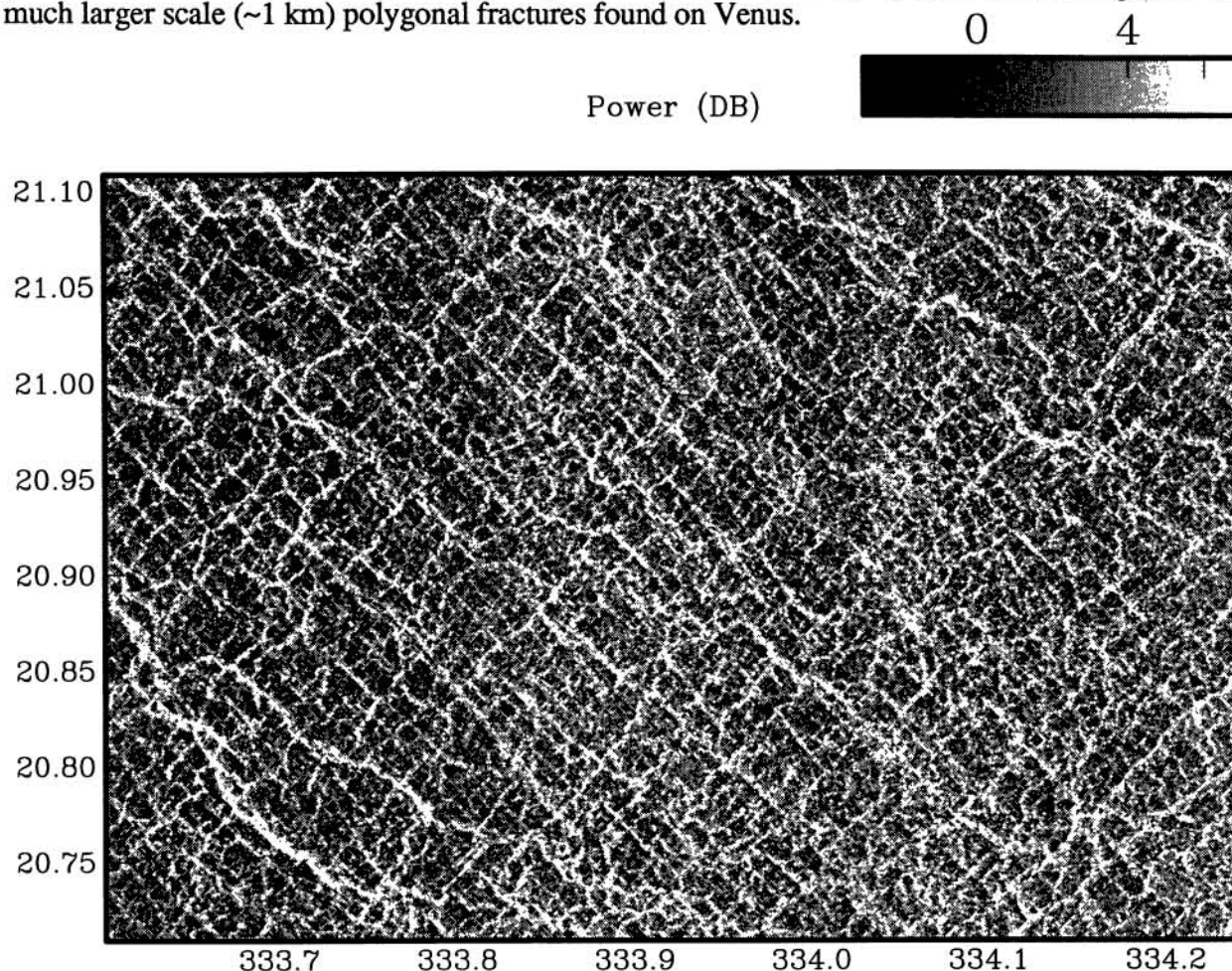


Figure 1. A Magellan SAR image of a highly fractured surface near Guinevere Planitia. In this region, lava appears to have flowed for several hundred kilometers down the regional topographic gradient toward the southwest. The fractures have characteristic spacings of 1.3 km and have preferred orientations in at least two directions. Widths of the individual fractures are at the resolution of the radar. We do not have a direct estimate of the thickness of this lava flow, however based on results from impact crater distributions (Phillips and Grimm, personal communication, 1990), it appears that major lava flows have obliterated craters over several large areas of the Venusian plains. Burial of major craters suggests that lava flows can be several hundred meters thick.

We calculate the temperature and thermal stress that develops in a thick (~200 m) basaltic lava flow (Figure 2). The flow (1200 C) is deposited on the surface of the Venusian lithosphere (25 km thick elastic layer). The upper surface of the flow is in contact with the constant temperature atmosphere (455 C) while the lower surface is in contact with the lithosphere having an initial temperature of 455 C. Temperatures and thickening of the upper layer are calculated using the

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Stefan solution while the "sill" solution is used for calculating the temperatures and thickening of the lower layer. After 40 years of cooling both the top and bottom of the flow solidify leaving a fluid core (dotted curve); by 256 years the core solidifies completely. By 800 years (dashed curve) the temperature falls below 720 C at all depths and by 4000 years (thick curve) the layer is almost completely cooled.

For the stress computation, we consider that the rock is perfectly elastic when it has a temperature less than 720 C (i.e. blocking temperature) but is able to relieve all of its shear stress when temperatures are greater. The stress that develops in the elastic material is proportional to the linear expansion coefficient times Young's modulus times the change in temperature. Stress accumulation is computed incrementally to account for both the thickening and the overall contraction of the layers. Between times of 0 and 800 years the interior of the flow is above the blocking temperature allowing the upper layer to be completely decoupled from the underlying lithosphere. The thin upper layer contracts laterally resulting in compression (negative) at the surface balanced by tension (positive) at depth (dotted curve). The interior of the flow, which is above the blocking temperature, has no stress. The uppermost lithosphere is heated and goes into compression. By 800 years (dashed curve) the flow has hardened completely causing the upper layer to become bonded to the lithosphere. Further cooling causes a rapid increase in tensile stress throughout the flow. Residual thermal stresses (thick curve) greatly exceed the strength of rock resulting in fractures. We have not yet related the fracture patterns to the stress field and cooling rate. However we speculate that in addition to explaining the polygonal fractures, residual thermal stress may also cause closely spaced (1-2 km) linear fractures; the orientation of the linear fractures may be controlled by a small regional stress field.

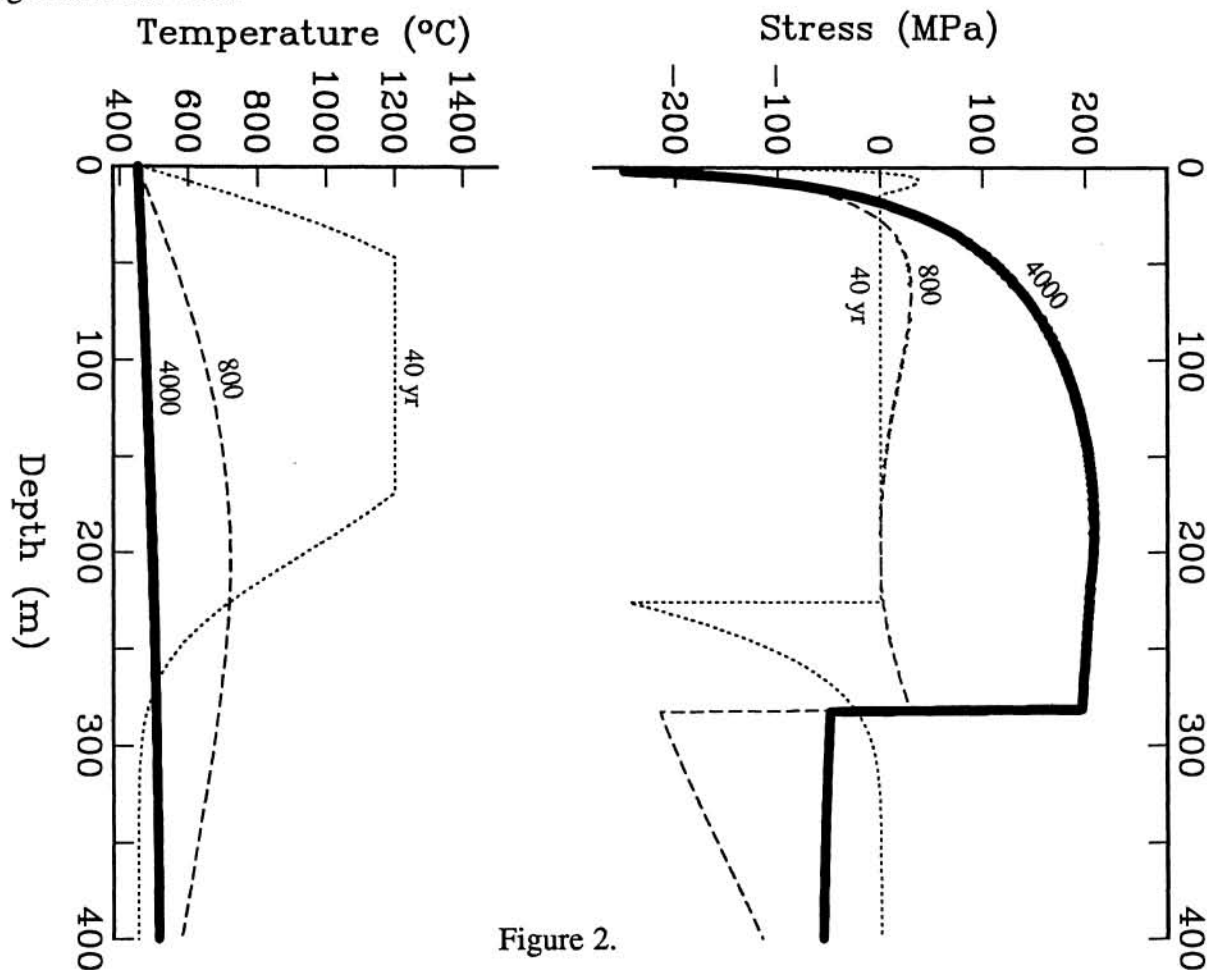


Figure 2.