in the southwestern part of Lavinia Planitia than in most places, it can be shown that many of the ridge belts are older than the areally dominant plains materials on which wrinkle ridges are developed [3]. This relationship indicates that the wrinkle ridges are younger than the ridge belts, and thus suggests that locally similar trends of ridge belts and wrinkle ridges must be explained as due to stress orientations that did not change with time. Nevertheless, there are places in the same general area where it appears as if wrinkle ridges grade along their lengths into ridges of a ridge belt. Taken at face value, this latter relationship suggests that both structures were formed by the same stress field, and presumably at the same time. Because the local relationships send conflicting signals concerning the geometric and kinematic kinship of wrinkle ridges and ridge belts, it is hoped that a more regional perspective might be helpful. At the scale of the entire planitia there is not a consistent relationship between the trends of wrinkle ridges and the trends of ridge belts. This preliminary result suggests that ridge belts and wrinkle ridges are different features. Local similarities in trend and the cases where one seems to grade into the other can be explained by inferring temporal coherence of stress field or by some form of geometric inheritance.

Finally, even though wrinkle ridges appear to be relatively young features, they are evidently older than most or all fresh impact craters. This inference is based mainly on the apparent obliteration of wrinkle ridges by crater ejecta, although this may not be a foolproof criterion (wrinkle ridges might not form in ejecta materials, or might be invisible if present because of no roughness contrast). A single example of a flow emanating from an impact crater being ponded by a wrinkle ridge has been found, and this relationship is considered to be good evidence of relative age.

Wrinkle ridges are important structures on planetary surfaces because they are so common and because they provide useful clues to stresses in the shallow crust. Because so much of Venus is plains, wrinkle ridges are especially useful for inferring crustal evolution on that planet.

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N93-14344

ESTIMATES OF ELASTIC PLATE THICKNESSES BENEATH LARGE VOLCANOS ON VENUS. Patrick J. McGovern and Sean C. Solomon, Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge MA 02139, USA.

Introduction: Magellan radar imaging and topography data are now available for a number of volcanos on Venus greater than 100 km in radius. These data can be examined to reveal evidence of the flexural response of the lithosphere to the volcanic load. On Earth, flexure beneath large hotspot volcanos results in an annular topographic moat that is partially to completely filled in by sedimentation and mass wasting from the volcano's flanks (see [1,2]). On Venus, erosion and sediment deposition are considered to be negligible at the resolution of Magellan images [3]. Thus, it may be possible to observe evidence of flexure by the ponding of recent volcanic flows in the moat. We also might expect to find topographic signals from unfilled moats surrounding large volcanos on Venus, although these signals may be partially obscured by regional topography. Also, in the absence of sedimentation, tectonic evidence of deformation around large volcanos should be evident except where buried by very young flows.

We have found two examples to date of volcanos with strong evidence for moat formation and infilling by flows. Radar images of Tepev Mons, a volcano about 125 km in radius near the southwestern corner of Bell Regio, reveal a bright flow unit draped around the northern and western flanks of the volcano. An unnamed volcano at 10°N, 275°E (southwest of Beta Regio) exhibits both circumferential flanking flows and lateral spreading of originally radially trending flows. The distal edges of these flows terminate about 240–260 km from the summit. The edges of these flows form an arc of greater than 120° to the north and west of the volcano.

Method: We use analytic solutions in axisymmetric geometry [4] for deflections and stresses resulting from loading of a plate overlying an inviscid fluid. Solutions for a set of disk loads are superimposed to obtain a solution for a conical volcano. The deflection of the lithosphere produces an annular depression or moat, the extent of which can be estimated by measuring the distance from the volcano's edge to the first zero crossing or to the peak of the flexural arch. Magellan altimetry data records (ARCDRs) from data cycle 1 are processed using the GMT mapping and graphics software [5] to produce topographic contour maps of the volcanos. We then take topographic profiles that cut across the annular and ponded flows seen on the radar images. By comparing the locations of these flows to the predicted moat locations from a range of models, we estimate the elastic plate thickness that best fits the observations, together with the uncertainty in that estimate.

Results: Figure 1 shows two cross sections through Tepev Mons. The areas covered by annular flows are marked with arrows. Figure 2 shows deflections calculated analytically for a conical load of height 10 km and radius 150 km for elastic plate thicknesses T_e of 10 km and 20 km. Arrows denote the predicted approximate extent of a moat due to loading in each model. Note that for the analytic solutions, increasing the elastic plate thickness increases both the maximum depth and the radial extent of the predicted moat. The model in Fig. 2a matches the northwestern cross section in Fig. 1a. The area of flows in Fig. 1b is somewhat larger in radial extent and is better matched by the predicted moat in Fig. 2b. Figure 3 shows a cross section through the volcano at 10°N, 275°E. Figure 4 shows calculated deflections for a conical load of height 5 km and radius 250 km, for elastic plate thicknesses of 10 and 20 km. The extent of annular flows is better matched by the smaller thickness.

Discussion: These two volcanos are apparently atypical of large volcanos on Venus in that both topography and flow morphology suggest the existence of a flexural moat. On other large shield volcanos such as Sif Mons and Sapas Mons, topographic evidence of a moat is lacking, and no flows that have convincingly ponded in annular moats can be identified. Large volcanos that form on or near large rift zones (such as Maat Mons, Ozza Mons, and others) also lack topographic evidence of a flexural moat. It should be noted that as altimetry data and stereo imaging from later cycles become available, coverage will improve, gaps will be filled in, and it may be possible to identify topographic signatures of moats that have eluded our search to date.

In contrast to Tepev Mons and the construct at 10°N, 275°E, most large volcanos on Venus are generally characterized by fractures and flow units that have dominantly radial orientations. Given this observation and the assumption that lithospheric flexure has occurred, then the moats must be filled or covered. Mass wasting,

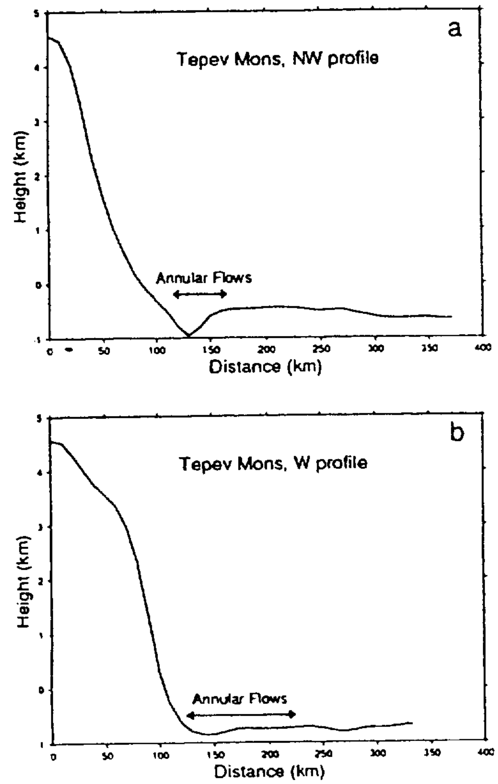

Fig. 1. Topographic cross sections through Tepev Mons: (a) northwestern profile; (b) western profile.

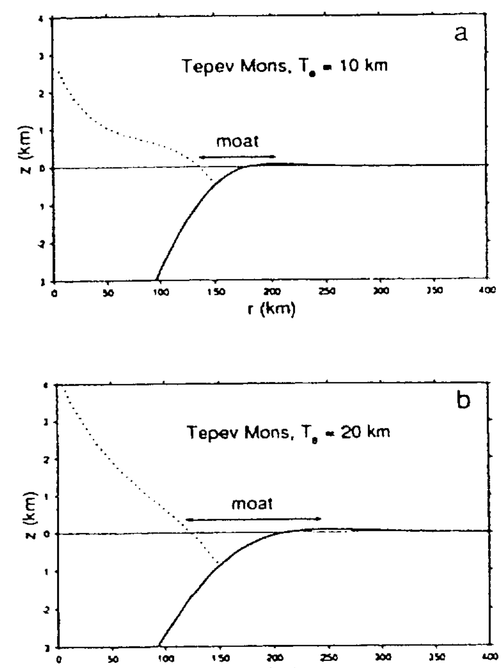

Fig. 2. Analytic solutions for lithospheric deflection by a conical load of height 10 km and radius 150 km. The solid line is the deflection solution, while the dotted line includes the topography from the load. (a) T_e = 10 km; (b) T_e = 20 km.

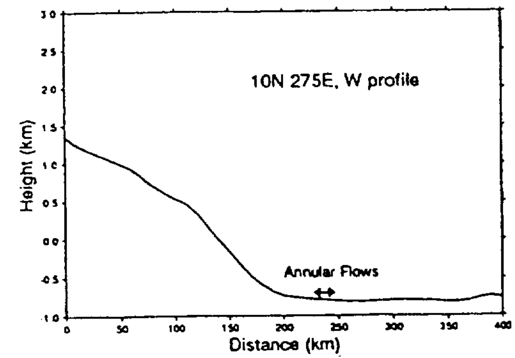

Fig. 3. Topographic cross section through the volcano at 10°N, 275°E, extending westward.

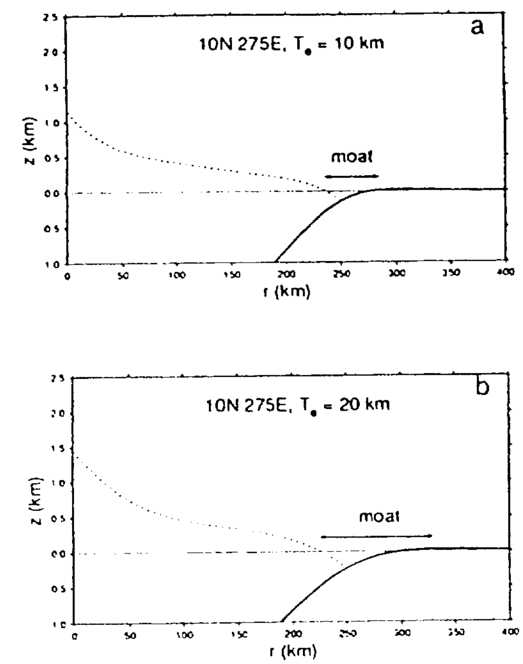

Fig. 4. Analytic solutions for lithospheric deflection by a conical load of height 5 km and radius 250 km. Solid line is deflection solution, dotted line includes the topography from the load. (a) T_e = 10 km; (b) T_e = 20 km.

through large landslides or slumps such as those discovered off the Hawaiian Islands [2], is one possibility. Moat-filling flows may be covered by later radial flows, a process that may have been repeated many times during volcano growth.

Conclusions: Under the assumption that circumferentially ponded flows surrounding volcanos have at least partially filled a flexural moat, we can compare the position and extent of the moat to predictions from analytic flexure models. For Tepev Mons, models that fit best have plate thicknesses in the range of 10 to 20 km. For the volcano at 10°N, 275°E, the best fit is obtained for a thickness of about 10 km. These values of elastic plate thickness can be converted to estimates of mechanical plate thickness and thermal gradient [6]. Using parameters appropriate for Venus [7] we obtain thermal gradients values of about 12–25 K/km for Tepev Mons and about 25 K/km for 10°N, 275°E. These gradients are in the range expected if Venus loses most of its internal heat by conduction through a globally continuous, if laterally heterogeneous, lithospheric shell [7].

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N93-14345

PANCAKELIKE DOMES ON VENUS. Dan McKenzie[1], Peter G. Ford[2], Fang Liu[2], and Gordon H. Pettengill[2], [1]Institute of Theoretical Geophysics, Bullard Laboratories, Madingley Road, Cambridge CB3 OEZ, UK, [2]Center for Space Research, Massachusetts Institute of Technology, Cambridge MA 02139, USA.

The shape of seven large domes on the plains of Venus, with volumes between 100 and 1000 km^3, is compared with that of an axisymmetric gravity current spreading over a rigid horizontal surface. Both the altimetric profiles and the horizontal projection of the line of intersection of domes on the SAR images agree well with the theoretical similarity solution for a newtonian fluid, but not with the shape calculated for a rigid-plastic rheology, nor with that for a static model with a strong skin. As a viscous current spreads, it generates an isotropic strain rate tensor whose magnitude is independent of radius. Such a flow can account for the randomly oriented cracks that are uniformly distributed on the surface of the domes. The stress induced by the flow in the plains material below is obtained, and is probably large enough to produce the short radial cracks in the surface of the plains beyond the domes. The viscosity of the domes can be estimated from their thermal time constants if spreading is possible only when the fluid is hot, and lies between 10^{14} and 10^{17} Pa s. Laboratory experiments show that such viscosities correspond to temperatures of 610°–690°C in dry rhyolitic magmas. These temperatures agree with laboratory measurements of the solidus temperature of wet rhyolite.

These results show that the development of the domes can be understood using simple fluid dynamical ideas, and that the magmas involved can be produced by wet melting at depths below 10 km, followed by eruption and degassing.

N93-14346

GROUNDBASED NEAR-IR OBSERVATIONS OF THE SURFACE OF VENUS. V. S. Meadows[1], D. Crisp[2], and D. A. Allen[3], [1]University of Sydney, Sydney, Australia, [2]Jet Propulsion Laboratory, Pasadena CA, USA, [3]Anglo-Australian Observatory.

Near-infrared observations of the nightside of Venus have revealed thermal emission from the lower atmosphere in relatively transparent regions of the spectrum centred on 1.0, 1.1, 1.18, 1.27, and 1.31 μm [1,2,3]. The emission in these windows is believed to originate from the very lowest scale heights of the atmosphere and from the surface. Recent groundbased work in the 1.0-μm window [4], and measurements made at 1.18 μm by the Galileo NIMS during its 1990 flyby [3], indicate that the Venus surface topography produces contrasts in the thermal emission. These contrasts are believed to be caused primarily by surface temperature differences associated with differences in surface elevation. A similar correlation of reduced emissivity with altitude has been seen in 17-cm radio maps [5], although these contrasts are not consistent with topographically related temperature differences alone, and are postulated to be the result of increased reflectivity due to the presence of conducting materials in the highland surfaces. As well as providing information about the surface, observations in the near infrared can be used to obtain estimates of the optical depth of the lower atmosphere at these wavelengths and to constrain the water abundance in the lower atmosphere.

We present images of the nightside of Venus taken in the near-infrared windows at 1.0, 1.1, 1.18, 1.28, 1.31, and 2.3 μm with the new infrared camera/spectrometer IRIS on the Anglo-Australian Telescope. These data were taken in spectral-mapping mode. This technique involves scanning the telescope perpendicular to the slit, while collecting spectra at successive slit positions across the planet. We produce data cubes with one spectral and two spatial dimensions. The spectra have a resolution $\lambda/\Delta\lambda \sim 400$. Images can be extracted over any wavelength regions. Each image has square pixels of 0.8" resolution. Spectral image cubes were obtained on a total of eight days during July, September, and October 1991. The July cubes cover the spectral region 0.820–1.511 μm and the September and October cubes 1.135–1.317 μm. We reduced the scattered light from the sunlit crescent in images extracted from each window by subtracting images taken on either side of the window, where the Venus atmosphere is opaque. Unlike the short wavelength windows, which reveal thermal contrasts that originate primarily from the surface and deep atmosphere, the emission in the 2.3-μm window is produced at much higher altitudes (30–40 km). Emission contrasts seen near 2.3 μm are associated with horizontal variations in the cloud optical depths, and have rotation periods of about six days [2]. These cloud contrasts fade at shorter wavelengths as the cloud deck becomes steadily more transparent, but are still present and must be removed to distinguish the surface emissivity contrasts.

We detect large contrasts in infrared emission (20–40%) across the disc of Venus in the 1.0-, 1.1-, 1.18-, 1.28-, and 1.31-μm images. Contrasts at these wavelengths may be due to a combination of variations in the optical depths of the overlying sulfuric acid clouds and differences in surface emission. Comparison with the 2.3-μm images show that the patterns seen in the 1.28- and 1.31-μm windows are consistent with cloud optical depth variations alone and require no contribution from the surface. However, images at 1.0, 1.1, and 1.18 μm from July 1991 show a dark feature having a contrast that increases with decreasing wavelength (Fig. 1). This behavior is contrary to that expected of cloud absorption. Images taken on three successive days in October show another dark feature that is stationary with respect to the surface. These regions of lower emission correspond closely to the high-altitude surface regions of Beta Regio and Aphrodite Terra.

The images can potentially reveal the near-infrared emissivity of the surface of Venus, thereby complementing Magellan radar reflectivity and groundbased radio emissivity measurements. The contrast ratio between highlands and plains is much smaller than would be expected for blackbody radiation from the surface alone. Unlike at radio wavelengths, where the atmosphere is essentially transparent, at near-infrared wavelengths the atmosphere emits, absorbs, and scatters radiation, and can modify the observed topographically induced contrasts. The additional radiation from the atmosphere reduces the contrast, and further modification would be expected if terrain at different altitudes has different emissivities. A fit to our data therefore requires, and may constrain, a model of the