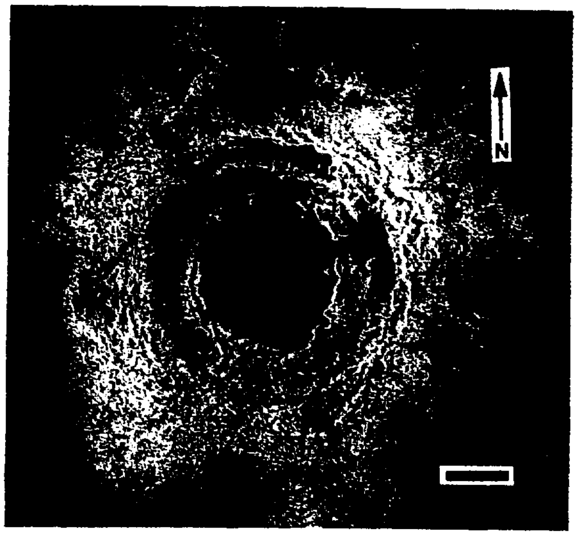

Fig. 2. Mona Lisa Crater, centered at 25.6°N, 25.2°E near the edge of Eisila Regio. Note partial flooding of outer moat structure and bright fracture pattern in the central floor plate. Scale bar is ~17 km (enlarged section of C1-30N027;1).

recognized. Although transected by a number of later wrinkle ridges, both the outer moat region and the central floor appear to be relatively smooth and may reflect a sequence of crater-centered volcanism after the uplift event, also observed in the lunar crater Posidonius. The second crater (Fig. 2) is larger (~75 km diameter) and somewhat less modified. In this case, a bright ridge nearly surrounds the central floor plate, and volcanism has only flooded the central floor and the northern half of the outer moat structure, allowing identification of the moat fractures in the south. Inside the central floor plate, concentric fractures bound the central floor with a set of radial/polygonal fractures in the center of the floor plate. Both craters occur in ridged lowland plains with elevations close to the mean planetary radius. Since the ejecta pattern and the scalloped southern crater rim indicate an oblique impact from the north [16,17], the northward offset of these central fracture patterns relative to the crater center is consistent with the uprange offset of both central peaks and basin rings in other oblique impact structures [5,16,17], whereas the distribution of moat-filling volcanism is consistent with the enhanced failure uprange proposed by [5,18,19] for cavity collapse in an oblique impact event.

The intrusion parameters derived from the relations of [13] can be related to the local crustal structure. For floor uplift of ~1.5 km (inferred for the craters described above), both craters indicate a magmatic driving pressure of ~375 bar for a basaltic melt. If this pressure then reflects the magmastatic head resulting from the density contrast between a basaltic magma (~2800 kg/m^3) and a basaltic crust (3000 kg/m^3), a magma column length of 22 km is indicated for both regions. Since the effective thickness of the floor plate is estimated at 2–6 km for crater 1 and 4–8 km for crater 2, this simple model requires a crustal (basaltic) thickness exceeding ~2530 km. Alternatively, if the basaltic crust on Venus is less than 10–20 km, as proposed in [20], the base of the magma column occurs within a denser mantle unit at depths of less than 20–25 km. If the base of the magma column corresponds to a deep, regional magma chamber, these magma column models should indicate either the base of the basaltic crust or rheological boundaries with the crust or lithosphere [21]. Consequently, the implications of floor-fractured craters on Venus for subsurface density provide an additional test for models of regional crustal structure.

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N93-14394

VENUS: GEOCHEMICAL CONCLUSIONS FROM THE MAGELLAN DATA.

J. A. Wood, Harvard-Smithsonian Center for Astrophysics, Cambridge MA 02138, USA.

Though the Magellan mission was not designed to collect geochemical or petrological information, it has done so nonetheless. Since the time of the Pioneer Venus mission it has been known that high-altitude (>2.5–5 km) mountainous areas on Venus exhibit anomalously low radiothermal emissivity ($e < 0.6$) [1]. Magellan has greatly refined and extended these observations. The low emissivity requires surface material in the uplands to have a mineralogical composition that gives it a high bulk dielectric constant, >~20. The dielectric constant of dry terrestrial volcanic rocks seldom exceeds 7. The high-dielectric character of high-altitude surface material cannot be a primary property of the local volcanic rock, because there is no reason why rock having the required special mineralogy would erupt only at high altitudes. Therefore it is a secondary property; the primary Venus rock has reacted with the atmosphere to form a mineralogically different surface layer, and the secondary minerals formed are controlled by the ambient temperature, which decreases with altitude on Venus.

Klose et al. [2] showed that, for a plausible assumption of oxygen fugacity in the Venus atmosphere (~10^{-21} bar), variation of the equilibrium weathered mineral assemblage with altitude and temperature would create such a situation: above a few kilometers altitude the stable assemblage includes pyrite (FeS_2) in sufficient abundance to create a "loaded dielectric" with a bulk dielectric constant >~20; at lower altitudes the stable Fe mineral is magnetite (Fe_3O_4), and this is present in insufficient abundance to give rise to such a high bulk dielectric constant. Pettengill et al. [3] first concluded that pyrite was the mineral responsible for the high-dielectric materials observed at high altitudes on Venus.

Fegley et al. [4] reject this interpretation. They note that the gas species COS is much less abundant in the Venus atmosphere than the equilibrium concentration, and argue that the reaction

$$3FeS_2 + 2CO + 4CO_2 = 6COS + Fe_3O_4$$

would tend to oxidize pyrite to magnetite at all altitudes, using its S to build up the deficit of atmospheric COS. This argument is specious. Fegley et al. argue from only one reaction and three species abundances in the Venus atmosphere, while [2] used an energy-minimization procedure that effectively considers all possible reactions simultaneously. Klose et al. [2] used as input the bulk elemental composition of the atmosphere, not the abundances of selected gas species in it. They determined the total equilibrium system, including concentrations of gas species in the atmosphere as well as surface minerals. Klose et al. found, as Fegley et al. say, that the equilibrium abundance of COS is greater than the concentration the Venus atmosphere appears to contain (~15 ppm vs. ~0.25 ppm). Apparently kinetic barriers prevent COS from attaining its equilibrium concentration at ground level. Thus the Venus system is not completely at equilibrium. One can debate how badly the system is out of equilibrium, but the nonequilibrium abundance of the minor species COS in the atmosphere by no means requires that the surface mineralogy is completely out of equilibrium; and to be in equilibrium with the atmosphere's concentration of SO_2, ~185 ppm, at the f_{O2} cited above, the mountaintop mineral assemblage must contain pyrite.

Fegley et al. [4] suggest that primary perovskite ($CaTiO_3$) in the rock might be responsible for low-emissivity mountaintops on Venus, since this mineral has a particularly high dielectric constant. They note the occurrence of perovskite in (relatively rare) SiO_2-undersaturated igneous rocks on Earth, but do not examine its thermodynamic stability in more typical basalts, or in Venus basalts having the compositions reported by Soviet landers. In fact, perovskite is not a stable primary mineral at crystallization temperatures in these expected Venus rock types: instead Ti appears as rutile, and most Ca as diopside and anorthite.

With time, the weathering reactions discussed by [2] work deeper and deeper into surface rock on Venus. The timescale of weathering—the time needed to weather rock to a depth sufficient to control the radiothermal emissivity measured by PVO and Magellan—is not known, but is expected to be long. Water is an essential ingredient of terrestrial weathering, and its near absence on Venus must greatly retard the process. To some extent this effect is offset by the much higher temperatures on Venus, but in spite of this it may take tens or even hundreds of millions of years to weather a high-altitude surface to a high-dielectric assemblage.

This is comparable to the timescales of other important processes on Venus, and an interplay between weathering and (e.g.) volcanism and tectonism is to be expected. In other words, it may be possible to use the presence or absence of weathering effects to distinguish between relatively young features on Venus and older landforms.

Volcanism: Klose et al. [2] and Robinson and Wood [5] have drawn attention to large and small flow units high on the volcanos Maat, Sapas, Ozza, and Theia Mons that display relatively high emissivities. They conclude these units are too young to have had time to weather to the high-dielectric pyritic state. This criterion, if confirmed, provides a crude basis for establishing a chronology of volcanism.

Tectonism: Klose et al. [2] and Pathare [6] have explored the complex relationship between altitude (a) and emissivity exhibited by Maxwell Montes. An a/e scatter plot of measurements made over the broad Maxwell landmass shows a well-defined band at e ~ 0.4, which presumably reflects the presence locally of completely weathered surface material; but there is also a broad scatter of points to higher values of e (<~0.6) in the diagram. Pathare [6] found these latter data points are provided by a belt of mountainous terrain (latitude ~67°, longitude 350°–05°) that defines the northern edge of the Maxwell Montes low-emissivity zone. Pathare [6] attributed the less-than-minimal emissivities in this belt to incomplete weathering, and concluded that this belt was uplifted more recently than other parts of Maxwell. The emissivity increases, and presumably the time of uplift decreases, westward along the belt.

The Magellan emissivity records contain other information of interest. For example, [5] found that some small volcanic domes and clusters of domes near plains level display anomalously low emissivity. At these altitudes, according to the model of [2], magnetite should be the stable Fe mineral, and weathered surface material should not have high-dielectric properties. Robinson and Wood [5] attributed this phenomenon to continued seepage of volcanic gas through the soil covering these domes, and showed that an admixture of only ~0.02% of sulfurous gas of the type emitted by the Kilauea volcano on Earth, with normal Venus atmospheric gas in the pores of the soil, would stabilize pyrite in the soil at plains altitude. They noted a correlation between the presence of apparently unweathered volcanic flows at the summits of volcanos, and nearby low-emissivity domes; both should be manifestations of recent volcanic activity.

Another interesting aspect of weathering and emissivity on Venus is the fact that the mineral reaction boundary separating pyrite (low-emissivity) from magnetite (high-emissivity), which presumably follows an isothermal surface in the Venus atmosphere, does not intersect all highlands at the same altitude. The observed "snowline" varies in altitude from ~2.5 km (Sapas Mons) to ~4.7 km (Maxwell). Curiously, the "snowline" altitude correlates well with the total height of the mountain; the "snowline" occurs at roughly half the peak height. This suggests that the thermal structure of the atmosphere is somehow modulated by topography on Venus, a concept that has not found favor with atmospheric scientists. An alternative explanation has not been forthcoming, and this phenomenon remains to be understood.

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N93-14395

FINITE AMPLITUDE GRAVITY WAVES IN THE VENUS ATMOSPHERE GENERATED BY SURFACE TOPOGRAPHY.

R. E. Young[1], H. Houben[2], R. L. Walterscheid[3], and G. Schubert[4], [1]NASA Ames Research Center, Moffett Field CA, USA, [2]Space Physics Research Institute, Sunnyvale CA, USA, [3]The Aerospace Corporation, Los Angeles CA, USA, [4]University of California, Los Angeles CA, USA.

A two-dimensional, fully nonlinear, nonhydrostatic, gravity wave model is used to study the evolution of gravity waves generated near the surface of Venus. The model extends from near the surface to well above the cloud layers. Waves are forced by applying a vertical wind at the bottom boundary. The boundary vertical wind is determined by the product of the horizontal wind and the gradient of the surface height. When wave amplitudes are small, the near-surface horizontal wind is the zonally averaged basic-state zonal wind, and the length scales of the forcing that results are characteristic of the surface height variation. When the forcing becomes larger and wave amplitudes affect the near-surface