

## ARE STEEP SLOPES ON VENUS PRESERVED AS A RESULT OF CHEMICAL CEMENTATION OF PORE-SPACES IN SURFACE ROCKS?

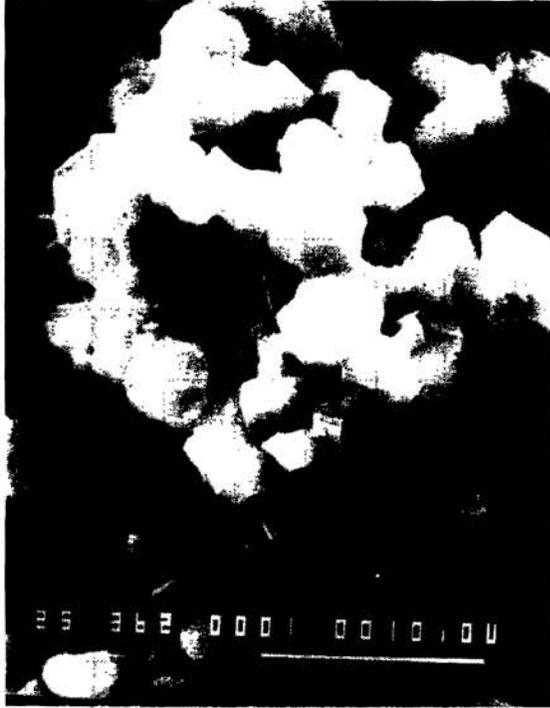
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*Introduction.* The surface of Venus has sustained approximately a billion years of volcanic, tectonic, and aeolian activity, yet it seems to lack evidence of substantial landform degradation, particularly in comparison to the intensely degraded surfaces of the other two terrestrial planets with atmospheres, Earth and Mars. Average kilometer-scale topographic slopes of 30° are not uncommon on Venus (*Ford and Pettengill, 1992*) and yet evidence of mass movement is sparse (*Malin, 1992*). Those impact structures on Venus that have escaped direct involvement in tectonic or volcanic activity show very little evidence of topographic degradation. They retain bright blocky ejecta deposits and steep rim topography (*Sharpton, 1994*). Despite the evidence of approximately a billion years of endogenic and impact surface processing there are relatively few sites on Venus where loose particulate matter is available to be moved by the wind (*Greeley et al., 1992*). These observations indicate that some process may act to stabilize surface materials on Venus. We propose that cementation of fragmental and other porous rocks has taken place by mineral precipitation as a result of chemical reaction between the atmosphere of Venus and rocks exposed at the planet's surface.

*Experimental studies.* Two different gas-solid reactions lead to the formation of chemical cement. Anhydrite (CaSO<sub>4</sub>) formation via the thermochemical reaction  $\text{CaCO}_3 + \text{SO} = \text{CaSO}_4 + \text{CO}$  was studied by heating high purity natural calcite crystals of known weight and surface area and synthetic calcium carbonate powder (ACS reagent grade) in SO<sub>2</sub>-CO<sub>2</sub> gas mixtures at ~1 atmosphere total pressure. The gas mixtures nominally contained 1% SO<sub>2</sub> by volume and therefore had a SO<sub>2</sub> number density comparable to that at the surface of Venus. The gas mixtures also typically contained <1 ppm O<sub>2</sub> and ≤ 10 ppm water vapor as impurities but experiments that were done with gas mixtures containing up to 100 ppm O<sub>2</sub> showed that the rates were independent of the O<sub>2</sub> number density within this range. The temperatures of the experiments ranged from 600-850° C because the slow reaction rates led to undetectable amounts of reaction at Venus surface temperatures over laboratory time scales. During the experiment, calcite crystal become coated with a porous layer of anhydrite. The derived growth rate of such a layer is 1µm per year under Venus surface conditions (*Fegley and Prinn, 1989*). Porosity determinations done by the line intercept method applied to SEM photomicrographs show a wide range of layer porosities, ranging up to 25%. However, the anhydrite layers typically have porosities of 5-15%. Consequently, the reaction is not expected to be diffusion controlled and is plausibly controlled by the chemical reaction rate at the calcite-anhydrite interface. The experiments done with the high purity synthetic calcium carbonate powders showed dramatic changes in the sample morphology: Individual particles become sintered or cemented together by the anhydrite and the originally sharp rhombic shaped crystals of the unreacted powder becomes increasingly corroded and welded together into irregularly shaped aggregates as the reaction proceeded.

## SLOPE STABILIZATION ON VENUS; Burke *et al.*

Figure 1



Calcite formation via the thermochemical reaction  $\text{CaO} + \text{CO}_2 = \text{CaCO}_3$  is being studied in  $\text{CO}_2$  at  $\sim 1$  atmosphere total pressure. This reaction is proxy for the formation of calcite, magnesite, and dolomite from the reaction of wollastonite, forsterite, and diopside with  $\text{CO}_2$  on Venus (Fegley and Treiman, 1992). Preliminary experimental work by B. Brackett, N. Izenberg, and B. Fegley shows that the silicate +  $\text{CO}_2$  reactions are slower than calcite formation from  $\text{CaO}$ , which is easier to study experimentally. In these experiments, highly reactive  $\text{CaO}$  is prepared by thermal decomposition of  $\text{Ca}(\text{OH})_2$ . Conversion of the  $\text{CaO}$  to  $\text{CaCO}_3$  again leads to the cementation of individual grains (Figure 1). The cementation is evident on a macroscopic scale because carbonate formation transforms free flowing powder into a single compact piece that maintains the cylindrical shape of the crucible after removal from the furnace. As yet, no

kinetic data are available for carbonate formation under Venus surface conditions.

**Conclusions.** Chemical cementation is a plausible means of keeping the global inventory of particulate material on Venus depleted in the presence of ongoing surface activity and may stabilize surface debris and preserve steep slopes associated with impact craters and tectonic features. If so, there may be no correlation between age and surface slope measured over short length scales. Chemical alteration and pore filling may also explain the gradual disappearance of dark haloes and parabolas around impact craters over time scales of  $10^8$  y as 'fresh' ejected debris is first stabilized then gradually altered to compounds that are chemically similar to the surrounding surface and in equilibrium with the reactive atmosphere. Steep slopes as well as aeolian features, such as dunes and wind streaks, may be stabilized structures that record ancient, rather than recent, events. In the absence of significant atmospherically driven weathering, topographic degradation would be dominated by volcanic processes such as burial under lava, or tectonic processes such as folding and faulting.

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