N90-12428

VENUS VOLCANISM: RATE ESTIMATES FROM LABORATORY STUDIES OF SULFUR GAS-SOLID REACTIONS. K. Ehlers, B. Fegley, Jr., and R.G. Prinn, Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139

Thermochemical reactions between sulfur-bearing gases in the atmosphere of Venus and calcium-, iron-, magnesium-, and sulfur-bearing minerals on the surface of Venus are an integral part of a hypothesized cycle of thermochemical and photochemical reactions responsible for the maintenance of the global sulfuric acid cloud cover on Venus (1-3). As schematically illustrated in Figure 1, SO_2 is continually removed from the Venus atmosphere by reaction with calcium-bearing minerals on the planet's surface. Maintenance of the global H_2SO_4 clouds, which are formed by the ultraviolet-sunlight-powered conversion of SO_2 into H_2SO_4 cloud particles (4), requires a comparable sulfur source to balance this SO_2 sink. The most plausible endogenic source is volcanism, which has occurred on Venus in the past (5), and which may have led to increased SO_2 levels above the Venus cloud-tops observed by the Pioneer Venus orbiter (6,7). The rate of volcanism required to balance SO_2 depletion by reactions with calcium-bearing minerals on the Venus surface can therefore be deduced from a knowledge of the relevant gas-solid reaction rates combined with reasonable assumptions about the sulfur content of the erupted material (gas + magma).

We are carrying out a laboratory program to measure the rates of reaction between SO_2 and possible crustal minerals on Venus. At present we have studied the reaction $CaCO_3$(calcite) + SO_2 $\rightarrow$ $CaSO_4$ (anhydrite) + CO (see Figure 2). Experimental details and preliminary results have been given by Fegley (8) and Fegley and Prinn (9). We find that the temperature dependence of the reaction is given by the equation $R = 10^{19.64(\pm 0.28)} \exp(-15{,}248(\pm 2970)/T)$ molecules $cm^{-2}s^{-1}$ and that the reaction rate exhibits no statistically significant variation with either O_2 or CO_2 partial pressure. If this reaction rate represents the SO_2 reaction rate with calcium-bearing minerals on the Venus surface (an assumption which we are currently investigating by studying SO_2 reactions with other minerals such as anorthite and diopside) then all SO_2 (and thus the clouds) in the Venus atmosphere will disappear in 1.9×10^6 years unless volcanism replenishes the lost SO_2. The Venus surface composition at the Venera 13, 14, and Vega 2 landing sites implies a volcanism rate of approximately 1 $km^3\ yr^{-1}$; a range of 0.4-11 $km^3 yr^{-1}$ is implied by assuming S/Si ratios appropriate for ordinary chondrites or for the terrestrial crust (9).

Acknowledgments. This work was originally supported by the NASA Innovative Research Program and by NSF Grant No. ATM-87-10102 to MIT.

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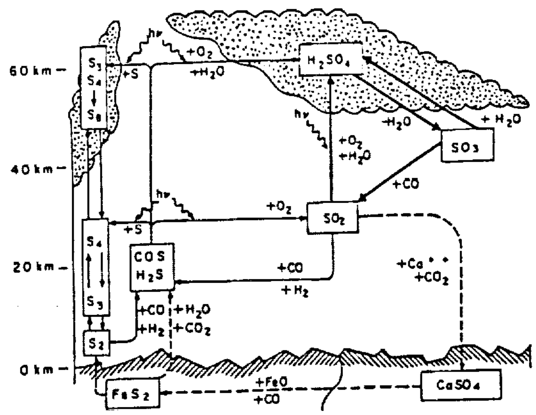

Figure 1. The cycle of sulfur compounds in the Venusian atmosphere (Prinn 1985). Volcanic eruptions or reactions of H_2O and CO_2 with volcanic surface rocks yields COS, H_2S, S_2, and SO_2. Various photochemical reactions convert these species to concentrated H_2SO_4 or elemental sulfur particles in the Venusian clouds. The H_2SO_4 evaporates at the cloud base, producing SO_3, which can then either recondense or be reduced to SO_2. Reactions of SO_2 with Ca^{2+} in rocks provides a sink that must be balanced by the volcanic and surface sources.

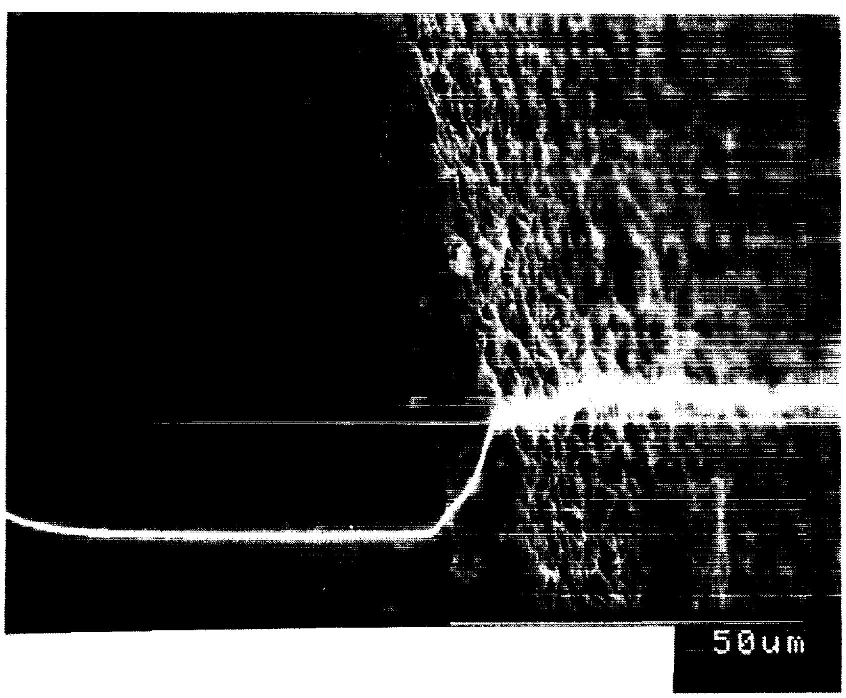

Figure 2. Scanning electron micrograph of the fracture surface of a reacted calcite crystal. The scale bar is 50 micrometers long. The horizontal white line on the micrograph shows the position of an X-ray line scan for the element sulfur. The wavy white line shows that sulfur X-rays are produced only at the reacted surface where grains of the mineral anhydrite ($CaSO_4$) are formed as a result of the gas-solid reaction.