

WEATHERING ON VENUS: DEPENDENCE OF MINERALOGY ON ALTITUDE AND ATMOSPHERIC COMPOSITION; J. A. Wood and A. Hashimoto, Harvard-Smithsonian Center for Astrophysics, Cambridge MA USA

The primary minerals that crystallize from basalts erupting on the surface of Venus are not stable at the ambient Venus surface temperature, in contact with the Venus atmosphere. They should "weather" to a different assemblage, at a rate enhanced by the high surface temperature (~470°C). We have calculated the stable soil assemblage from thermodynamic principles, using an energy-minimization routine described earlier at the LPSC [1] which we developed to investigate mineral stability in the solar nebula. In its original form this procedure treats closed systems, but we modified it to work with systems "open" to atmospheric elements (O, C, H, S) in order to treat mineral reactions at the Venus rock/atmosphere interface. The following assumptions were made and inputs were used.

Rock composition. Abundances of Si, Mg, Fe, Ca, Al, and Na were taken to be those of average terrestrial oceanic basalt. The assemblages of soil minerals are not sensitive to these values. Ti, Cr, Mn, and other involatile elements were not treated.

Atmospheric composition. Bulk concentrations of C, H, S, and O were used to specify the composition of the atmosphere. N was not treated, nor were halogens.

Concentration of C. This is defined by the atmospheric abundance of CO₂, 96.4% [2].

H. This is defined by the observed atmospheric abundance of H₂O. A concentration of 100 ppm H₂O was assumed, the value recommended by [2]. (We have also determined the stable phase assemblages in contact with atmospheres containing from 20 to 1350 ppm H₂O: results are remarkably insensitive to this parameter.)

S. This is defined by the observed atmospheric abundance of SO₂, the most abundant S species. Results are reported for two assumed SO₂ concentrations, 185 ppm and 40 ppm, corresponding respectively to the value found in 1978 by the Pioneer Venus gas chromatograph experiment [3]; and a value inferred from the absorption of microwave radiation emitted by the planetary surface (measurements made more recently, 1987) [4]. These may represent real fluctuations of SO₂ in time and/or space on Venus.

O. This is defined largely by the atmospheric content of CO₂. However, very small departures of the bulk atmospheric O content from CO₂ stoichiometry make large differences in f_{O_2} and the stable mineral assemblage. We treat a range of values of atmospheric O content, which we describe in terms of δ , the fractional deviation from the amount of O that would be needed to satisfy CO₂ stoichiometry (and also oxidize all H to H₂O and all S to SO₂). For our purposes this is a more useful descriptor of O abundance than f_{O_2} , which is a function of temperature as well as composition.

Temperature and pressure. Temperatures in the range 644-757K were treated, corresponding to conditions in the range of altitudes on the Venus surface. Similarly, pressures in the range 42-109 bars were assumed, appropriately keyed to temperature (and altitude).

Results. The calculated phase diagrams appear in Fig. 1. The vertical axis in the diagram shows the effect of altitude on soil minerals, in an atmosphere with uniform bulk elemental abundances. Much depends upon just what the O content of the Venus atmosphere

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(δ) is. If the concentration of CO detected by the Pioneer Venus gas chromatograph at 22 km altitude (its last measurement) is assumed, along with the concentrations of CO₂, H₂O, and SO₂ discussed above, and if other atmospheric components are less important to the overall O concentration, then $\delta \sim 10^{-5}$ (22 km marker shown in the 40 ppm SO₂ panel of Fig. 1).

This is interesting because the $\delta = 10^{-5}$ vertical intersects a major field boundary in the 40 ppm SO₂ diagram, at which the reaction



converts diopside to anhydrite, at just the altitude of Venus' plains province, which covers ~75% of the planet. Thus the diopside/anhydrite reaction could act to buffer the SO₂ content of the Venus atmosphere to ~40 ppm (this is one of a series of possible Venus buffer systems proposed by [5]). This may mean that the 185 ppm of SO₂ observed in 1978 was a transient volcanic effusion, which has since been largely absorbed by reaction with diopside grains in the Venus soil profile.

References

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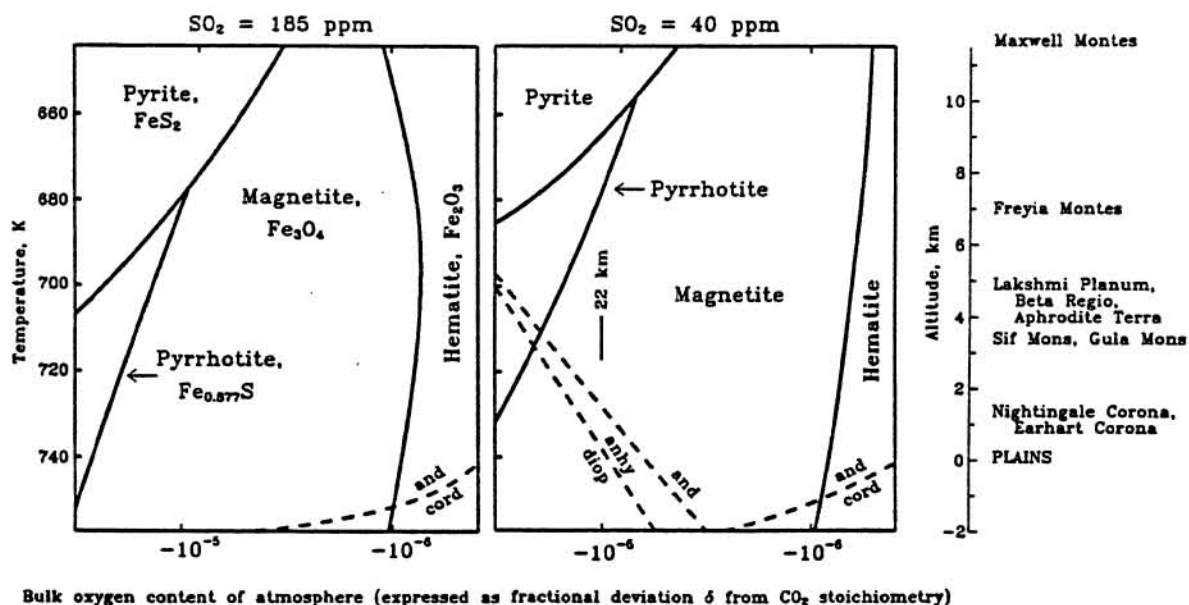


Figure 1. Equilibrium mineral assemblages on the surface of Venus as a function of altitude and O content of the atmosphere (δ). The stable assemblage over most of both diagrams is orthopyroxene + quartz + plagioclase + andalusite + anhydrite + the Fe mineral shown. Beneath the *and/cord* curves, cordierite replaces andalusite. Beneath the *and* curve, andalusite is not present. Beneath the *anhy/diop* curve, diopside replaces anhydrite.