Alteration of crustal rocks under Venus surface conditions

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Rocks at Venus' surface react chemically with its atmosphere, which is hot, dense, and reactive (~740K, 96 bars, 96.5% CO_2, ~ 50 ppm SO_2). Suggested alterations include formation of Fe sulfide, hematite, and chalcogenide frosts [1-3]; most earlier work has emphasized reactions of individual minerals and formation of volatile-bearing species [4,5]. New simple modeling of the alteration of basaltic rocks at the Venus surface suggests that anhydrite, hematite, enstatite, and cordierite should be abundant at the surface. Beneath the surface, alteration may become more reduced and sulfur-poor, and could be sequester significant masses of carbonate minerals.

Venus' surface is dominated by volcanic landforms consistent with basalt, and all the rocks analyzed by the Soviet Venera and VEGA landers are basaltic [5]. So, we have calculated chemical equilibria between basaltic minerals and bulk compositions (e.g., MORB like the V14 rock), based on accepted thermochemical data and computer codes. Iron in the silicates should react to form iron oxide or sulfide: hematite, magnetite,or pyrite. Pure enstatite and forsterite should remain stable. The anorthite component of plagioclase should alter via: $CaAl_2Si_2O_8 + SO_3 \Leftrightarrow CaSO_4 + Al_2SiO_5 + SiO_2$ (anhydrite + andalusite + quartz) [4]. This reaction would be at equilibrium for plagioclase activities near 0.3, which (at such low T) would repesent nearly pure albite. Diopside should alter via $CaMgSi_2O_6 + SO_3 \Leftrightarrow CaSO_4 + MgSiO_3 + SiO_2$ [4].

Alteration of basalt glass compositions can be modeled using analog systems, chemography, and thermochemical calculations. From a typical MORB (e.g., V14) composition, Ca would form anhydrite, $CaSO_4$. Na and K would end up in feldspar, and Fe would form an oxide (hematite or magnetite). The silicate 'residue' would have molar Si:Al:'Mg+Mn' of 2.1:1:1.6, and would equilibrate to cordierite + enstatite + quartz [6] (Table 1). If Fe were not oxidized, the mineralogy would lack Fe oxides but otherwise be similar (Table 1). The volume increases in these alterations, >10%, could be responsible for the platy structure visible in lander images of the Venus surface.

Table 1. Masses of Alteration Products from 100 grams of a MOR Basalt, & Volume Change on Alteration.

Grams	Divalent Fe	Fe as hematite
Anhydrite	28.3	28.3
Albite	21.4	21.4
Cordierite	30.8*	30.1
Enstatite	26.4*	8.9
Quartz	5.1	13.67
Hematite	0	11.5
Total Mass	112.0	113.9
Δ Volume %	+12	+14.6

Beneath the surface, carbonate phases may be important. Alkali carbonate melts are likely to be stable in the near subsurface [6], and carbonate minerals (dolomite or calcite) may be stable or metastable.

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