

CHEMICAL WEATHERING ON VENUS: PRELIMINARY RESULTS ON THE INTERACTION OF BASALT WITH CARBON DIOXIDE. Allan H. Treiman¹ and Carlton C. Allen². ¹Lunar and Planetary Institute, 3600 Bay Area Blvd. Houston TX 77058. ²Lockheed Engineering and Sciences Co. 2400 NASA Rd. 1, Houston TX 77258.

Chemical reactions between the atmosphere and surface of Venus are thought to exert strong controls on the compositions of both [1-3]. Reactions between Venus atmosphere and basalt may be important because 80% of Venus is surfaced by volcanic units and most of them are basaltic [4]. Preliminary experiments show that basalt glasses react with 1 bar of CO₂ to become coated with thin films of Ca-Mg carbonate (?). However, the rate of this reaction is slower than the rate of reaction with SO₂-bearing gas [5], suggesting that the weathering of basalt is not a likely source of carbonates on the Venus surface.

Samples and Method. Our approach is to subject samples of basalt and basalt glass to model Venus atmospheres and temperatures. Samples were reacted in a vertical tube furnace, in which weight change can be monitored continuously by an electronic microbalance. Before each experiment, the furnace was preheated to the run temperature and purged with CO₂ for several hours. Approximately 200 mg of powdered sample was weighed and placed in an open platinum crucible, which was suspended in the furnace by a platinum wire. The furnace was resealed, evacuated to remove air, and flushed with argon or CO₂. A controlled flow of 5 cm³/min CO₂, upward past the sample, was then initiated. The sample weight change was monitored periodically during each experiment. At the conclusion of an experiment, the furnace was cooled rapidly to 200°C. The sample was removed and weighed to confirm the weight change indicated by the microbalance. In our experiments, weight changes measured by both methods were identical within error. After reaction, mineral proportions in the samples were determined by X-ray diffraction analysis. Samples were then mounted for SEM/EDX analysis (and eventually transmission EM/EDX). Knowledge of reaction products and rates may eventually be interpreted in terms of reaction mechanisms.

Experimental Results. By Jan. 7, 1994, two experiments have been completed. In both cases, samples reacted with the CO₂ gas and did gain weight. The weight gain was approximately proportional to $\sqrt{\text{time}}$, consistent with diffusion-controlled reactions at grain surfaces.

In experiment VBW2, synthetic glass of Apollo 11 basalt composition (#1 of [6], crushed to 840-149 μm) was reacted at 750°C for 5 days. During reaction, VBW2 partially devitrified to yield augite and gained 0.25% in mass. Its surfaces became coated with an optically thin layer that shows Fizeau interference colors of gray through orange. In SEM, the glass surfaces are coated with a bumpy layer, <10 μm thick, composed of grains ~0.1 μm across. SEM/EDX chemical analyses suggest that the layer is rich in Ca and Mg. The layer did not effervesce under 1-M HCl, but did detach from the underlying glass.

In experiment VBW1, porphyritic tholeiite basalt JSC-1 [7] (crushed to <840 μm) was reacted at 800°C for 4 days. The sample gained 0.7% in mass, and changed color from black to dark ochreous red. Diopside and plagioclase phenocrysts showed no signs of reaction. Crystals of Fe oxide, 10 μm across, were abundant on glass immediately adjacent to phenocrysts and were rare elsewhere. Glass surfaces were covered with a thin bumpy layer similar to that of VBW2; SEM/EDX analyses suggest it was also enriched in Ca and possibly Mg.

Interpretation. Interaction of basalt and basalt glass with CO₂ involved two reactions: oxidation of iron, and formation of a Ca-Mg-rich surface layer. The color of VBW1 (from JSC-1

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basalt) suggests that the Fe oxide is hematite. The absence of Fe-oxide from VBW2 is puzzling as its starting material (simulated A11 basalt glass) contained more FeO than did JSC-1 (~13% vs. ~10.5%). The abundance of Fe-oxides adjacent to phenocrysts in VBW1 suggests that formation of Fe oxide is rapid only in the compositional boundary layer that surrounds crystals in basalt. It is possible that these layers in VBW1 were molten during reaction.

The surface layer that formed on the basalt glass could be a carbonate, dolomite or magnesian calcite, given its composition (rich in Ca and Mg) and the mass gains during reaction. Unequivocal identification of the mineralogy of the surface layer will require additional analyses by SEM and TEM/EDX.

Implications. At this point, few conclusions about Venus can be drawn from these preliminary experiments because: 1) temperatures were higher than those at Venus' surface; 2) pressure was much lower than at the Venus surface; 3) the gas lacks reactive minor species of the Venus atmosphere; and 4) effects of basalt composition and crystallinity are uncontrolled.

Most important is that the rates of carbonate (?) formation on basaltic solids under 1 bar CO₂ appear to be significantly lower than rates of sulfate formation under 1 bar {CO₂ + 1% SO₂} [5]. Specifically, [5] found that diopside reacted with this sulfur-bearing gas to form anhydrite crystals (to 15 μm) in 2 days at 833°C. We saw no detectable reaction on diopside, and significantly less reaction on basalt glass, with pure CO₂ in twice as much time. This comparison suggest that basalt glass on Venus may weather directly to sulfate minerals and may not be a source of carbonate for buffering atmosphere composition (as in [1,3]).

Future Work. Future experiments at more realistic pressures, temperatures and gas compositions will yield more complete models of the chemical weathering of basalt on Venus. Experiments at 1 bar can be extended to lower temperature, longer times, and more realistic gas compositions, as in [5]. Experiments at Venus surface pressures, ~90 bars CO₂, can be performed in externally heated (cold-seal) pressure vessels. Through these and similar experiments it will be possible to understand the mutual chemical influences of Venus atmosphere and Venus basalt.

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