A Laboratory Simulation Experiment of Hydrothermal Processes on Mars
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Abstract #2638

Introduction
It has been suggested that hydrothermal process may have been active in the history of Mars. The first surface confirmation of hydrothermal activity on Mars was made by Spirit, through exploration around the Home Plate area in Gusev Crater.

In order to gain a better understanding on the hydrothermally produced secondary minerals under Mars relevant atmospheric conditions, especially their precipitation sequences and the compositional and structural details of the minerals and mineral assemblages, we designed and conducted a set of hydrothermal simulation experiments under well controlled environmental conditions.

Experiment Design

Our experiments has two characters:

(1) the use of an oxygen-poor environment: a dry CO₂ (purity 99.9%) environment (>1 atm during the first four exp steps);
(2) the use of three temperature ranges to separate the produced secondary minerals.

The experiment was conducted in five steps:

(1) to react basaltic sand with acidic fluids (H₂SO₄ : HCl in 4:1 molar ratio) with four different densities (5, 10, 15, 20%) and at two fluid to sand ratio (2:1 and 10:1) at 90°C (P_CO₂ > 1 atm);
(2) to separate the fluids from the sand after 1,3,10 days reactions (operation in P_CO₂ > 1 atm);
(3) to allow precipitation to occur in the decanted fluids at 50°C (P_CO₂ > 1 atm);
(4) to separate the precipitated solid (operation in P_CO₂ > 1 atm);
(5) to evaporate the residual fluid at room T.

Chemistry and mineralogy of the starting Basalt

HP03 was collected from a recent PuuOo flow of the Kilauea volcano in Hawaii. For our experiment, a piece of HP03 was crushed, ground, and sieved. The basaltic sand with size 250 µm < d < 850 µm was used.

We prepared a polished HP03 basalt chip, and made EMP analysis on it. The result of EMP analysis shows that HP03 includes great amount of glass, pyroxene, and plagioclase.

Analysis procedure & early results

Understanding the reaction process at 90 °C in CO₂ through the mineral ID by laser Raman spectroscopy

We have conducted laser Raman measurements on each of the 20 reaction residual solid samples from 90°C experiments, 200 Raman spots per sample. Raman analysis suggests that the most abundant secondary minerals are sulfates. The most common phases are Ca-sulfates. Al-, Mg- and Fe-sulfates were also observed, as well as some remaining igneous mineral phases, e.g., anatase [TiO₂].

Ca-sulfates: High content of silicate glass in original basalt sample would facilitate the release of Ca. Large amount of Ca-sulfate was found in the white-toned top salty soil at Tyrone site near Home Plate at Gusev. Gypsum (CaSO₄·2H₂O), bassanite (CaSO₄·0.5H₂O) and anhydrite (CaSO₄) are found as the major secondary minerals in the remaining solids from all 20 reactions at 90°C. It is important to notice that gypsum exist only in the reaction residues from the experiments using low density acid (5%), or from the experiments of short duration (1-3 days) using mid-density acid (10%). The Ca-sulfates with lower hydration degrees were found from the experiments using high density acid or using mid density acid but longer duration. Apparently, the formations of Ca-sulfates with different hydration degrees are directly linked to the water activities of fluids.

Al-, Mg, Fe-sulfates: Minerals as alunogen [Al₂(SO₄)₃·17H₂O], epsomite [MgSO₄·7H₂O] and coquimbite [Fe³⁺₂(SO₄)₃·9(H₂O)] appeared only in the reaction residues of the experiments with acid density > 15%, especially those at 15% and 20%. Reacted with higher density acids, a higher variety of cations get released from original HP003 basalt, thus produced the secondary minerals with more variety of cations.

TiO₂: Anatase is a mineral phase identified in the original basaltic sand. It stays in the reaction residues of all 20 experiments, which is a firm demonstration of the structural resistance of this phase in acidic environment. This observation is consistent with the enrichment of Ti in the white-tone soil at Gertrude Weise site (near Home Plate at Gusev) which were interpreted to be hydrothermal origin.

Acknowledgement

This work was partially supported by NASA Mars Fundamental Research ProjCouncil (YHZ). We want to thank the help given by Ms. Y. L. Lu and Mr. Paul Carpenter in Raman, IR, and XRD laboratories. ect NNX10AM89G (AW) and by the Chinese Scholarship.

References