

Characterizing Rock-Water Interactions in a Simulated Martian Aquifer

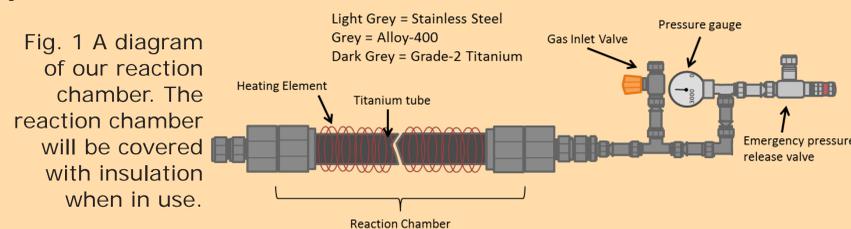
Introduction

- Biomarkers, are compounds that indicate current and/or past biological activity and as such are of great interest when exploring the potential habitability of Mars throughout its history.
- One proposed biosignature are long-chain organic compounds thought to be unique to biological activity. Such organics make a good biosignature because they are relatively easily detectable and preservable, allowing them to persist for millions of years after biological activity has ceased.
- One major disadvantage however is that the possible production of these molecules through purely inorganic (non-biological) processes has not been broadly explored.
- To this end, we have begun an experiment to simulate possible abiotic reactions, mixing brine and a simulated Martian crustal material under temperatures and pressures consistent with conditions in the Martian subsurface where such a brine would be stable.
- We are simulating a hypothetical aquifer about 2 km under the surface where a Marsquake or impact event opens up the brine to fresh rock.
- In this poster we present some of the preliminary results from our first experiment, which ran for approximately 60 days. We present SEM analysis of both "before" (unreacted) and "after" (reacted with brine) grains of the three most common minerals in our mars crust simulant, namely Feldspar, Pyroxene and Olivine. We also examined evaporitic residue from a small sample of "after" brine.

Procedure

We built two identical reactors to simulate conditions appropriate for modern Mars (past few million years) where temperatures and pressures allow a liquid brine to be stable within an "open" martian crust (roughly 85°C, 120 Bars). The reactors contain a small sample (about 400 mg) of our Mars crustal analog, about 40 mL of synthetic Mars brine and are pressurized with dry CO2 gas. They were constructed of non-reactive Grade-2 Titanium tube with Monel (a corrosion-resistant alloy) fittings. Stainless Steel was used only in fittings that could not contact reactants. The reactors were heated with resistance heating elements (Fig. 1). To minimize organic contamination, reactants were handled under clean conditions and minimal contact with plastics, and all materials and the reactors were rinsed with a 10% hydrogen peroxide solution prior to closure of the reactors.

As in any such experiment, we've had to make some difficult choices concerning the composition of our martian crustal stimulant and brine. Where possible such choices were based on common assumptions from the literature. As a crustal analog, we chose a crushed mixture of basalt (Ferrari dolerite) with added olivine and iron oxides (from an alpine peridotite nodule). This composition can be considered the modal equivalent to either of an olivine-phyric shergottite or a basalt with added eolian olivine. Choosing and creating a brine composition was challenging. In the end, we chose two different brines for our two reactors. The first brine chosen was that described in [1], where experimental reactions between simulated martian crust and distilled water produced model brines for Mars. This brine simulates an earlier period in Martian history. Our second brine is a derivative of the first. Given evidence (in the form of gullies on crater walls) for possible ephemeral surface brines on the Martian surface, we chose to simulate a "hyper-saline" brine that might leak out of an underground aquifer. Such brines have been hypothesized as the result of long term cryoconcentration on Mars [2]. To produce this brine we cryo-concentrated our initial mixture by a factor of 2 using a freeze-dryer.

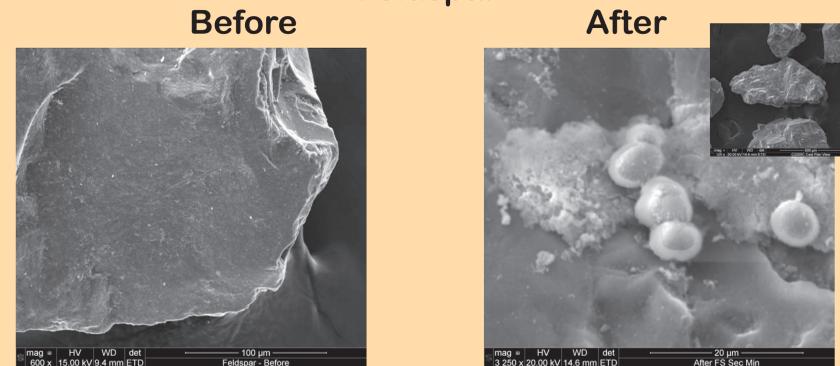


Results

SEM Analysis

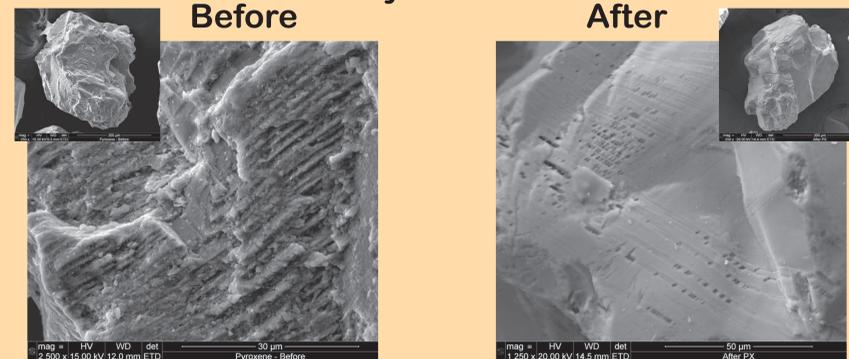
We examined representative grains of olivine, pyroxene and feldspar from both "Before" (unreacted) and "After" (reacted for 60 days) aliquots of our martian simulant using the FEI Quanta ESEM in the Swagelok Center for Surface Analysis of Materials at Case Western Reserve University. Multiple grains from each aliquot were mounted on carbon tape and coated with a few nm of palladium to avoid charging. A few grains of evaporated solids from the "After" brine were also examined.

Feldspar



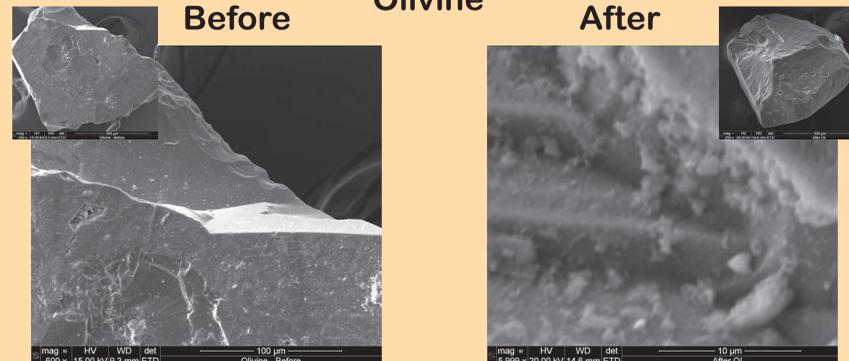
Representative grains of both "Before" and "After" feldspar show little etching along grain boundaries. The "After" feldspar showed some deposition of secondary minerals identified as Ni salts by EDS (see discussion).

Pyroxene



Both "Before" and "After" pyroxene grains show signs of etching. The "Before" pyroxene shows characteristic monoclinic patterns on one side strongly suggesting significant terrestrial weathering was present before the reactions took place. The "After" grain shows only faint etching along the same monoclinic boundaries with some prominent pitting along crystal boundaries.

Olivine



"Before" olivines show little etching; most grains show clear grain boundaries and preserve percussion marks from crushing. In contrast, "After" olivines show consistent deep etching along crystallographic boundaries and deep pits throughout the grains, lined with faceted olivine due to dissolution.

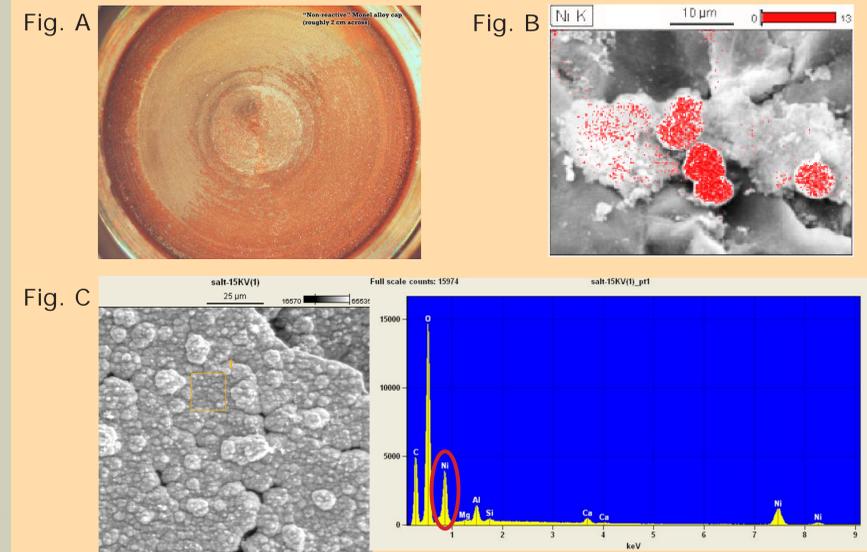
Discussion

The etching along crystallographic boundaries observed in the SEM analysis suggests the acidic brine in the reactor was dissolving the minerals as expected. Olivine shows the most significant dissolution along crystallographic grain boundaries, which is expected. Pyroxene is slightly less reactive than olivine and shows obvious but less prominent dissolution, also as anticipated. Feldspar was the most resistant with few observed changes.

We did not observe any replacement of the primary minerals by secondary (metamorphic) phases. This is not unexpected since our temperatures and pressures were not high enough for the metamorphic reactions needed. Minor deposition of evaporites was noted on the feldspar and were probably present on other phases as well.

"Non-corrosive" reactors

The biggest surprise of our research so far is that our reaction chambers themselves are affecting the experiment. As noted in our design, our reactors were purposefully built with supposedly non-corrosive materials, particularly the Ni-Cu alloy Monel. Upon opening the reactor, we noticed that the Monel cap had been corroded (Fig. A below). Our suspicions were confirmed when we observed salt grains on Feldspar after the reactions and identified them as nickel salts (Fig. B below). Grains recovered from the evaporated "After" brine appeared structurally and chemically identical to those seen on "After" feldspar and returned EDS spectra consistent with a Ni-carbonate composition (Fig. C below).



Acknowledgments

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References

- [1] Bullock M. A.; Moore J. M.; Mellon M. T. (2004) Icarus, 170, 404-423. [2] Burt D. M. and Knauth L. P. (2002) Icarus, 158, 267-271.