Hydrothermal Geochemical Experiments Simulating High Pressure and High Temperature Environments:

Applications to Hydrogen and Methane Production by Olivine

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Description of Serpentinization

$(Fe, Mg)_2SiO_4 + H_2O \rightarrow Mg_3Si_2O_5(OH)_4 + H_2 + FeO \cdot Fe_2O_3$

olivine water serpentine magnetite

Mid-oceanic Ridges and Hydrothermal Vents

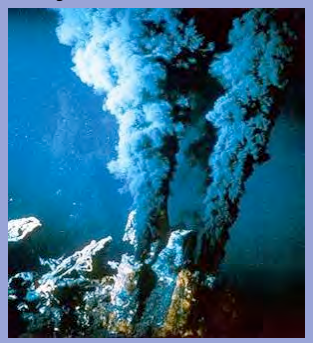

Fig. 1: An example of a black smoker. These occur at hydrothermal vents. Heated seawater is ejected and forms a precipitate in the shape of a chimney.

This is an example of where serpentinization occurs.

Research Goals

- To model the serpentinization reaction.
- To measure the rate of reaction for production of molecular hydrogen and methane.
- To understand the reaction sequence that takes place alongside and after serpentinization.
- To test chromite as a catalyst for serpentinization and methane production.
- This research has implications for:
  - energy resources
  - the origin of life
  - environmental hazards

Hypotheses:

1. The rate of hydrogen production increases with increasing temperature, if pressure is 100 to 500 bar.
2. Methane production due to serpentinization is inhibited without chromite as a catalyst.

Experiment 1: Olivine rock, and synthetic seawater

Experiment 2: Olivine, synthetic seawater, chromite, and $NaHCO_3$

Results

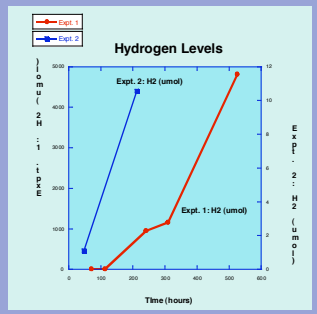

Fig 1: Hydrogen levels were much lower in Expt. 2 than in Expt. 1; hydrogen steadily increased in both

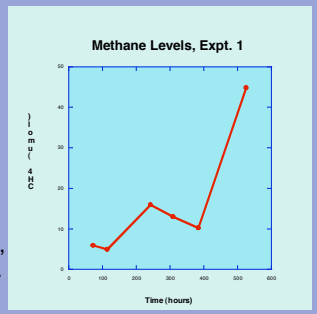

Fig 2: Methane levels increased, but not steadily. Expt. 2 data not avail.

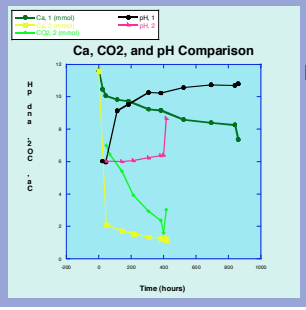

Fig 3: Calcium levels drop steadily in both experiments, especially in the beginning of experiment 2. Carbon dioxide levels go down steadily as well, except for the last data point, which corresponds to a spike in pH, which would affect solubility levels of carbonacious solid species.

Fig 2: Camille Jones and Kaitlynn Heflin working with a hydrothermal autoclave

Discussion

- **Hydrogen:** Chromite may actually catalyze the production of methane from the serpentinization reaction, contrary to Hypothesis 2. Methane is produced by a reaction between carbon dioxide and hydrogen, so a possible explanation for less hydrogen in Expt. 2 is that the hydrogen reacted to form methane.
- **Methane:** Due to faulty sampling tubes, gas leakage occurred; no data available for experiment 2.
- **Carbon, Calcium:** The fact that both carbon and calcium drop steadily throughout the experiment suggests a calcium carbonate solid is being formed. The spike in pH during increased absorbed carbon levels supports this idea, because the equilibrium of calcium carbonate with calcium and carbon in the water would be altered by pH.

Experimental Materials

- Inert gold reaction cells
- Pressure-control vessels
- Ceramic high-temperature rocking autoclaves
- Sampling tube allows fluid samples to be taken while experiment runs

Fig 3: Bob Rosenbauer and Kaitlynn Heflin place the flexible gold cell and pressure fluid into the pressure vessel

Analytical Methods

- Scanning electron microscopy (SEM)
- Refractive Index (RI)
- pH
- Carbon coulometry
- Gas chromatography (GC)
- Inductively coupled mass spectrometry (ICP-MS) for cations
- Electron microscopy for composition of starting solids

Fig 4: Kaitlynn Heflin sampling the experiment

Further Research

Due to the unexpected appearance of carbon in the reaction vessel, the experiment would need to be repeated several times to ensure good results.

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