Awaruite, Serpentinitization and Icy Moons

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The experiment we designed, aimed to understand the catalytic action of the nickel-iron alloy awaruite and how it can affect serpentinitization. We use this to simulate what could be observed in possible planetary scenarios where plumes can occur [6, 7]. Combining the data collected by Cassini’s instruments with our experimental results, we expect to shed light in what processes still occur in Enceladus and Europa.

Serpentinitization is the aequous alteration of olivine to form minerals of the serpentinite group. On Earth, they are part of rocks from the ultramafic upper mantle and mafic/ultramafic crust. Serpentinitization is proposed to be an important geological process that affects the cycle of bio-essential elements not only on Earth but on other planetary bodies of the Solar system.

Oxidation of the ferrous iron of olivine to magnetite results in the release of H2 and precipitation of secondary minerals. When this fluids contact with CO2 rich water, under certain constraints can lead to methane formation, as shown in the equation:

\[(Mg, Fe)_2SiO_3 + H_2O + CO_2 + Ni, Fe \rightarrow Mg_2SiO_3(OH)_4 + Mg(OH)_2 + Fe_{2}O_3 + CH_4 + H_2\]

Using this data, some constrains for the ocean can be set, in order to understand the geochemical processes at work in this icy moon of Saturn [2].

Results & Discussion

Fayalite olivine is incubated for 500 days, with a 20mM NaOH solution at 90°C in borosilicate vials. The awaruite is synthesized via hydrazine hydrate reduction in an ethanol solution [8]. Characterization is obtained through Scanning Electron Microscope (SEM) coupled with EDS microanalysis system, XRPD and FTIR.

The vials are hermetically sealed, and gassed with N2. The experimental setup is prepared for 8 different runs, to be collected at pre-established points in time.

After the incubation period, the vials are opened and gas, liquid and solid samples are collected for analysis. FTIR-IR, TXRF and XRPD is performed to determine mineral assemblage and presence of serpentinitization products.

Some vials present a reaction surface (b, c), where a circulation pathway for the water through the olivine can be observed.

XRF performed on the different solid fractions collected show that, although no new minerals were formed at this point in time (51 days of incubation), some alterations on the crystallinity of the olivine can be detected (as seen on the diffractogram shown above). Measurements from the liquid fraction will be used to model how silicate materials associated with hydrothermal alteration are dragged, captured in less, and released from the interior by a possible planetary plume formed in Enceladus or Europa [2].

Surface Catalysts

Two naturally occurring serpentinitization products that can act as catalysts for the formation of abiotic methane are iron oxides (Fe3O4, magnetite) and a nickel-iron alloy awaruite (with chemical composition ranging from Ni2Fe to NiFe).

Magnetite can suffer further alteration into awaruite, when H2 is present, and in the presence of Ni-bearing olivine. Awaruite was selected as the catalyst to be used in this experiment because its formation is usually connected to low T-serpentinitization processes, during which it acts as a surface catalyst for the series of reactions that lead to methane formation. We believe that, the alloy is important to the environments suggested to exist in various planetary scenarios [5].

Introduction

Recent observations on the icy moon Enceladus point towards the existence of ongoing hydrothermal activity in its silicate mantle that heats a recently discovered global ocean beneath the moon’s ice shelf. This global ocean beneath Enceladus is assumed to be the source of the chemical species detected by Cassini’s INMS (Ion and Neutral Mass Spectrometer) [1].

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Geochemical processes such as serpentinitization that reduce carbon in hydrothermal systems, are the chemical reactions thought to be at the origin of the first lifeforms on Earth’s primitive oceans. Methane is thought to be the first hydrocarbon to be “harnessed” as a source of energy [4]. Understanding the mechanisms and catalysts behind its formation is important.

This exothermic reaction, is potentially a source of heat in both moons, causing further silicate mantle differentiation and chemical evolution. This process occurs under a wide range of T and P conditions although fluid pH must range between 9-11 [4]. Without the presence of catalysts, the formation of methane is painstakingly slow.

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Discussion

Hydrothermal Vents as analogs to the Icy Moons

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Literature Cited


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Further information

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