Report for the Joint Use/Research of the Institute for Planetary Materials, Okayama University for FY2024

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Category: ☑International Joint Research ☐General Joint Research ☐Joint Use of Facility ☐Workshop

Name of the research project: Identification of biogeochemical signatures in analogs of altered volcanic glasses (and related minerals) on the Martian surface

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Collaborator

Name: Christian Potiszil

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Research report:

The purpose of my visit during September-December 2024 was to continue the project started in January 2024 in collaboration with Dr. Christian Potiszil and other PML researchers. The overall goal is to determine biogeochemical signatures on altered glasses of Antarctica and Iceland and related alteration products primarily using an organic geochemistry and stable isotope geochemical approach. The research plan and science accomplished during the September-December 2024 visit is described below.

Three studies with independent datasets were divided as follows:

1) Icelandic and Antarctic Hyaloclastites. These correspond to samples analyzed in Nikitczuk et al., 2022a, b. Primary samples REY2, LAU1, KBH17, and CPN2 were selected for this study. An additional subset of micro and mesoporous minerals already analyzed for N concentrations and isotopic compositions was included for CHO isotopic analyses (12 samples).

2) Icelandic amygdules. These correspond to samples provided by Tobias Björn Weisenberger and Amel Barich from two localities (Hvalfjördur, SW Iceland and Breiddalur, East Iceland). Samples include amygdaloidal basalts composed of basalt, mafic phyllosilicates of CS-mixed layer clays, and zeolites (Walker 1960; Weisenberger and Selbekk, 2009).

3) Surtsey core. Samples from borehole SE-2b on Surtsey Island in Iceland obtained during ICDP funded drilling project in 2017. Samples were provided by Tobias Björn Weisenberger and Amel Barich (Jackson et al., 2019; Prause et al., 2020; Weisenberger et al., 2019).

Icelandic and Antarctic Hyaloclastites (Study 1)

Samples REY2, LAU1 KBH17, and CPN2 were analyzed for organic geochemistry by GC-MS with Dr. Potiszil.

Goal: Characterize biogeochemical signatures in the form of organic compounds and isotopic signatures in Icelandic and Antarctic Hyaloclastites as Mars analogs.

The objective is to provide a protocol for the analysis of Mars return samples. This protocol provides a comprehensive biosignature of terrestrial altered glasses with a focus on nitrogen, including the work already performed at Lehigh and PML by Matthew. This work included fine-scale mineralogy, analysis of microstructures, N isotopic analyses, and major and trace element geochemistry. To extend and provide a more comprehensive biosignature, organic geochemistry work and other isotopic tracers are needed.

Work accomplished during the joint/use research program:

1) SEM C-element maps on the microtome sections produced in January, 2024. This corresponds to the coarse-grained samples from Antarctica.

2) Raman spectroscopy on the microtome “chips” guided by the SEM C element maps.

3) Whole-rock GC-MS analyses in 2 samples from Iceland (Rey2 and LAU1). Initial work in January was performed on powders already produced by Matthew that did not follow the procedure necessary

for avoiding contamination during organic geochemistry work. Microtome sections of these 2 samples are needed to produce new powders. Only whole-rock analyses are possible in these samples given the fine grain size.

4) GC-MS analyses of separates from 1 Antarctic sample (KBH17 in principle). So far, a whole-rock analysis of 2 samples was performed with newly produced powders at PML. 3 new powders were produced with microtome sections of the cement, the palagonite, and the glass.

5) Orbitrap analyses (7 samples). Orbitrap analyses were performed to characterize the lipids in the 2 samples from Antarctica (KBH17 and CPN2), 3 separates from KBH17 (cement, palagonite, and glass), and the 2 samples from Iceland (Rey2 and LAU1).

Icelandic Amygdules (study 2)

Initial work by Matthew characterized the incorporation of N in a variety of micro and mesoporous minerals on Earth relevant to Mars. This work included several phases (phyllosilicates, zeolites, sulfates, clays, and other hydrated phases) from various localities worldwide.

Having identified these alteration products of particular interest as Mars analogs and containing appreciable amounts of N and potentially preserving both isotopic and organic biosignatures, the work will be expanded by targeting N in amygdules of a variety of zeolites/phyllosilicates from 2 individual localities in Iceland with the goal of better constraining fluid sources, geologic context, and environmental conditions (with additional CHO isotopes).

Work performed thus far:

Nitrogen concentration and isotopic composition of 40 samples. The samples include 19 zeolite separates, 13 clay separates, and 8 mixtures of basalt+clay+zeolite and clay+zeolite in varying proportions.

Work accomplished during the joint/use research program:

1) CH analyses (n = 40) to elucidate fluid sources and C content.

2) Organic Geochemistry work (GC-MS + Orbitrap) on 3-4 sufficiently coarse-grained samples. This task required producing new powders using microtome.

3) XRD work. Primarily in the zeolite separates (n=19) to identify the zeolite phases.

Surtsey Core basaltic glasses (study 3)

The goal is to characterize N incorporation as related to palagonitization extent, temperature, fluid sources, and secondary minerals present. The Surtsey core samples are well characterized for these parameters allowing to make correlations between N and different parameters present in a hydrothermal alteration context. The sample set consists of 26 whole-rock basaltic glasses comprising different alteration zones, depths, temperatures, types of circulating fluids and styles, and degrees of alteration from a drill core of the Island of Surtsey in Iceland.

Work accomplished during the joint/use research program:

CH analyses of the 26 samples primarily to elucidate fluid sources.

An abstract with the preliminary N data was submitted and a talk given at AGU2024 (9-13 December, 2024 Washington, USA).

Summary table of work performed during the joint/use research program 2024

Study	Goal	Objectives	Work performed in January 2024	Tasks performed during September-December 2024
Icelandic and Antarctic Hyaloclastites (Study 1)	Characterize biogeochemical signatures in the form of organic compounds and isotopic signatures in terrestrial hyaloclastites serving as Mars analogs.	1) Provide a protocol for analyzing Mars return samples. 2) Extend biosignature work to include organic geochemistry and isotopic tracers.	GC-MS analyses (4 samples) with pending peak characterization. CHN analyses (22 samples). O analyses (7 samples).	1) SEM C-element maps on microtome sections. 2) Raman spectroscopy guided by C element maps. 3) Whole-rock GC-MS on Iceland samples (Rey2 and LAU1). 4) GC-MS on separates from Antarctic sample (KBH17). 5) Orbitrap analyses
Icelandic Amygdules (Study 2)	Target N in amygdules from two localities to better constrain fluid sources, geologic context, and environmental conditions (with additional CHO isotopes).	Expand work on N incorporation in alteration products relevant to Mars (zeolites/phyllosilicates) from specific localities. Improve understanding of preservation of biosignatures in such phases.	N concentration and isotopic composition of 40 samples (19 zeolites, 13 clays, 8 mixtures).	1) CH analyses (n = 40). 2) Organic Geochemistry work (GC-MS + Orbitrap) on 3-4 coarse-grained samples. 3) XRD work primarily on zeolite separates (n = 19).
Surtsey Core (Study 3)	Characterize N incorporation related to degree of alteration, temperature, fluid sources, and secondary minerals present.	Identify controls of N incorporation during basalt alteration in a hydrothermal setting	N data (n=26). Talk given at AGU2024.	1) CH analyses of 26 samples.