Mineralogical Effects on Organic Detectability in Mars Analog Sediments

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GEOL394

Introduction

The Planetary Science and Astrobiology Decadal Survey (2023–2032), has prioritized understanding:

- geologic context shaping other planets over time
- the habitability of environments on other planetary bodies
- how we can detect past or present signs of life if is present[1]

This study focuses on using a drill core from an analog site, Lake Sandvatn, to provide a reference frame for geologic processes on Mars and understand how the geology (minerals) present on Mars will affects the detectability of organic macromolecules.

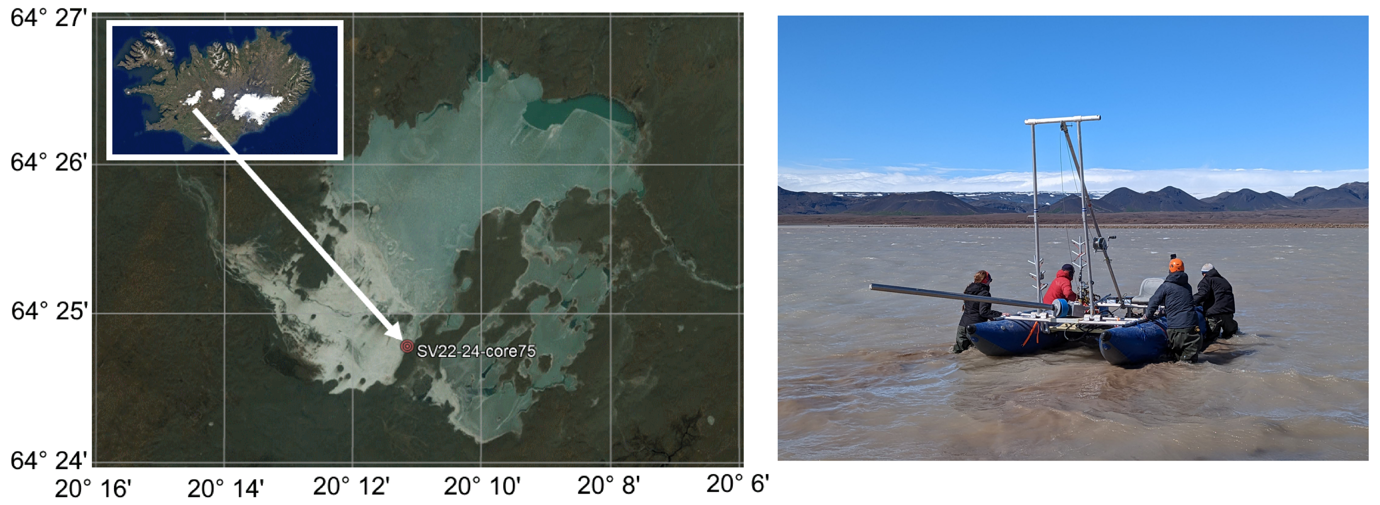


Fig. 1: (Left) Aerial view of Lake Sandvatn (Credit: Google Earth), (Right) Photograph of drill rig used at Lake Sandvatn to collect drill cores.

Purpose

Goal 1: Characterize subsurface mineralogy in a Mars analog lacustrine environment and compare this mineralogy to Mars.

Hypothesis 1: Sediments at Lake Sandvatn will be a comparable mineralogical analog for Gale crater

Goal 2: Test the effects of mineralogy on the detectability of two lipids with laser desorption mass spectrometry (LDMS)

Hypothesis 2: Mineralogy will have an effect on the detectability

Methods

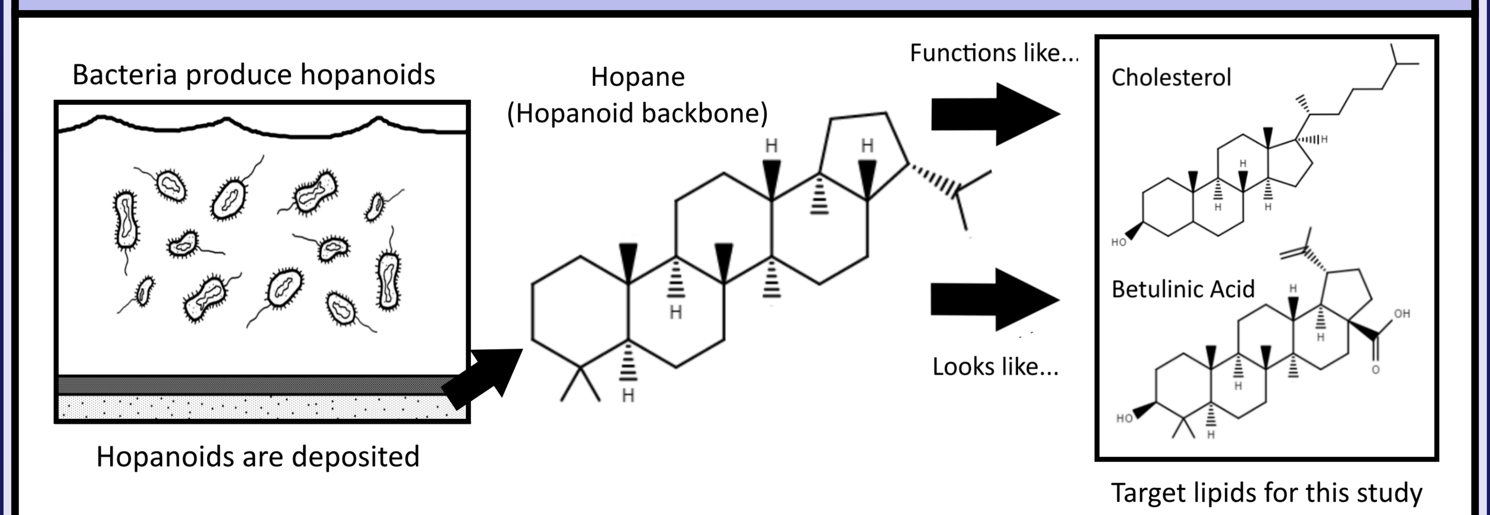


Fig. 2: Schematic for the relevance of the target lipids used in this study. Hopanoids are a diagenetically resistant group of lipids produced by bacteria often found in the rock record

X-ray diffraction (**XRD**) — characterizes modal mineralogy of sample, data processing completed in MDI Jade™

Laser desorption mass spectrometry (**LDMS**) — characterizes organic signal of mineral surfaces, data processing completed in Thermo Fisher FreeStyle™ and MATLAB

Results—Mineralogy

Lake Sandvatn

- Sand and clay layers
- Plagioclase, pyroxene, olivine, hematite, some clay, amorphous material
- No trends with depth
- About 50% amorphous

Gale crater, Mars

- Diverse lithologies
- Similar mineralogy, pyroxene, plagioclase, olivine
- More diverse mineralogy (includes K-spar, sulfates, carbonates)
- About 50% amorphous

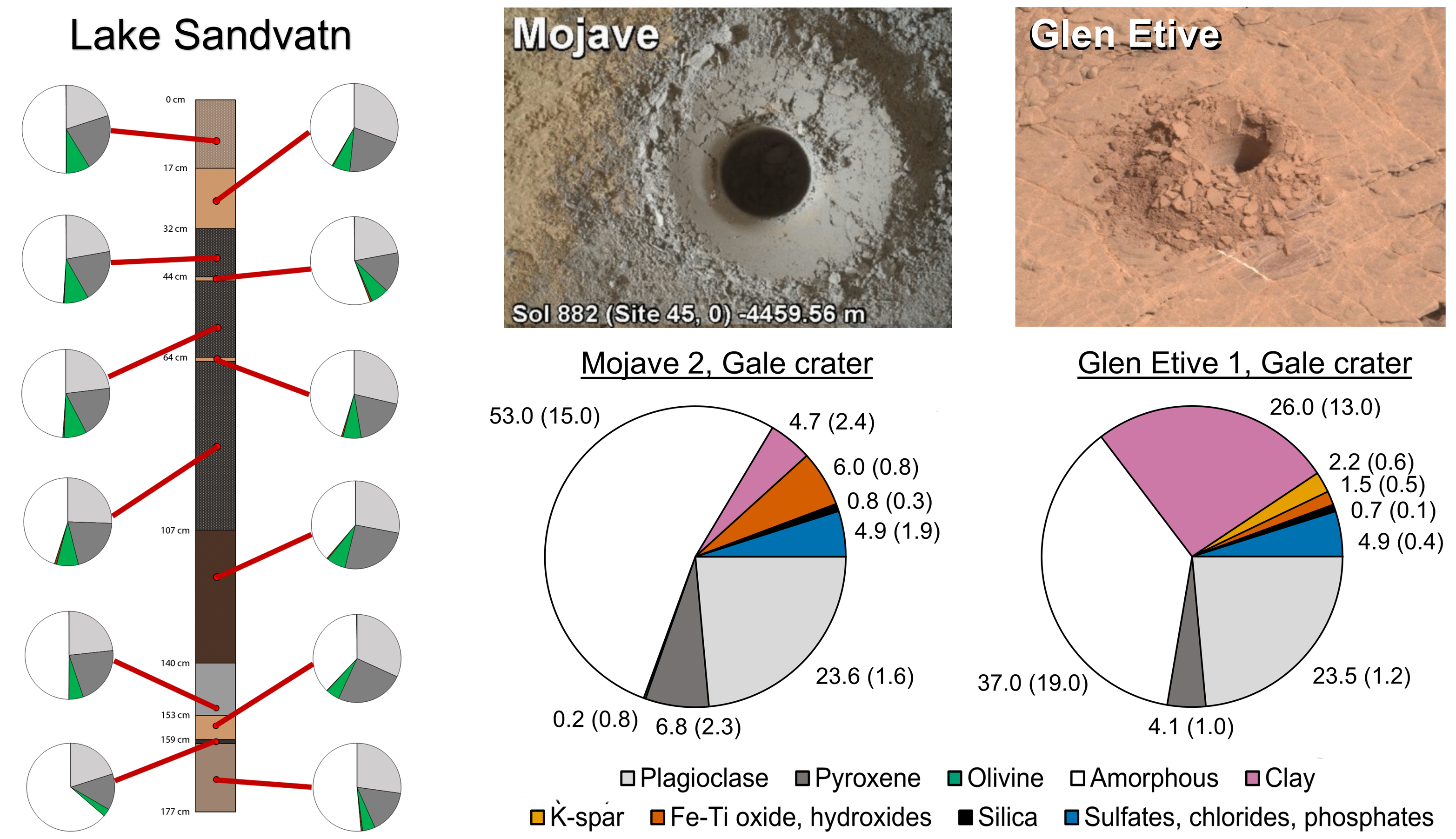
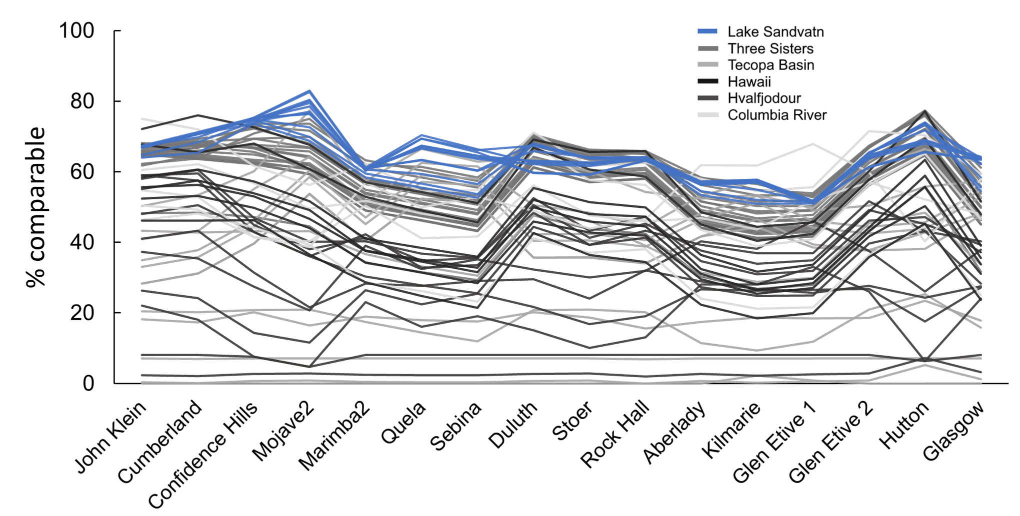


Fig. 3: Mineralogy of samples from Lake Sandvatn against their location in the drill core. And mineralogy and drill core holes (Source: CheMin ODR) of two samples analyzed by CheMin, the XRD instrument onboard the Curiosity Rover.



Lake Sandvatn has many of the same minerals present on Mars. When compared to samples from Mars it was up to 80% comparable and 64% comparable on average. For context, other martian analog sites were also compared to samples from Mars. These included other environmental, climatic, and geologic (basaltic terrains) analogs for Mars. The most significant difference between Lake Sandvatn and Mars in clay mineralogy.

Fig. 4: Comparison between analog mineralogy[2-6] and mineralogy at Gale crater.

Results—LDMS

Cholesterol was detectable on minerals (reference materials) present at Lake Sandvatn and on Mars—pyroxene, plagioclase, olivine, clay.

- S/N of cholesterol on clay was higher on average than the other minerals
- S/N of cholesterol on olivine was lower on average than other minerals
- Cholesterol was also detectable on drill core samples from Lake Sandvatn
- S/N for drill core samples was on average lower than individual minerals (except for olivine)

Betulinic Acid was only detectable on clay

- Measured at one concentration near its maximum solubility—no further experiments completed

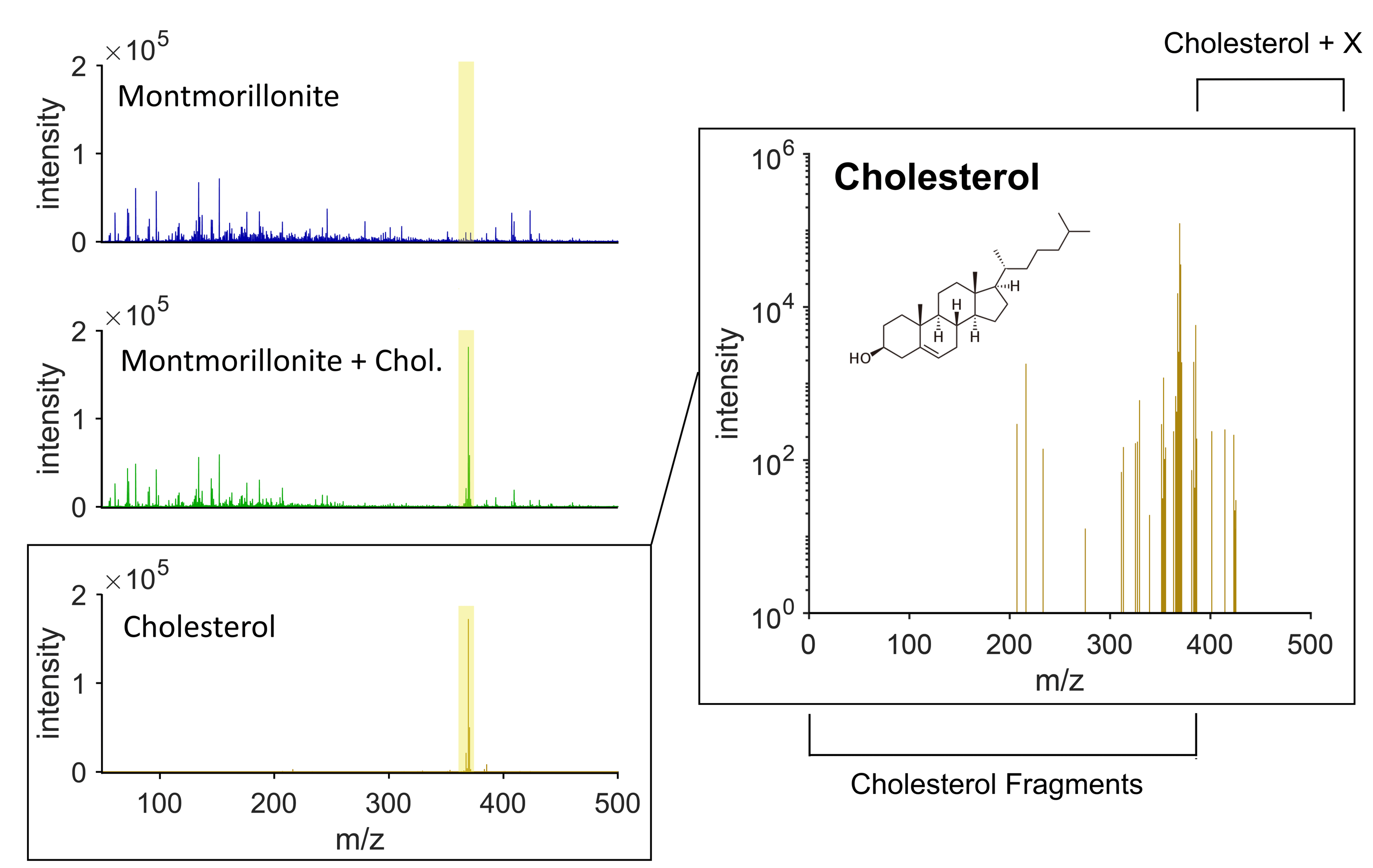


Fig. 5: LDMS spectra for a mineral reference, a doped mineral reference, and the new peaks produced by cholesterol. Cholesterol spectra shown also in log scale.

Discussion

- The drill core represents a range of depositional environments from deep lacustrine to deltaic or closer to shoreline
- Lake Sandvatn in most comparable to lacustrine samples from Pahrump Hills and least comparable to fluvio-lacustrine samples from Glen Torridon.
- May be more poorly crystalline clay at Lake Sandvatn in amorphous material (which geochemically is a mixture)

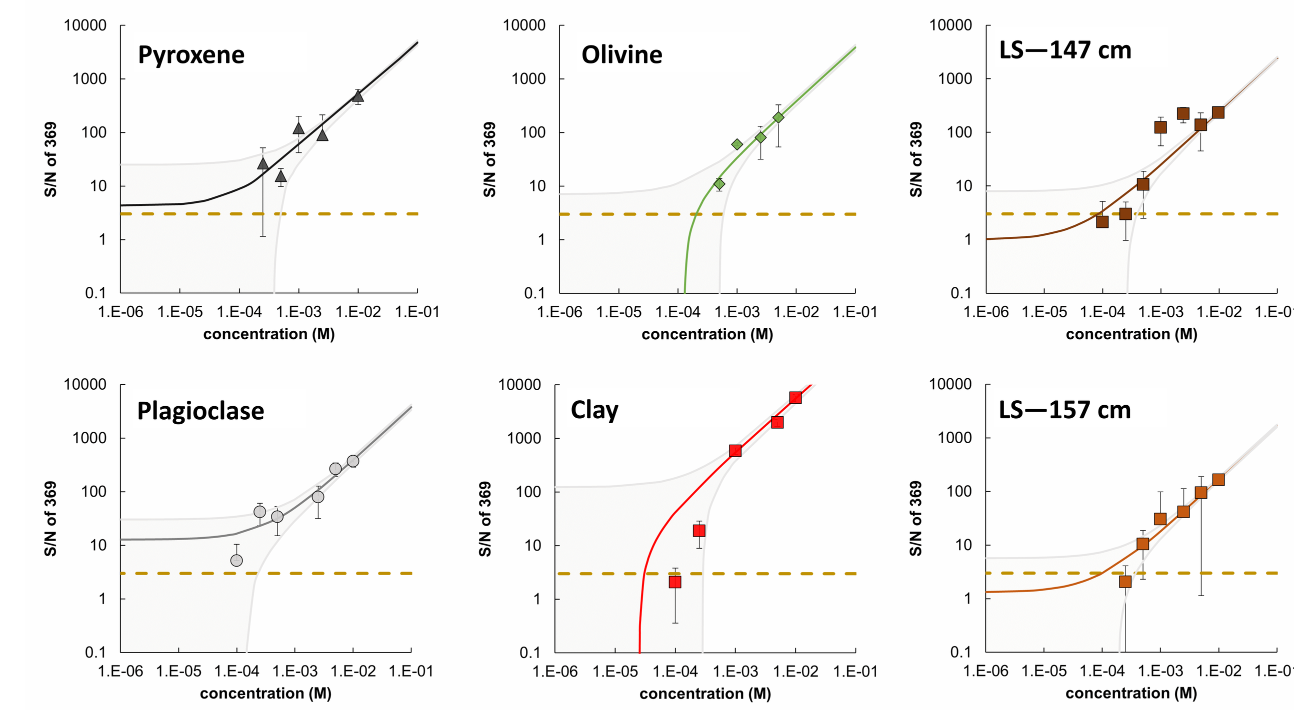


Fig. 7: Linear regressions for extrapolation of the limit of detection for cholesterol on mineral references and Lake Sandvatn samples.

- Limits of detection for cholesterol were extrapolated using robust linear regression on a sensitivity curve
- Clay had the lowest limit of detection at 0.00003 M and olivine had the highest limit of detection at 0.00021 M.
- Lake Sandvatn samples had higher LODs—the major difference in these samples compared to mineral references is the presence of amorphous material
- Variability in detectability may be attributed to absorbance of laser wavelength by the minerals[7], mineral chemistry[8], and or mineral surface and interlayer properties for adsorption of organics[9].

Conclusions

Lake Sandvatn is a comparable analog site for Gale crater.

Minerals had varying affects on the detectability of cholesterol and betulinic acid, and further work will be required to fully understand the mechanisms control variations in detectability.

References

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