

A large diversity of hydrated minerals formed from interaction with hydrothermal fluids in Noctis Labyrinthus, Mars.

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Abstract

The processes that formed hydrated minerals on Mars remain unconstrained. A suite of minerals including all mineralogical classes known on Mars (clays, sulfates and oxides) has been identified in Noctis Labyrinthus. The particular mineralogical association and proximity to settings of volcanic activity suggests coeval formation in a unique local hydrothermal environment.

1. Introduction

Phyllosilicates on early Mars are interpreted as evidence for persistent liquid water at low temperatures. Formation of sulfate deposits postdating phyllosilicates could reflect increasingly dry conditions with time in early Mars history [1]. Yet, the relative roles of geological processes and timing of the formation of alteration minerals on Mars remain poorly constrained.

2. Background

We recently characterized several classes of alteration minerals in the chasmata of Noctis Labyrinthus (NL) [2], next to which tens of shield volcanoes of similar age have been identified [3]. Deposits in a chasma of NL have one of the most diverse mineralogy observed on Mars, and a relatively young age (Late Hesperian or younger).

3. Data and observations

Mineralogy was determined from data acquired by CRISM [4]. We looked for absorption bands diagnostic of hydrated minerals (Figure 1). We define and map spectral criteria for these bands (Figure 2).

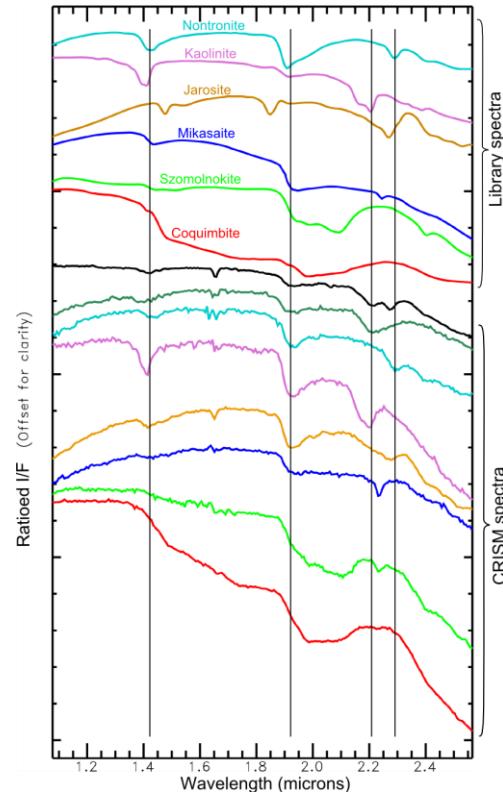


Figure 1: Spectra from CRISM data over the studied site, and spectral libraries.

Spectral features diagnostic of various Fe-sulfates span a continuous outcrop. A distinctive signature given by other small outcrops fits jarosite, another Fe sulfate. Absorption bands at 1.4, 1.9 and 2.2-2.3 μ m reveal phyllosilicate bearing units : a 1:1 Al-phyllosilicate bearing unit (dubbed “kaolinite” unit) and a Fe-smectite bearing unit. Spectra with a distinctive broad 2.2 μ m band sign Si-OH bearing material. Finally, a distinctive unit has spectra with a 2.21-2.28 μ m double absorption, consistent with a

mixture of the Si-OH, Fe-smectite and jarosite bearing materials.

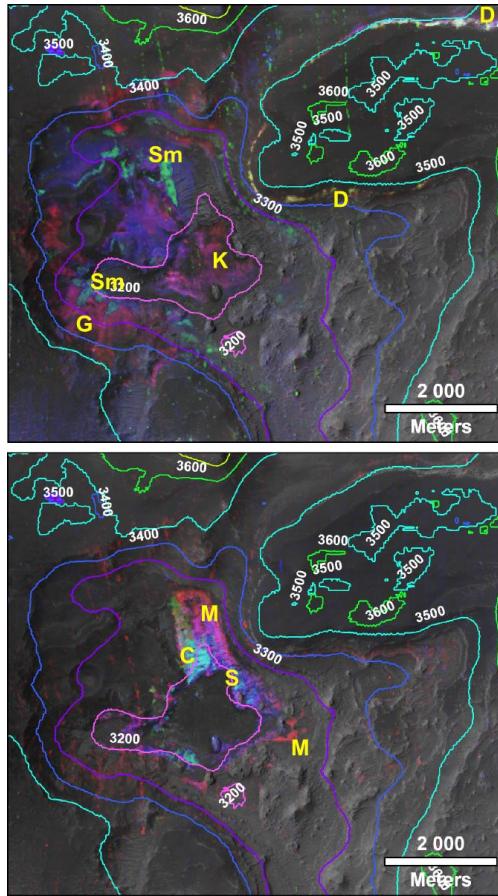


Figure 2: Spectral criteria maps from CRISM: R-G-B composites: 2.2-2.3-1.9 μm (top) and 2.23-1.7&1.9-2.1 μm (bottom) absorption bands. D: Doublet, Sm: Smectite, K: Kaolinite, G: hydrated glass, M: Micasite, C: Coquimbite, S: Szomolnokite

Most units show different patterns of polygonal fractures, consistent with dehydration. The sulfate unit bears parallel dune-like landforms indicative of a past eolian deposition or reworking. The Fe-smectite unit appears to drape kaolinite and sulfate outcrops, and is finely layered. The doublet unit is distinctively deformed and is found at the base of a spectrally neutral landform.

4. Discussion and implications

A stratigraphic sequence consistent with observations is, from most ancient to youngest : a kaolinite (lower) and Si-OH (higher) bearing bedrock, draping Fe-

sulfate and Fe-smectite bearing successive layers. Si-OH and kaolinite may be the result of acid sulfate alteration of a basaltic terrane at varying pH. The finely layered structure of the sulfate and smectite bearing units, is consistent with volcanic ash deposits. Fe-sulfates would have formed by precipitation of Fe and sulfate rich evaporating solutions. Alteration of ash material to Fe-smectite or leaching of Fe in solution requires the presence of liquid water, and preservation of several 100m of these deposits requires rapid cementation. The presence of sulfate salts cementing the Fe-smectite unit is evidence for precipitation likely driven by periodical variations in hydrothermal fluids input.

On a basaltic terrane, volcanic activity would have generated acid sulfate hydrothermal fluids. Dissolution of primary minerals would have leached Ca, Na, Fe, Al and Si in solution. At low pH, Si-OH bearing amorphous silica would have precipitated but as leaching buffered initial acidity, kaolinite could have formed. Slow circulation of the same fluids at low water/rock within ash deposits would have dissolved the glass, increasing pH and promoting Fe-smectite formation. Eventual evaporation of the fluids would have led to Fe-sulfate precipitation. Periodic input of acid waters and ash deposits would have thus formed several classes of alteration minerals. Preservation of the unique deposits of this NL chasma show that local environments with liquid water have existed after the end of the “early Mars” era. The late presence of liquid water for a period of time sufficient to form alteration minerals, also has positive implications for habitability.

References

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