Post- Early Mars local aqueous environments in Noctis Labyrinthus Chasmata

Thollot P.(1), Mangold N., Le Mouélic S., Ansan V., Milliken R.E., Roach L., Mustard J.F.

(1)Laboratoire de Planétologie et Géodynamique de Nantes, UMR 6112 CNRS / Université de Nantes, France
Context

A site of **exceptionnal** mineralogical diversity, close to **volcanic** constructs

Shield volcanoes of ~Late Hesperian age

*Shield volcanoes of ~Late Hesperian age (Baptista et al., 2008)*
Context of the studied chasma

- 3-4 km elevation gradient
- Landslides
- 2 depressions or « inner troughs » with layered deposits
- LOCALIZED layered deposits
- NO morphologies suggestive of transport of material to the chasma: local alteration
- CRISM data
Mineralogical diversity (1/2)

Fe-sulfates

Jarosite \((K,Na)Fe^{3+}_3(SO_4)_2(OH)_6\)
Mikasaite \(Fe^{3+}_2(SO_4)_3\)
Szomolnokite \(Fe^{2+}SO_4\cdot H_2O\)
Coquimbite \(Fe^{3+}_{2-x}Al_x(SO_4)_3\cdot 9H_2O\)
Mineralogical diversity (2/2)
Clay minerals, etc.

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Spectral units correlate to morphological units

No layering

Halloysite

Si-OH bearing

Bedrock
Spectral units correlate to morphological units

Fe Smectite

Thin layers

Fe-sulfates

Paleodunes

Layered deposits

50 Meters

250 Meters

100 Meters
Draping of layered deposits

Spectral criteria over morphology

Fe Smectite (Layered)

anhyd. Fe Sulfate

North

3x vertical exaggeration

Halloysite

Fe Sulfates (Layered)

Fe Smectite (Layered)

Halloysite
Draping of layered deposits

Spectral criteria over morphology

Fe Smectite (Layered)

Fe Sulfate

anhyd.

North

3x vertical exaggeration

Interpretative Cross-section

Halloysite

Halloysite

Fe Sulfates (Layered)
Interbedding of Fe sulfates & smectites

Spectral criteria over morphology

Fe sulfate jarosite (Layered)

Si-OH

Fe Smectite (Layered)

Fe Sulfates (Layered)

Halloysite

3x vertical exaggeration

Interpretative cross-section

North

Si-OH

Sm

Su
Obs. summary: inner-trough cross-section

- Current inner trough cutting through layered deposits
- Layered deposits draping a « proto » inner trough in the bedrock

Layered deposits emplaced, altered, cemented after chasma formation
Chronology

Late Hesperian Plateau:
~3.6 Ga

Chasma floor: areas as old as
~3-3.6 Ga

Capping unit
~100 Ma
Some geochemical constraints
Fe-smectite vs. Fe-sulfates vs. Fe oxi/hydroxides?

Ranges of phase stabilities of Fe sulfates and Fe oxi/hydroxides (King & McSween, 2005)

Fe-smectite formation field (Harder, 1976)

Acid-sulfate solution
oxidative (surface?)

Observed minerals

Low pH, high sulfate:
Ferric/Ferrous sulfates – f(Eh)

Low/Neutral pH, low sulfate:
Fe oxi/hydroxides (high Eh)

Neutral pH, low sulfate:
Fe smectite (low Eh)
Hypothetical formation processes

Primary material: Basaltic bedrock & repeated deposition of basaltic tephra layers (volcanic activity). Possibly heterogeneous composition.

Authigenic alteration minerals

Diagram:

- **No alteration**
- **Hydrothermal/Epithermal environment (surface/subsurface)**
- **Fe-ox**
- **Fe-sulf**
- **Fe-smect**
- **SiO₂**
- **H₂O**
- **O₂**
- **H₂O₂**
- **Si**
- **Al**
- **Fe**
- **H⁺**
- **H₂SO₄**
- **Mg**
- **Ca**
- **layered deposits**
- **Evaporation**
- **Fluctuating water table**
- **Hot**
- **Cold**
- **Isotherm**

Legend:
- **acidic**
- **mildly acidic**
- **neutral**
Conclusion

- Associated *phyllosilicates* + sulfates + hydrated silica
- Post Noachian/Phyllosian phyllosilicates
- Local processes from volcanic activity & hydrothermalism:
  - Acid-sulfate alteration: Fe leaching and Fe-sulfates precipitates
  - Local buffering by water-rock interaction: clays

- A localized environment can generate most mineral classes observed anywhere on Mars (silica, clays, sulfates, oxi/hydroxides)

- Post « early Mars » environment with liquid water and variable Eh and pH conditions, suitable for biochemical reactions