Exhumed Hypanis Fluvial Deltaic system in Xanthe Terra

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What makes fluvio-deltaic systems special?

• Form part of sediment routing systems – have predictable properties – grain size trends, textural trends, facies transitions,

• Integrate erosional products from large areas of bedrock – bedrock erosion and redistribution over large areas

• Efficient grain size fractionating systems – large fluvial systems produce large quantities of fine-grained sediment

• Concentrating systems
Volumetric budget and grain-size fractionation of a geological sediment routing system: Eocene Escanilla Formation, south-central Pyrenees

Nikolas A. Michael, Alexander C. Whittaker, Andrew Carter and Philip A. Allen

*Geological Society of America Bulletin* published online 3 February 2014; doi: 10.1130/B30954.1

Transport direction

![Graph showing transport direction with facies percentages over time intervals.](image-url)
What makes deltaic-lacustrine systems good for biosignature formation and preservation?

• Rapid deposition due to abrupt change in sediment transport efficiency => rapid burial => enhanced preservation of organics
• Enhanced settling of fines (silts & clays) from suspension – include clay minerals
• Input of mineral ‘resources’ – nutrients
• Low energy environments – reduced destruction by high energy fluid flows
Delta toe deposits interfingering with basinal mudstones

Mud glorious mud.....
Preservation?

- Rapid deposition and burial – organics enter sediment column rapidly – limits near surface alteration
- Burial close to entry point of sediment routing system – reduction of multiple cycles of erosion and deposition
- Progradation of coarser facies over finer creates geologic ‘protection’
Why an ancient delta?

<table>
<thead>
<tr>
<th>Martian context → early Mars environment</th>
<th>Support biotic OM formation</th>
<th>Support for abiotic OM formation</th>
<th>Support OM concentration</th>
<th>Support preservation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eolian sediments (sand)</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Altered eolinites (dust)</td>
<td>very low</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Fluvial channel</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Fluvial floodplain</td>
<td>low-mod</td>
<td>low</td>
<td>mod</td>
<td>mod</td>
</tr>
<tr>
<td>Alluvial fan</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Deltaic</td>
<td>high</td>
<td>low</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Lacustrine (perennial)</td>
<td>high</td>
<td>low</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Lacustrine (evaporitic)(Cl)</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>high-very high</td>
</tr>
<tr>
<td>Lacustrine (evaporitic)(SO₄)</td>
<td>mod</td>
<td>low</td>
<td>high</td>
<td>high-very high</td>
</tr>
<tr>
<td>Regional groundwater pore system</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Glacial deposits</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Permafrost</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>mod</td>
</tr>
<tr>
<td>Soil (surface fines chemically altered by atmosphere)</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td>Regolith/Fractured bedrock (not soil)</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
</tbody>
</table>

Ancient deltas and lakes are excellent exploration targets for NASA 2020

- Low energy fine-grained sediments
- Higher sedimentation rates – due to abrupt gradient in sediment transport rates
- Concentrates organics + potential for detrital organics

Summons et al., 2011
Overview location of the Hypanis system in Xanthe Terra
Extensive drainage systems fed Hypanis Chryse escarpment

Hypanis delta system

Shalbatana Vallis
Source of Hypanis

- Hypanis fan system is fed by a very extensive bedrock valley – Hypanis Vallis – several hundred kilometres long (?), ~75 m deep
  - Perhaps connects to Nanedi Vallis

- Large volume of rock has been removed by fluvial erosion

- Valley network is very different to drainages sourced from crater rims cf. Gale crater fan and other crater-rim fed fans

- Hypanis is a much bigger system

- Hypanis and Sabrina deltas are located at margin of Chryse escarpment – abrupt transition from erosional to depositional realm

- Timescale of fluvial erosion
  - Difficult to estimate precisely
  - Valley form is different to outflow channels
  - Narrow width, sinuous valley form
  - Suggests long-lived erosion – not instantaneous or short-lived erosion
Provisional mapping
Timing of fluvio-deltaic activity

Early Hesperian

Hauber et al 2013
Mineralogical Description

CRISM Mineralogy -

- Analogous fan mineralogy, ~75 km west of Hypanis.
- Fe/Mg phyllosilicates (nontronite?) at low stratigraphic level in fan deposits.
Mineralogical Description

CRISM Mineralogy – within ellipse (just!)

- Limited by available data – only two CRISM images intersect edge of Hypanis regions.
- Limited (ambiguous) mineralogy near Hypanis, although possible phyllosilicates.
Mineralogical Description

CRISM Mineralogy – predicted

• More CRISM images have been requested, covering distal (low stratigraphy) fan region.
• New CRISM data could show evidence of aqueous alteration, as:
  1. Allochthonous deposits – channel eroding and depositing Noachian material.
  3. Deep alteration products – brought up and distributed by impacts.
Hypanis sedimentary system
Forms a point-sourced depositional body.
Hypanis – multiple depositional lobes
Channel-lobe body extends basinward of lobe to west.

Erosional ‘front’ of lobe

Late stage incision after lobe deposition

~5 km
Variation of delta shape as a function of sediment grain size from numerical simulations

Caldwell & Edmonds 2014
Large-scale geometry of the Hypanis system

- Hypanis system comprises multiple depositional lobes

- Individual lobes appear to cross-cut each other

- => we observe temporal variation in deposition – lobes are shifting sideways through time – this is classical behaviour – called compensation cycles

- Channel-lobe features appear to shift basinward
  - System progrades basinwards...

- In eastern part of ellipse, we observe long, inverted channel system extending beyond termination of central lobe
  - Does this indicate further basinward progradation of fluvial systems?
  - Maybe an overall progradational system. Would prograde over finer-grained basinal lower energy deposits
What is the bath-tub that ponded water?

Was the Chryse basin the bathtub?
Hypanis - Sedimentology and Stratigraphy
CTX image and dtm
Hirise image and dtm
~40 m high mesa
2 km long

Hirise image and dtm
Preservation of deltaic deposits in the stratigraphic record
Laminated delta front mudstones

Mouth-bar sandstones

10 m
Volcanism near Hypanis?

Ledergberg crater
Tuff cone??
## Meeting 2020 Criteria

<table>
<thead>
<tr>
<th>Objective A: Characterize geology of astrobiologically relevant area</th>
<th>Analyze clear fluvio-deltaic system of Early Hesperian age. Likely potential to characterize lacustrine environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective B: Determine habitability and biosignature preservation potential</td>
<td>Lacustrine system associated with Hypanis delta like to have formed habitable environment. Deltas have high rate of deposition and fine-grained material in distal areas with high preservation potential of OM</td>
</tr>
<tr>
<td>Objective C: Caching of scientifically selected and compelling samples</td>
<td>Will be able to access wide variety of sedimentary rocks of aqueous origin Access possible volcanic rocks as float</td>
</tr>
</tbody>
</table>
Hypanis – key points 1

• Late Hesperian aged, sedimentary rocks throughout the area
  ➢ Therefore, lots of science targets
• Clear fluvio-deltaic context – excellent aqueous geological setting
• Sourced from extensive fluvial system – likely long duration of activity
• Likely downstream association with low energy fine-grained pro-delta and lacustrine deposits
  ➢ High rates of sedimentation
  ➢ Good biomarker preservation potential
Hypanis – key points 2

- Extensive layered sedimentary rocks associated with geomorphic features
- One of several deltaic systems in the region – this could be a representative example of widespread, ancient deltaic systems at Chryse basin margin
- No downstream topographic boundary – what created the basin – a large Chryse lake/sea???

Potential to investigate and cache a large variety of sedimentary rocks from an ancient aqueous environment. Possible volcanic rocks as float?
Land on distal sedimentary layers