Using Temporal Relationships to Maximize Science Return: Lower Mound in Gale Crater

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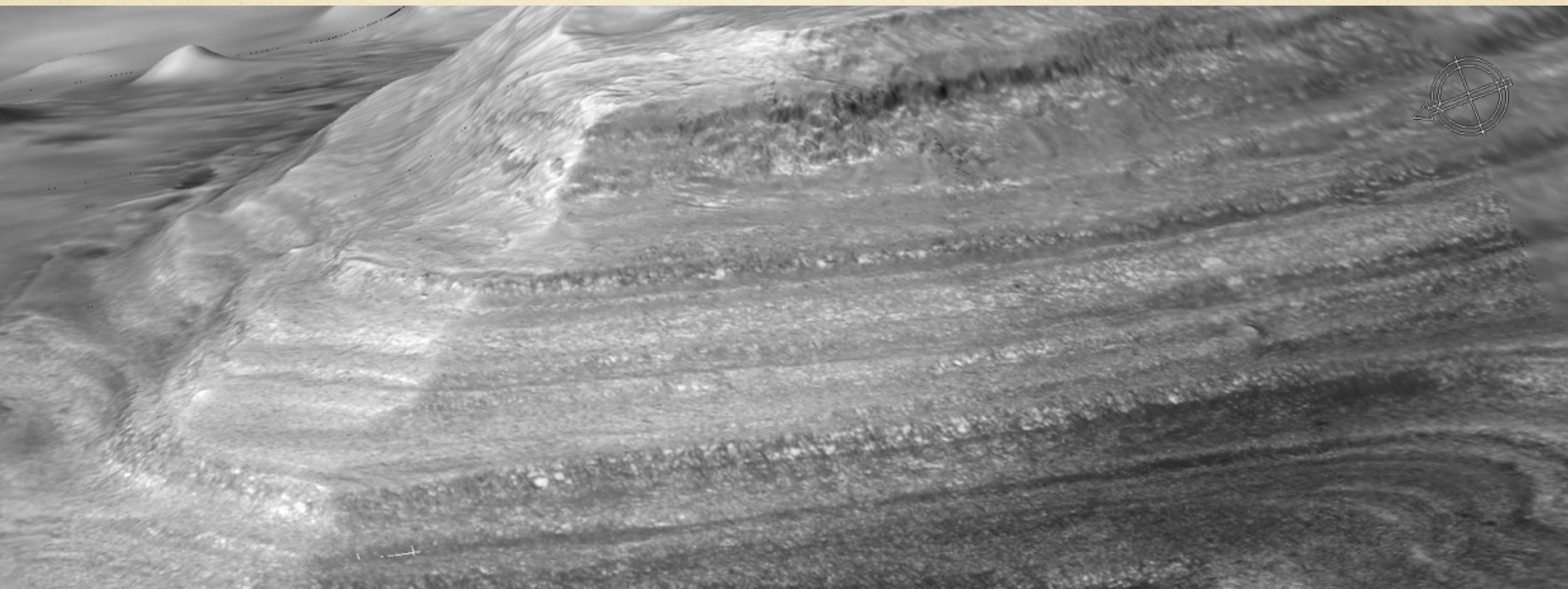
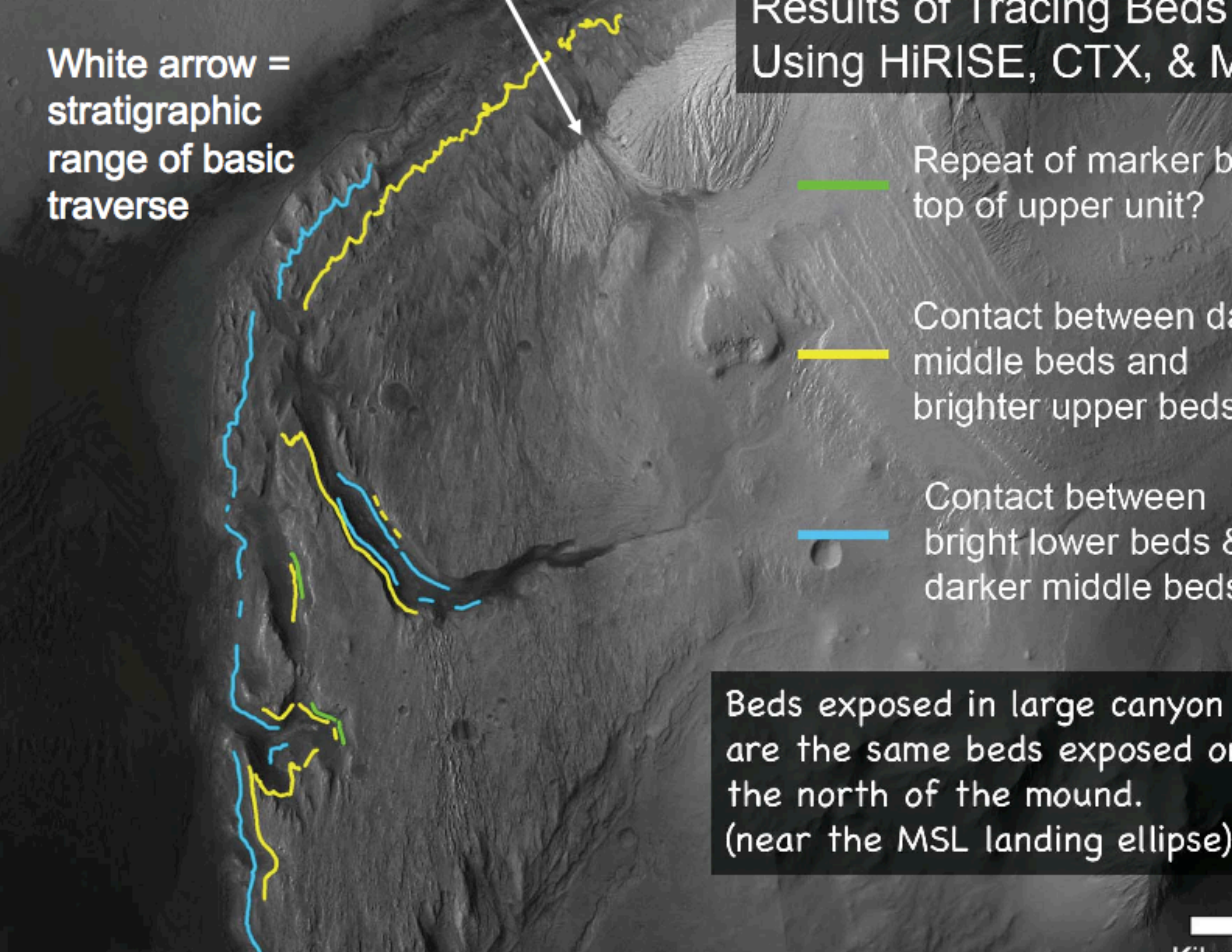
Outline:

- Summary of Basic Observations
- Reasonable Deductions for Origins of Strata
- Testing the Origins of Sulfate and Clay Minera
  - Timeline of depositional and erosional events
  - Predicted relationships for water-rock interactions
  - Places we can test predicted relationships



What we observe:

- Finely layered, approximately flat-lying strata with vertical variations in outcrop characteristics
- Clay-mineral and sulfate-mineral signatures that va with stratigraphy
- Similar strata, including marker beds, extend for 10 km from the field site into the “grand canyon” and possibly to the SE edge of mound
- Incised channels with remnant sediment in them coming off the mound
- “Mound skirting unit” and indurated surface units he unconformity developed on lower mound strat


Results of Tracing Beds
Using HiRISE, CTX, & M
White arrow = stratigraphic range of basic traverse
Repeat of marker b
top of upper unit?
Contact between da
middle beds and
brighter upper beds
Contact between
bright lower beds &
darker middle beds
Beds exposed in large canyon
are the same beds exposed o
the north of the mound.
(near the MSL landing ellipse)

What we can deduce for the Lower Mound 1:

- Lateral continuity of beds suggests nearly uniform depositional environments from the field area to the "grand canyon" and beyond.
  - Reasonable Environments: lacustrine, playa, eolian dune fi controlled by water table, air-fall deposits (pyroclastic, dis impact, dust stones)
  - Unlikely Environments: fluvial, alluvial, shoreline (althou these could have been present elsewhere in the crater duri deposition of the lower mound strata)

What we can deduce for the Lower Mound 2:

Vertical variations in mineral signatures and outcr style, plus the presence of marker beds, suggest temporal changes in deposition. Example tempora variations could include:

- Changes in water supply vs. evaporation rates causing variations in evaporite mineral precipitation rates
- Variable influx of clay minerals vs. other sediment types
- Event deposition from pyroclastic flows or impacts

Strata likely represent variations on a similar them e.g. “Walther’s Law”

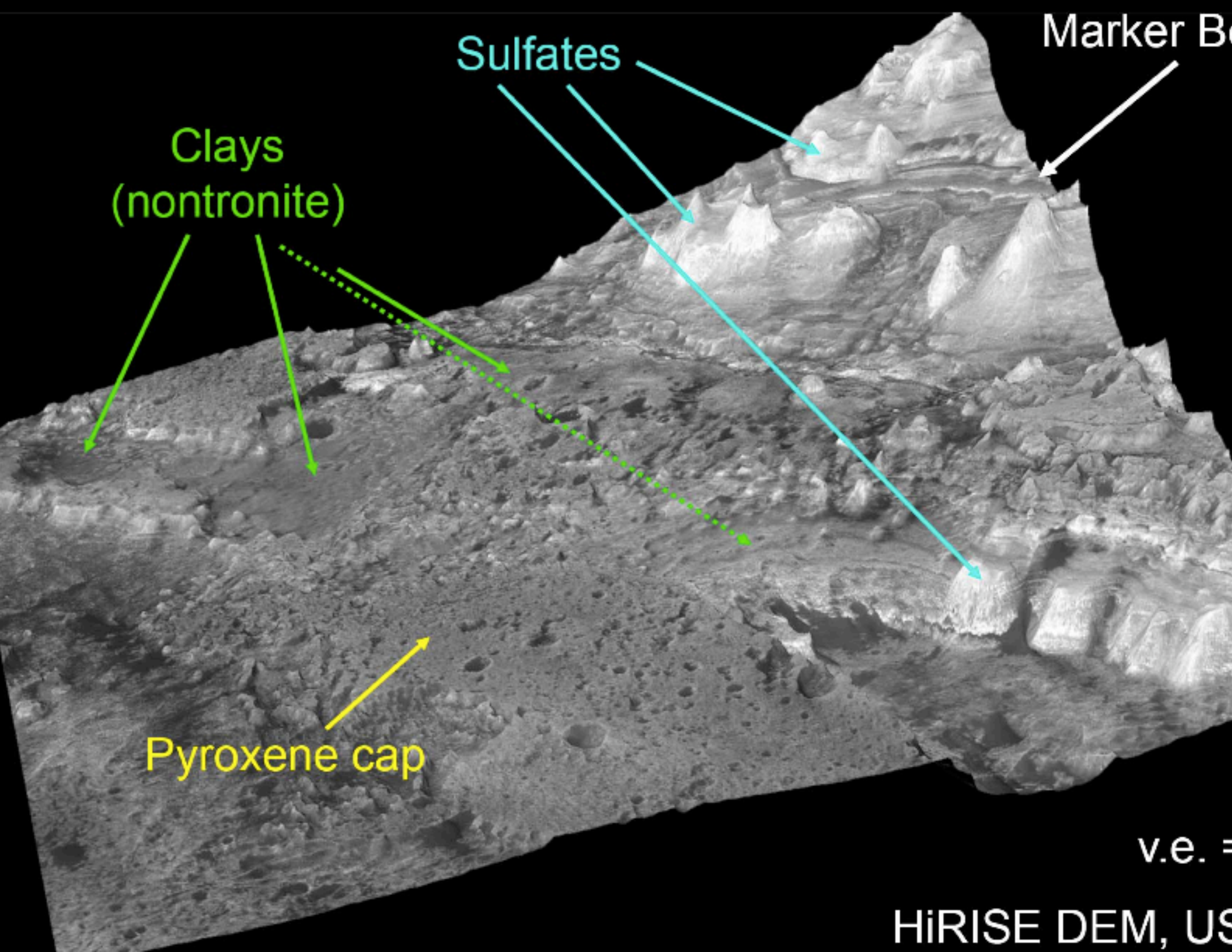
Walther's Law:

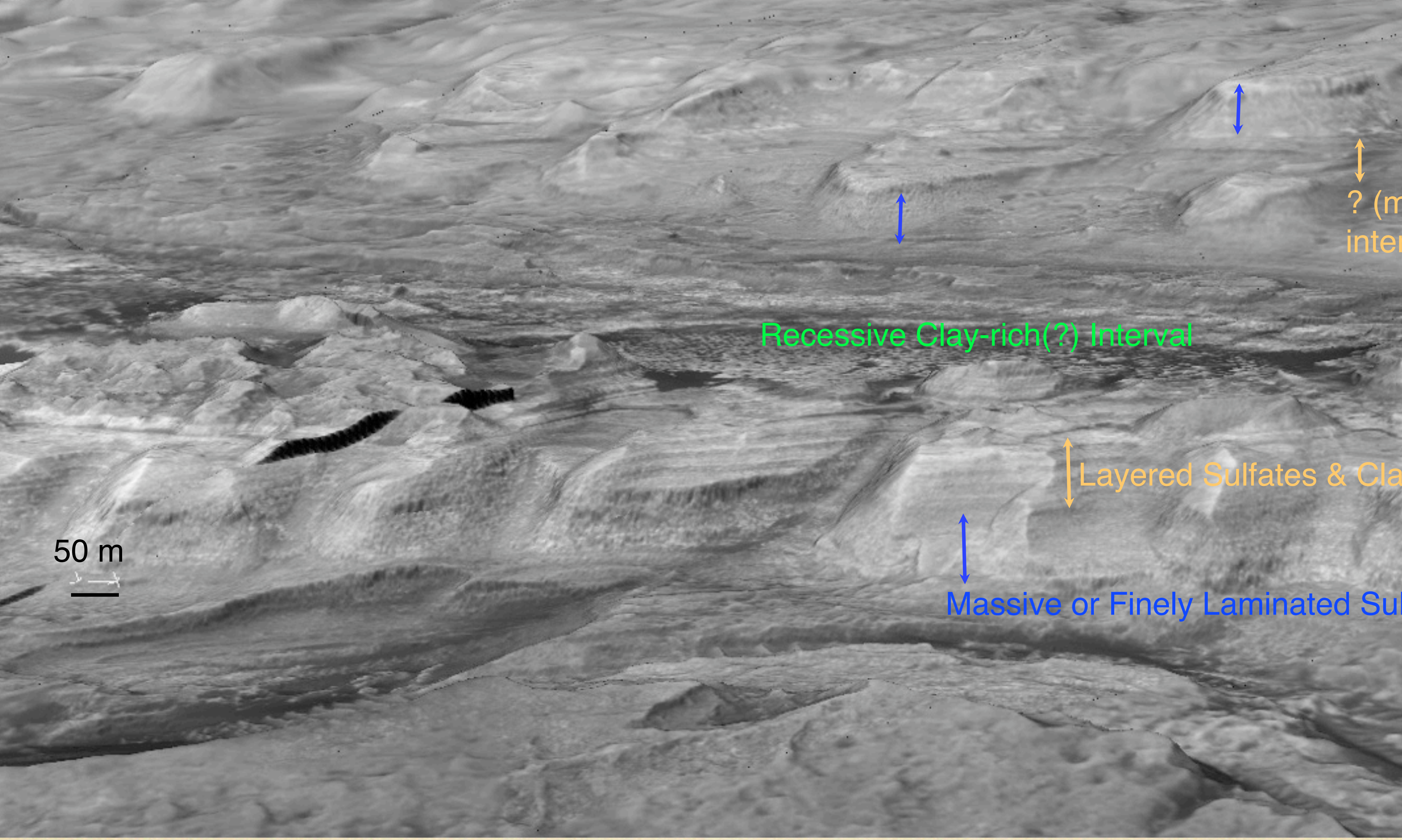
Depositional environments vary in space and time
uch that "The facies [rock types] that occur *conform*
next to one another in a vertical section of rock will
he same as those found in laterally adjacent
lepositional environments." (Johannes Walther, 18

Exceptions: Depositional events, rapid temporal environm
changes, rocks separated by unconformities, etc.

This concept allows one to build a consistent
lepositional model for a suite of rocks.

Example: Festoon ripple cross laminated sand associated w
several meter-scale cross stratified sands represents a diffe
environment than festoon ripple cross laminated sand
associated with planar laminated sand that fines upward


Marker Be
Sulfates
Clays
(nontronite)
Pyroxene cap
v.e. =
HiRISE DEM, US



peating packages of strata suggest shifts among related
ironments. Sulfate cliffs to clay-bearing recessive strata to su
's suggests gradational (Walther's Law type) environmental
nges. (Even if the minerals are diagenetic, they likely reflect

Environment Field Tests:

- Observe sedimentary structures, grain size variatio
  bedding style changes, etc. to build a depositional r
  - Typical field observations for any layered sequence
- Evaluate changes laterally to test predicted lateral
  imilarity of environments
- Focus on vertical changes in features to build a mo
  nvironmental change through time, allowing stro
  onstraints to be developed for environmental
  nterpretations.
  - Key relationships will be found in the strata containing bo
    sulfate and clay minerals. Interbedded? Intermixed?
    Sedimentary structures?

the Sulfate and Clay Minerals?

This is one of the most intriguing questions about

- Both can be transported into sedimentary environments.
- Both can form in sedimentary environments.
- Both can form due to diagenesis (post-depositional water reactions).

The origins of these minerals in Gale can shed ligh global questions concerning the origins and tempo distribution of similar minerals elsewhere.

se Crosscutting Relationsh
to Test Mineral Origins

Sulfate minerals are (variably) soluble.

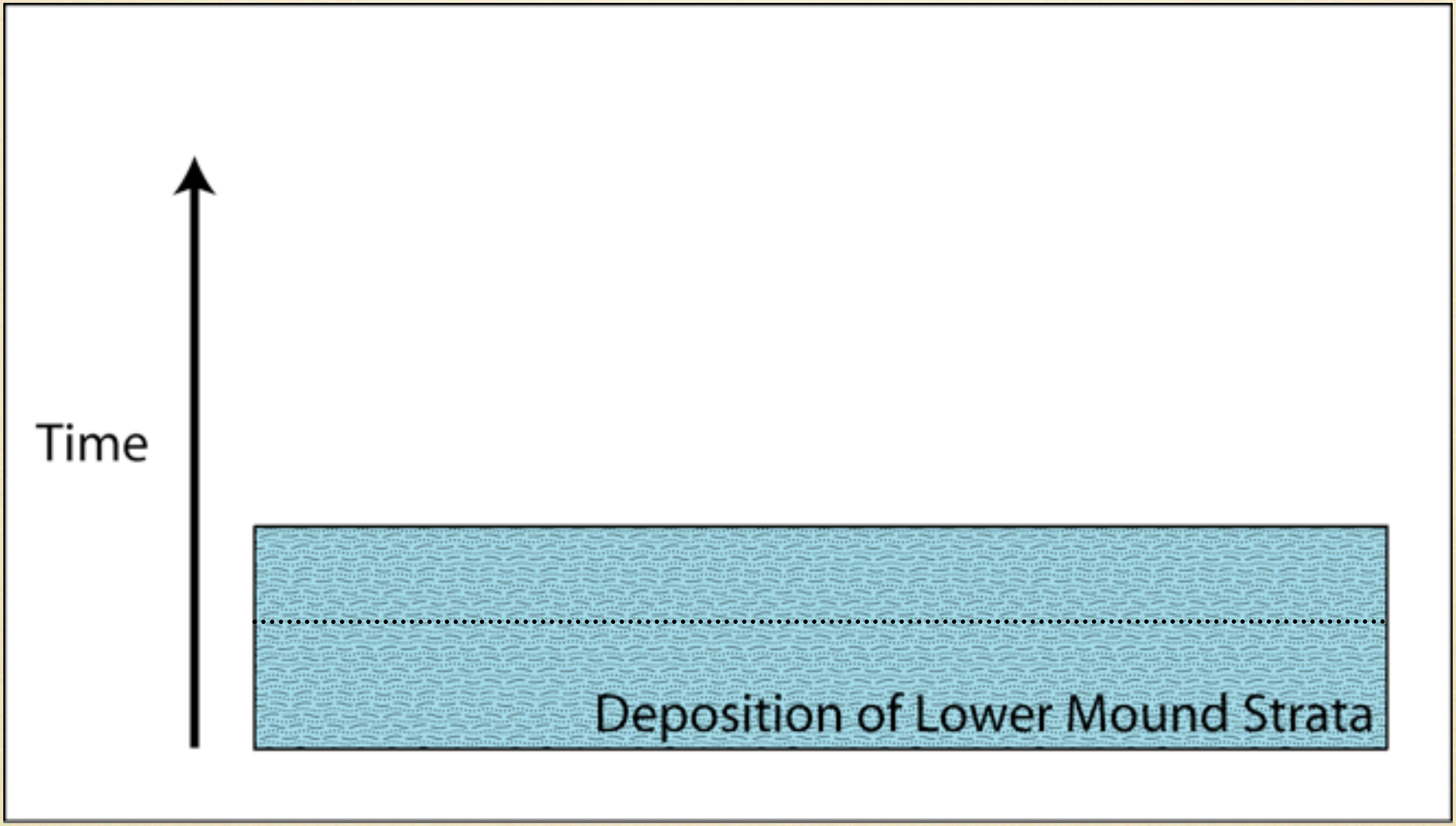
Clay minerals are (generally) insoluble.

When fresh water flows over or through rocks, it will di
ionic minerals (salts) until the water becomes supersatu
with respect to each soluble phase. It can alter rock to fo
clay minerals.

We have evidence of surface water flow. How did it aff
mineralogy?

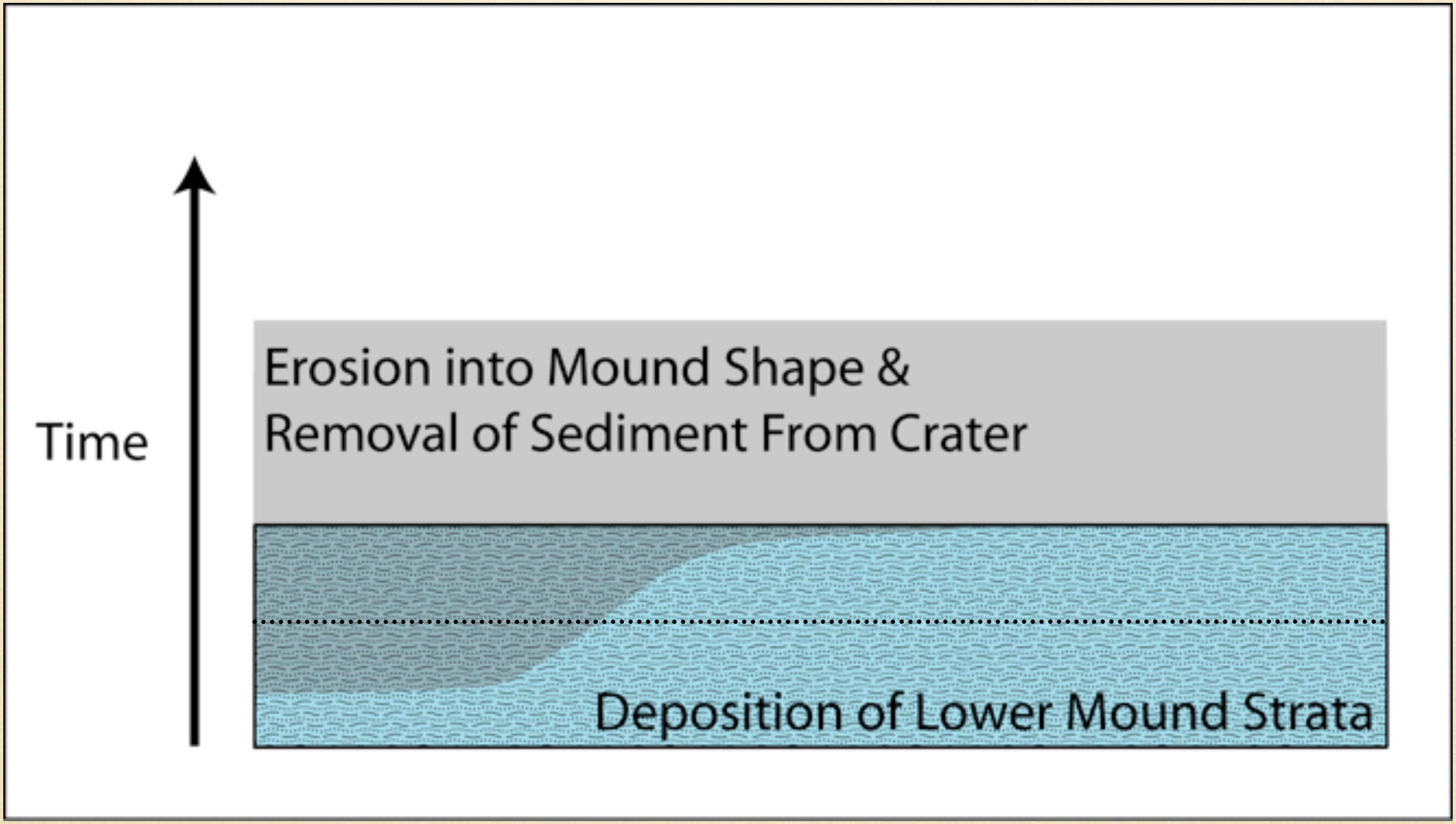
- We can use temporal relationships to evaluate this question anc
the origins of the minerals.

Timeline:



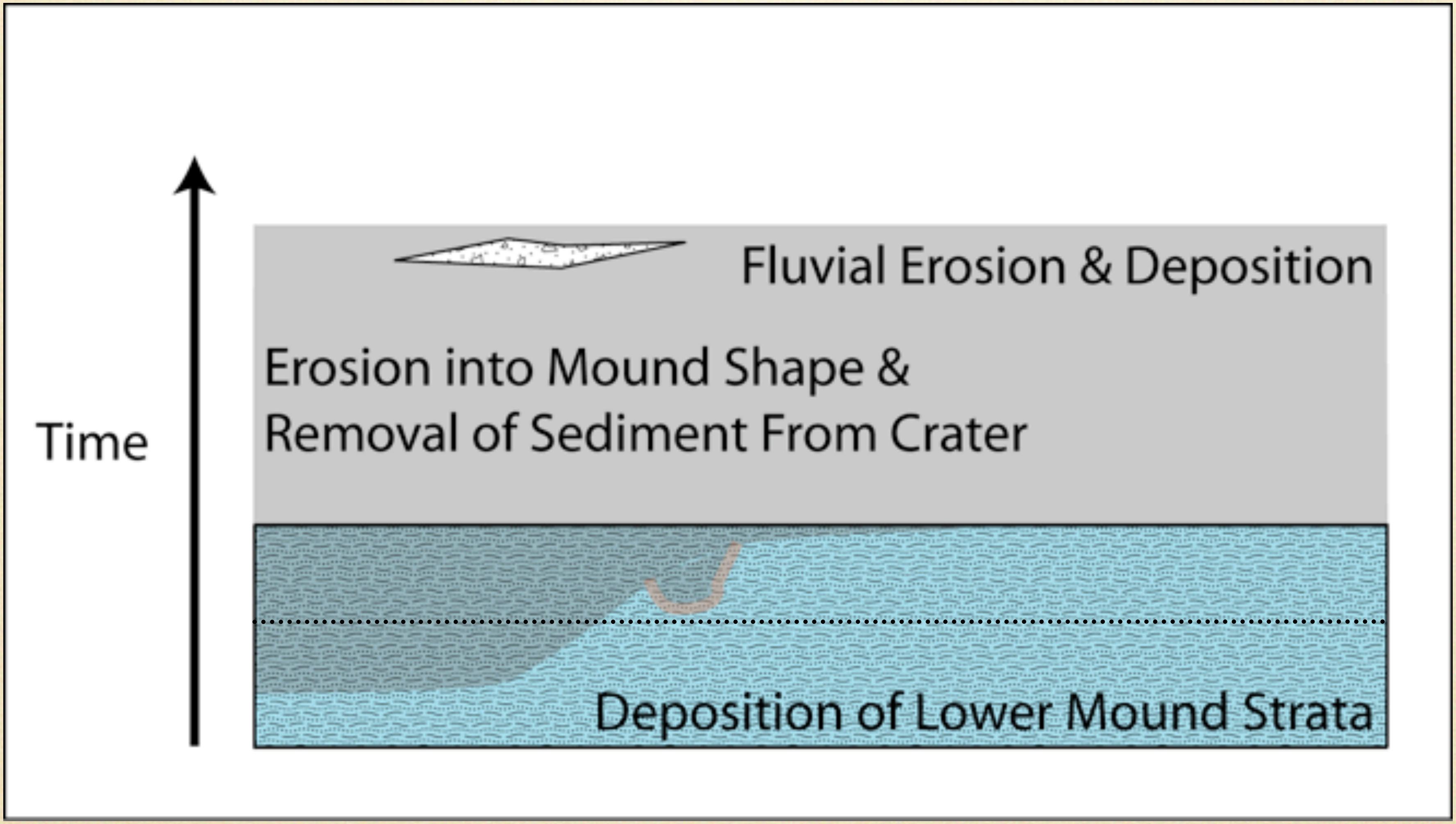
re sulfate and clay minerals present during deposi
not? Mineral assemblages and observations of how
y are distributed in layers can help answer this.

Timeline:



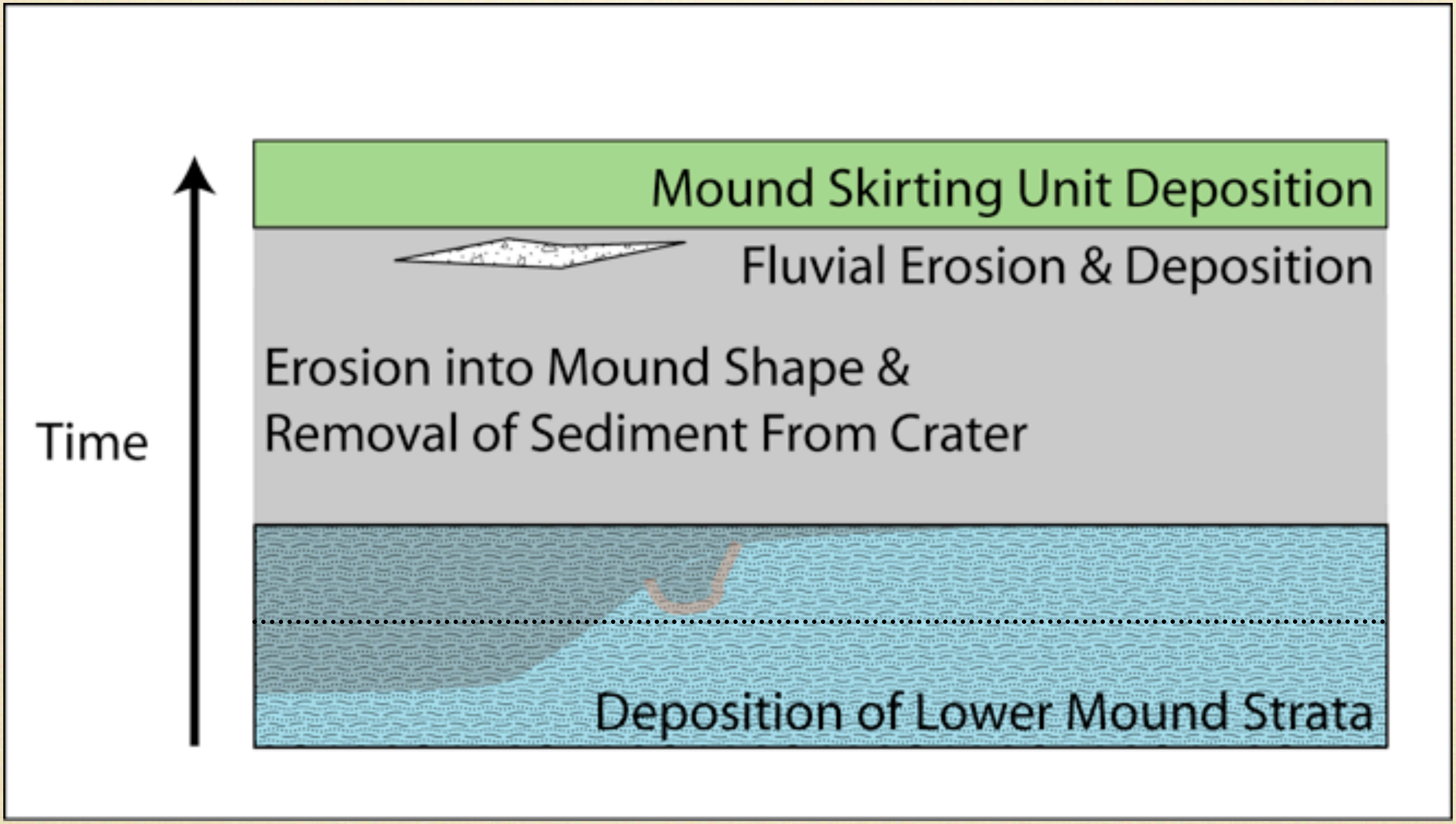
erial had to be removed from Gale Crater, but there is no out
nnel. Therefore, erosion was likely eolian with arid condition
 might induce salt precipitation on the unconformity due to
king of groundwater or atmospheric moisture-related
ystallization

Timeline:



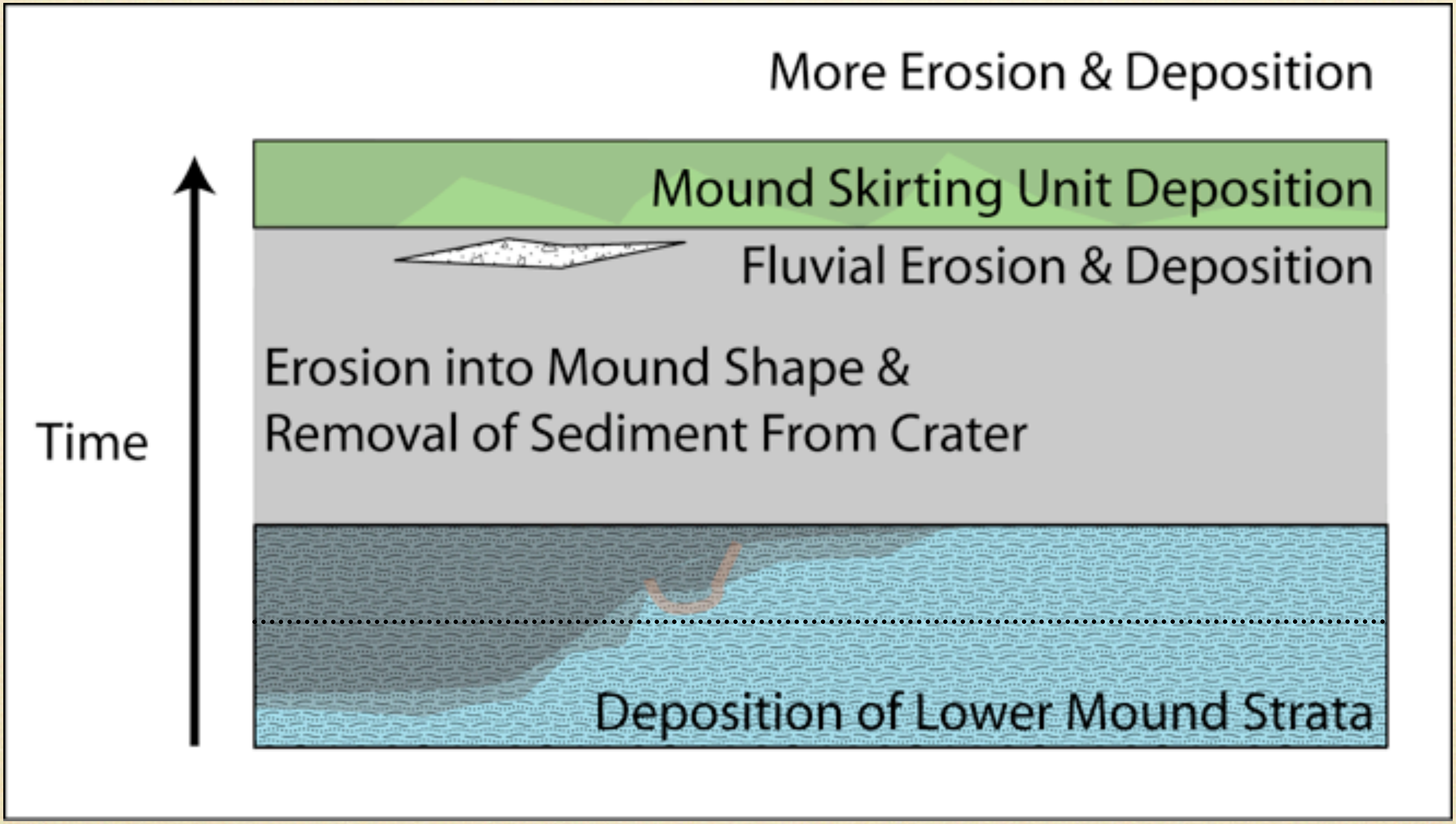
vial erosion of canyons exposed lower mound strata to water
transported eroded sediment. Was this fresh (rain, ice melt)
ne (ground) water? Did it dissolve salts in the transported
ment? In the bedrock banks? Did mafic minerals alter durin

Timeline:



derson & Bell (2010) suggest that the mound skirting unit is
ociated with inverted channels. There may also be eolian du
uggesting variable surface water but the likely presence of g
er. Salts may have repeatedly dissolved and reprecipitated

Timeline:



ditional changes in water supply through time would affect s
ent eolian erosion may expose diagenetic gradients in lower
und strata.

Example Predicted Relationships

the channel water was fresh and the sulfates

Synsedimentary, they should:

- vary among layers.
- be dissolved/recrystallized near fluvial channels.
- not be present in water-transported sediment.

Diagenetic and formed during eolian erosion pre-fluvial in
they should:

- crosscut layers.
- be dissolved/recrystallized near fluvial channels.
- not be present in water-transported sediment.

Diagenetic, post-fluvial incision, they should:

- crosscut layers.
- have similar characteristics near & far from fluvial chann
- be present in water-transported sediment (if it was the ri
composition).

If the channel water was saline:

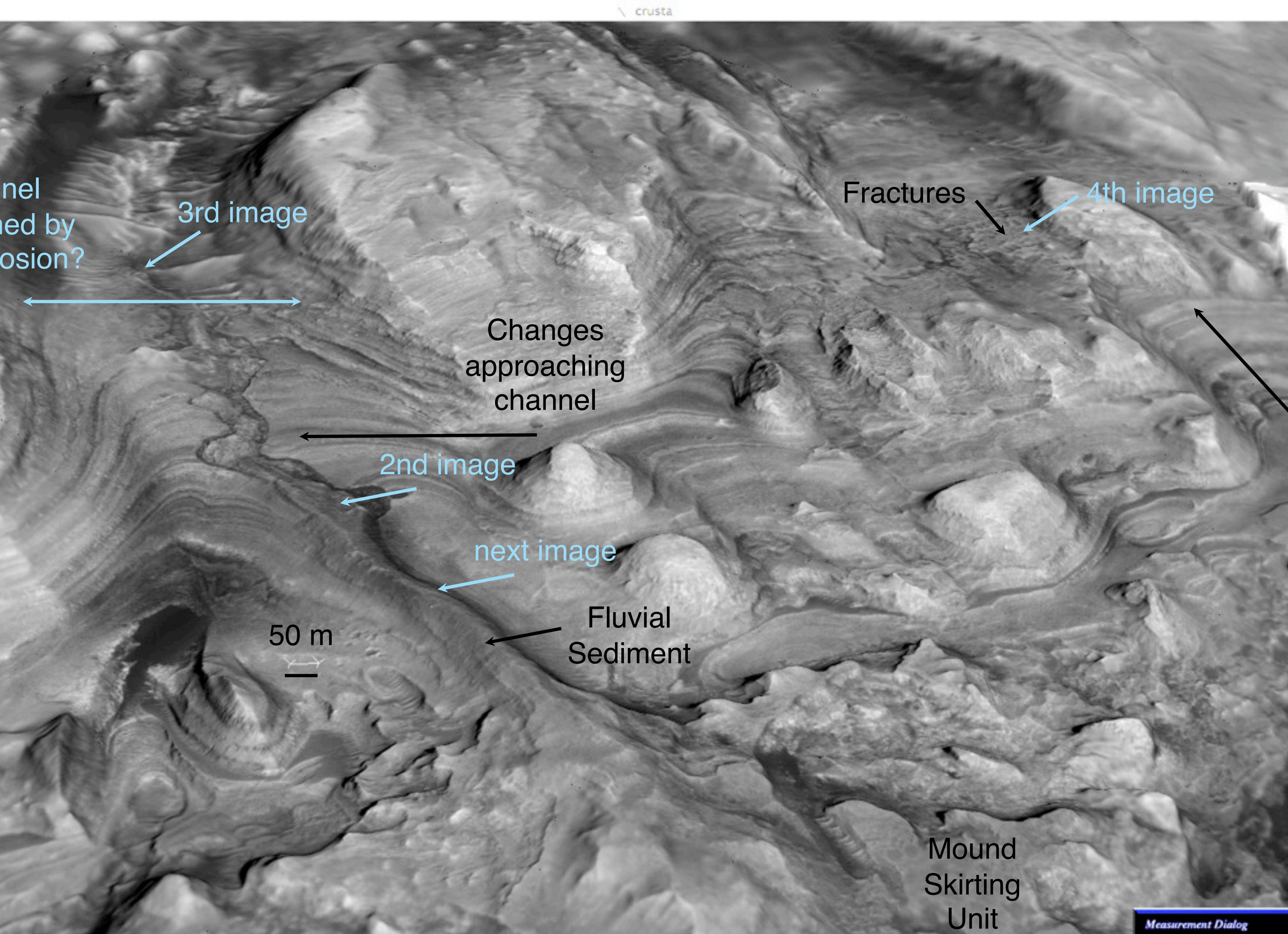
Recrystallization of bedrock salts would occur if t
water was out of equilibrium with respect to thos
particular salts.

Evaporation of water would have caused salt mi
precipitation.

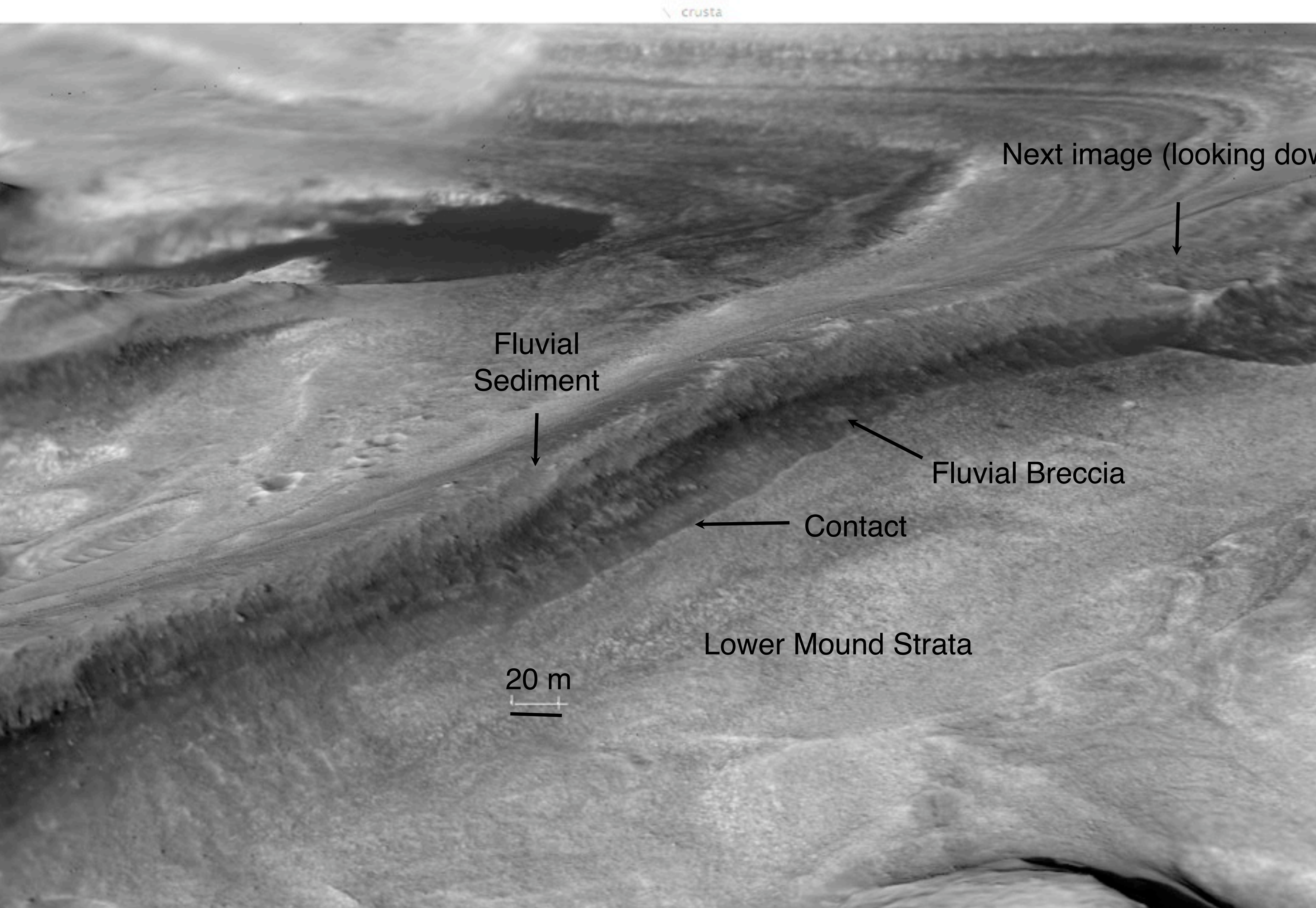
Some salts might have precipitated in fluvially transported sediment.

- Movie: http://www.youtube.com/crustamars

Where we can test predictions.

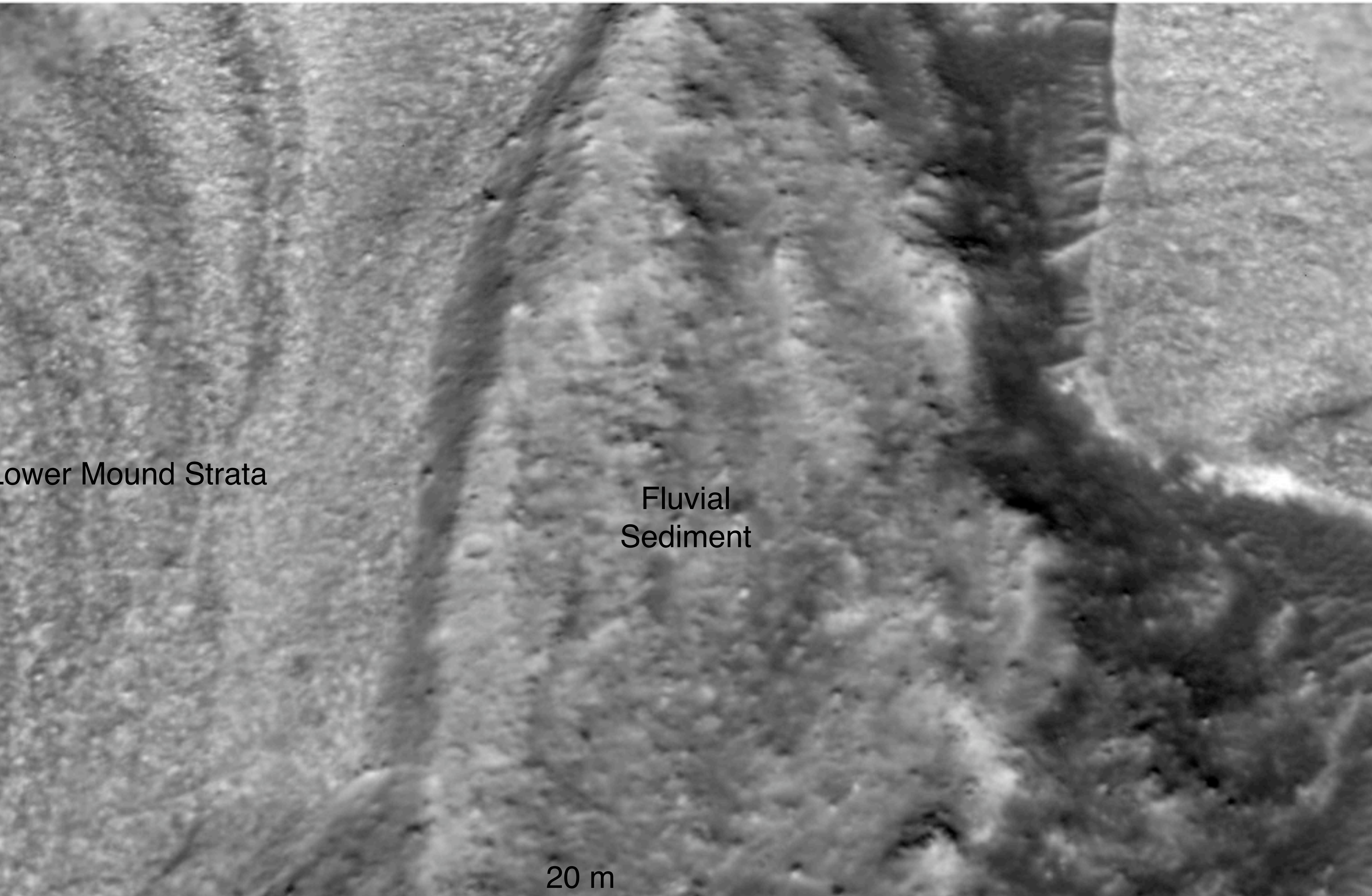


wer Mound - Fluvial Sediment Con

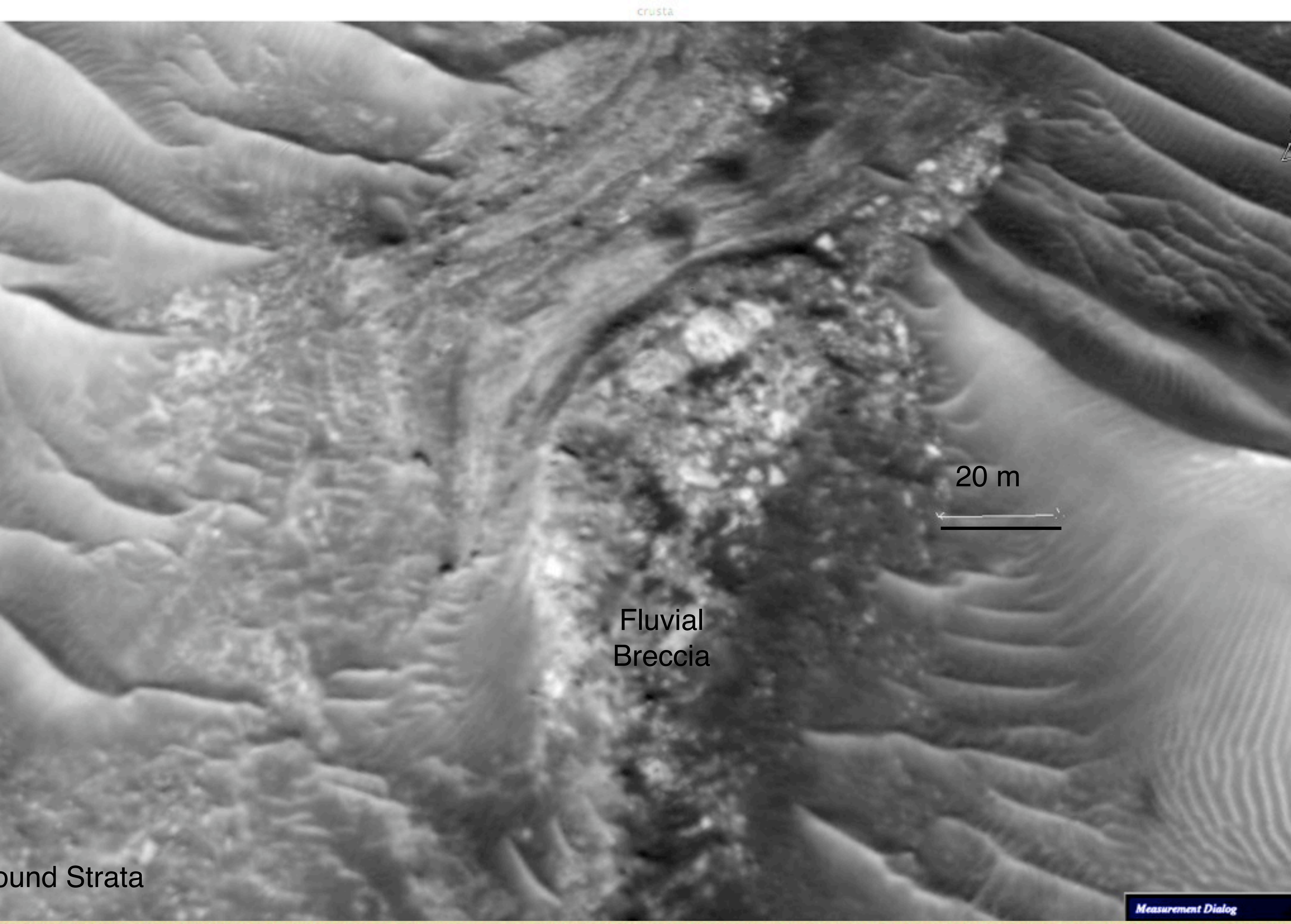


Fluvial Sediment - meter-scale bloc

crusta

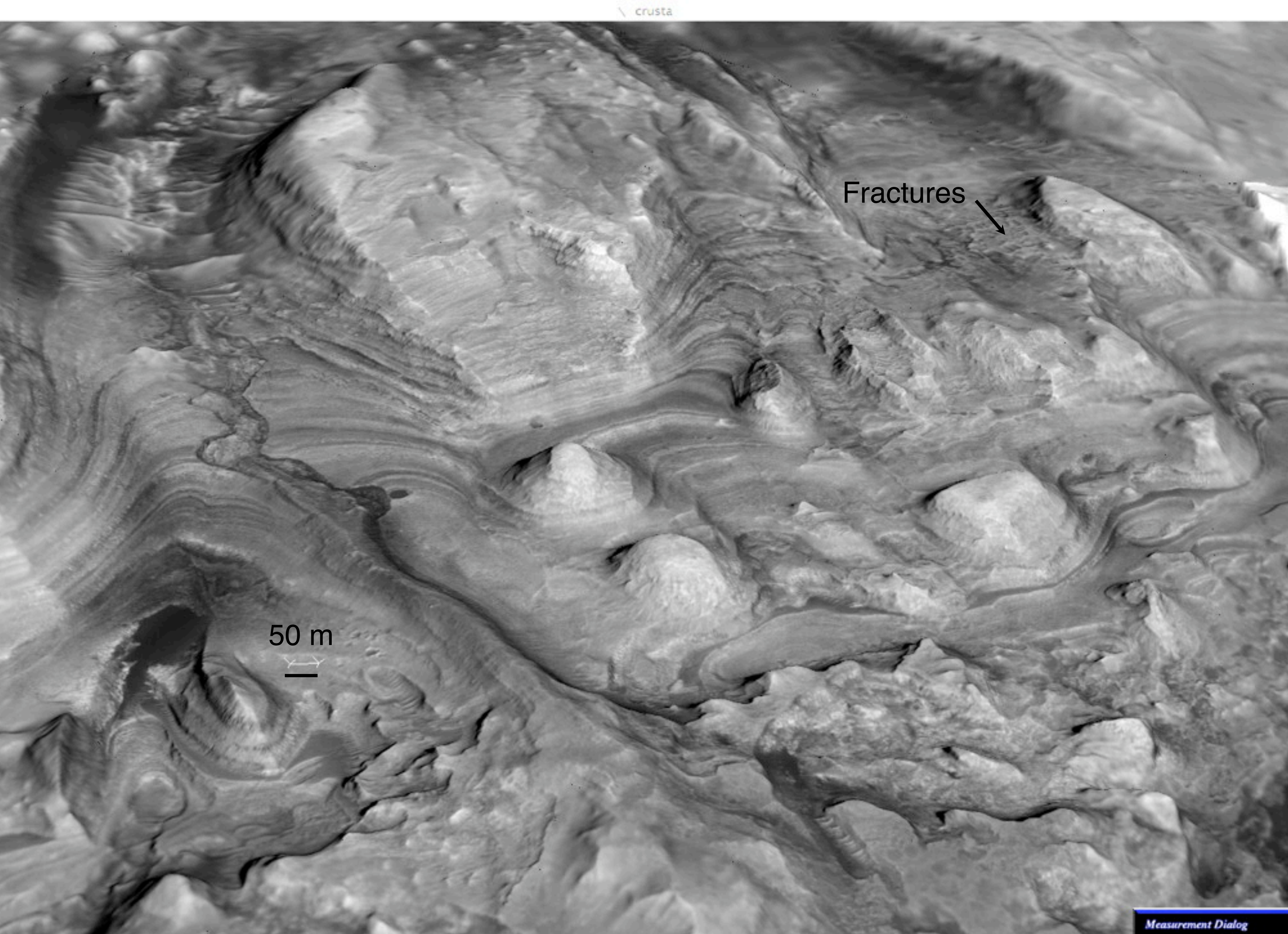


ore Proximal Fluvial Breccia w/ Large Bl



Interactions (timing unknown)

An Incredibly Rich Field Area…



reservation of Potential Biosignatu

Biosignatures could be captured from either sedimentary o
groundwater ecosystems (if present).

Clay minerals are good for preserving organics.

Sulfates preserve organics if they don't recrystallize in the
presence of oxidizing fluids.

Recrystallization is bad for preservation of both morpholo
and chemical biosignatures.

My top priority for evaluating preservation potential at Ga
would be to better constrain the extent of recrystallization,
this may not be possible prior to landing site selection, e.g.
orbit. If you have any good ideas, put them to the test!

Summary 1:

Gale lower mound strata show a diverse history of w
rock interactions based on morphology as well as mineralogy.

The presence of both sulfate and clay minerals allow
evaluation of the depositional and chemical relation
of these two VERY important classes of minerals on

Morphological relationships can be used to develop
testable hypotheses on the origin(s) of sulfate and cl
minerals. For example:

- The distribution of (variably soluble) sulfate minerals shoul
  with different water-rock interactions scenarios.
- The distribution of clay minerals vertically and near channel
  provides the opportunity to evaluate synsedimentary versus
  diagenetic origins.

Summary 2:

An exceptional depositional history is recorded in G
mound strata.

- Strata are laterally continuous, suggesting relatively consiste depositional environments laterally.
- Morphological similar layers repeat vertically, suggesting systematic changes in depositional environment.
- Marker beds provide ties to strata well beyond the field area
- Five kilometers of section provide the thickest record of environments known.
- Stratal thickness plus the presence of unconformities sugges strata represent a long interval of time.

Conclusion: The Gale lower mound provides an outstanding field site to evaluate suites of habitable environments spanning a substantial period of time.


50 m