Curiosity's Candidate Field Site in Gale Crater, Mars

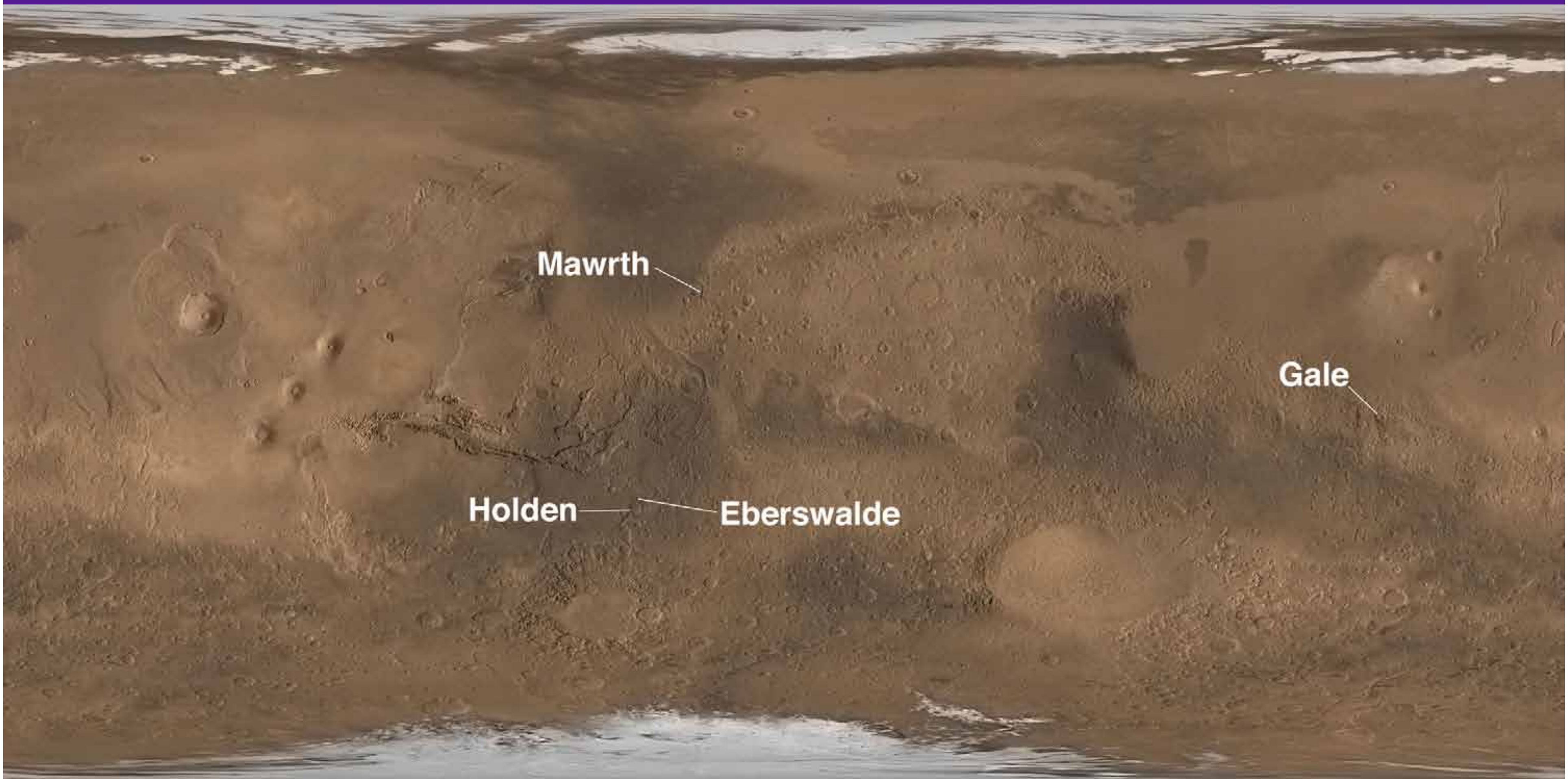
K. S. Edgett – 27 September 2010

Simulated view from Curiosity rover in landing ellipse looking toward the field area in Gale; made using MRO CTX stereopair images; no vertical exaggeration. The mound is ~15 km away in this view. Note that one would see Gale's SW wall in the distant background if this were actually taken by the Mastcams on Mars.

Gale Presents Perhaps the Thickest and Most Diverse Exposed Stratigraphic Section on Mars

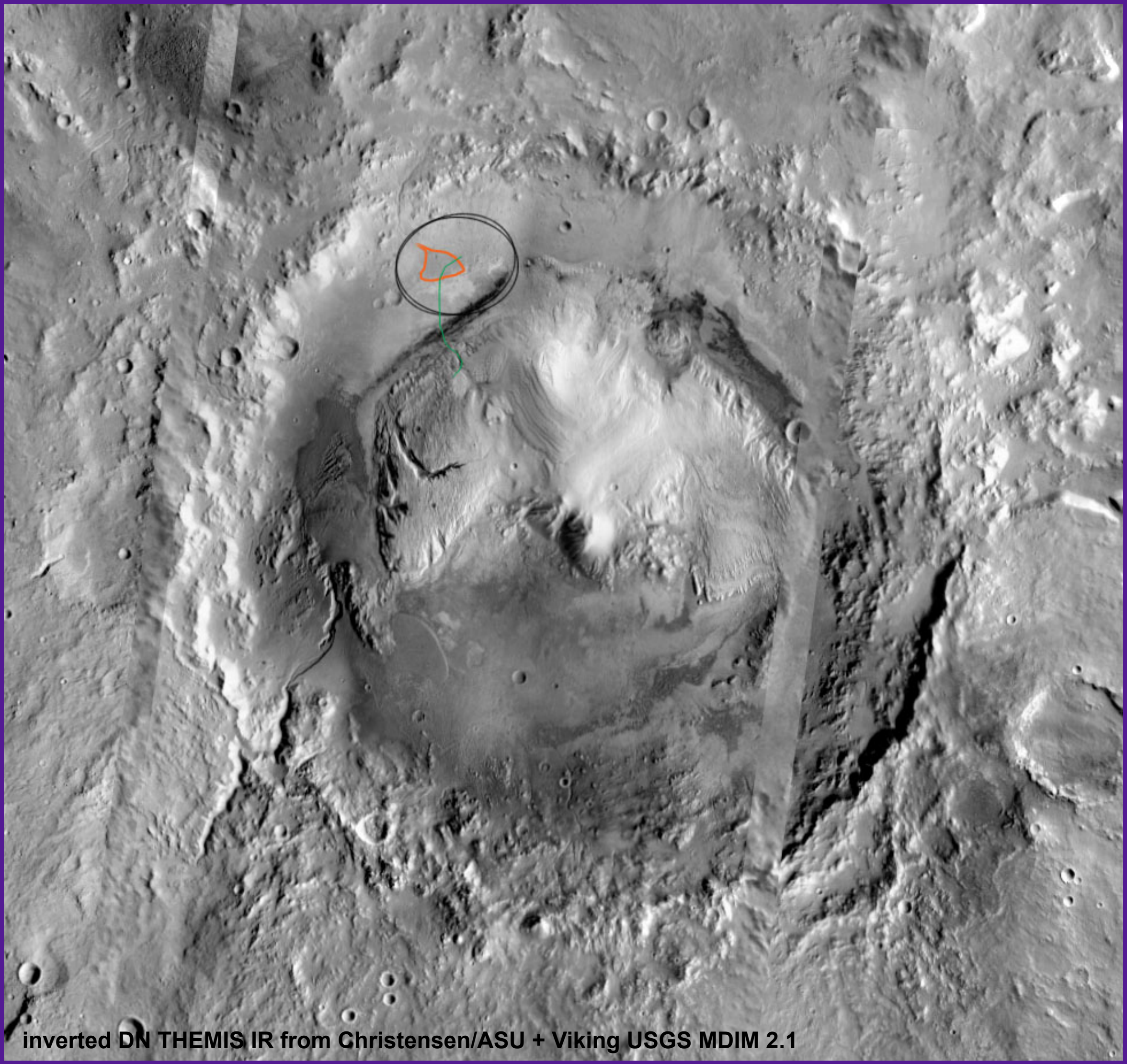
- Gale’s Mound appears to present the thickest and most diverse exposed stratigraphic section on Mars that we can hope access in this decade.
- Mound has ~5 km of stratified rock. (That’s 3 miles!)
- There is no evidence that volcanism ever occurred in Gale.
- Mound materials were deposited as sediment.
- Diverse materials are present.
- Diverse events are recorded.
  - Episodes of sedimentation and lithification and diagenesis.
  - Episodes of erosion, transport, and re-deposition of mound materials.

Gale is at ~5°S on the "north-south dichotomy boundary" in the Aeolis and Nepenthes Mensae Region



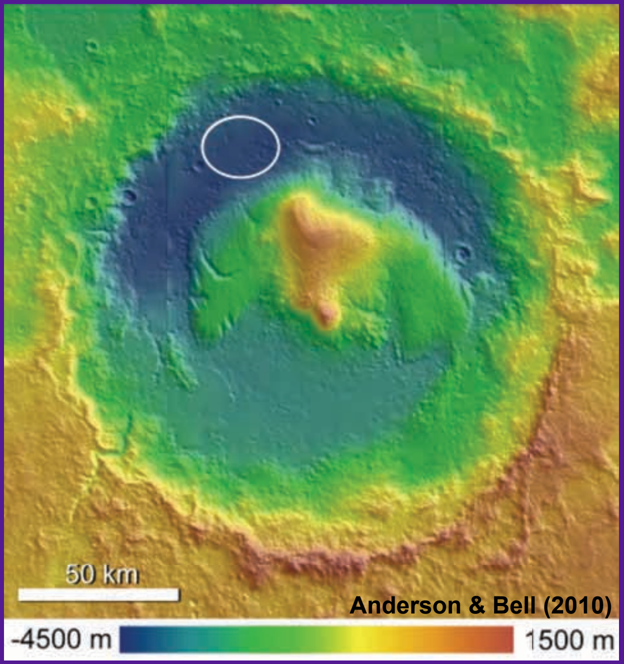
base map made by MSSS for National Geographic (February 2001); from MOC wide angle images and MOLA topography

Proposed MSL Field Site In Gale Crater

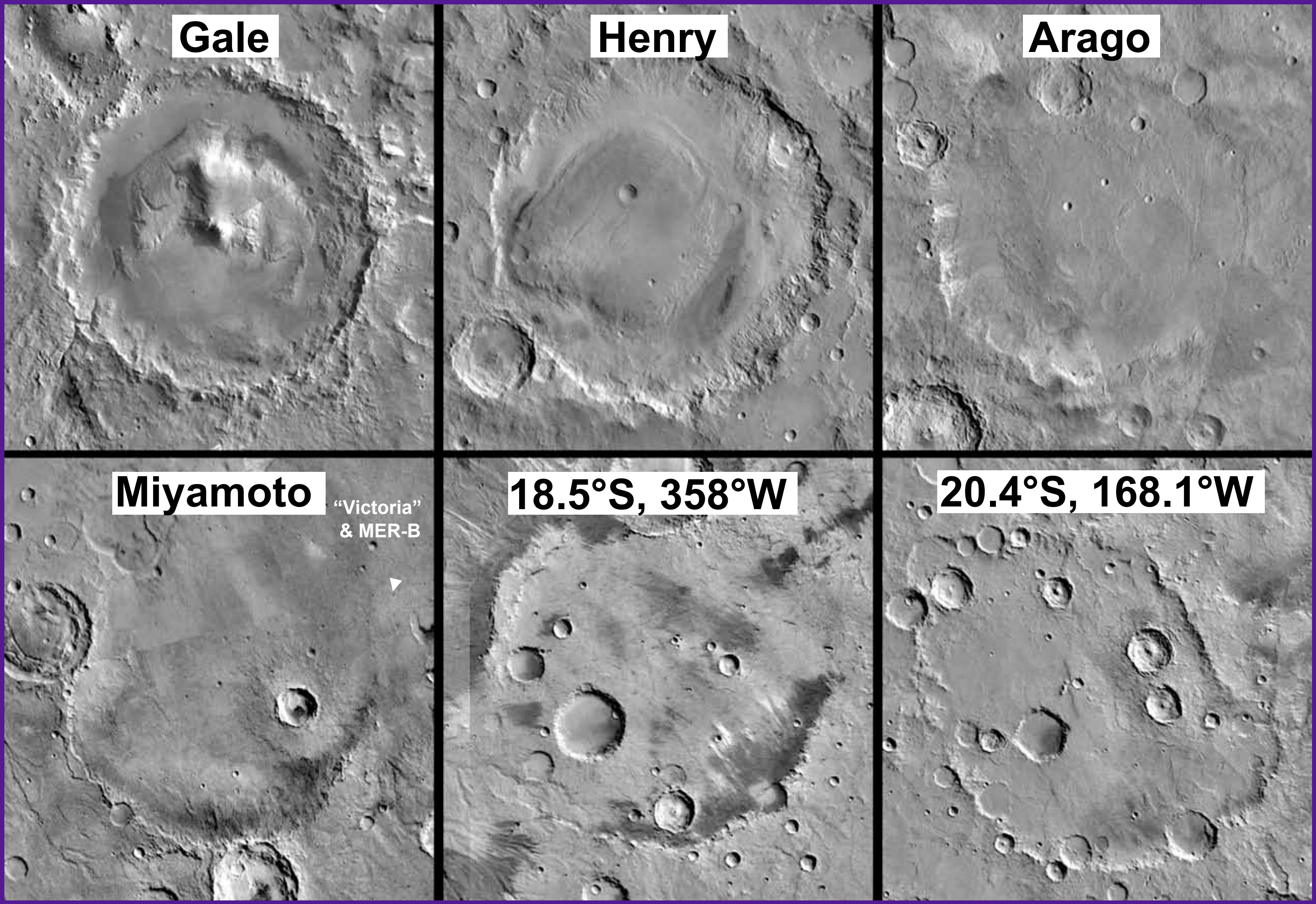


Landing ellipse

- very low elevation (–4.5 km)
- shown here as 25 x 20 km
- alluvium from crater walls
- drive to mound

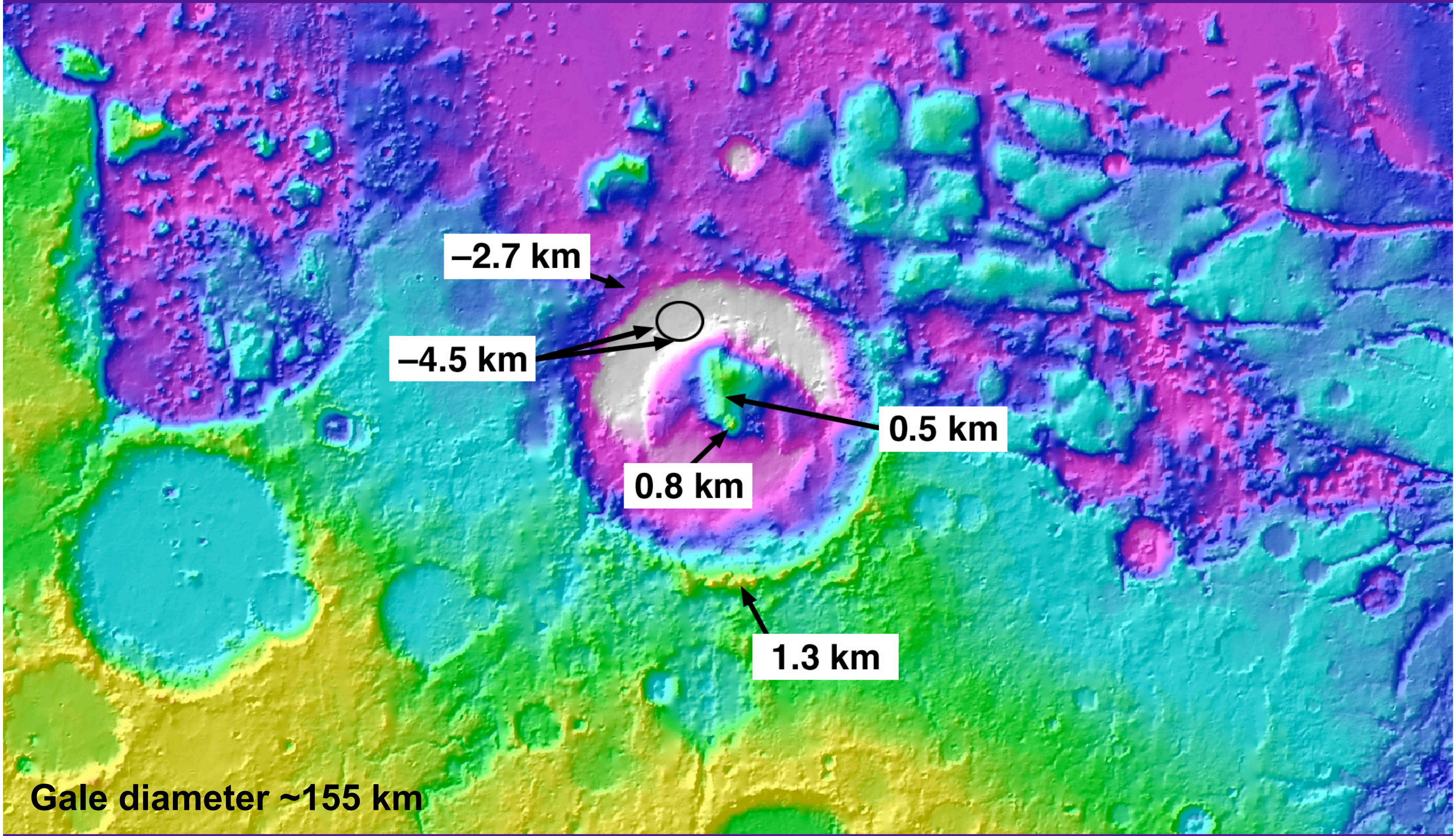


Mars Craters of Gale Size with Substantial Fill Material; Henry's fill forms a Mound; Miyamoto is Partly Exhumed



- all craters ~155 km in diameter
- USGS Viking MDIM 2.1 maps

Gale's Key Topographic Attributes
Mound is 5 km High



MOLA topography

CRISM Mineral Story (Milliken et al. 2010)

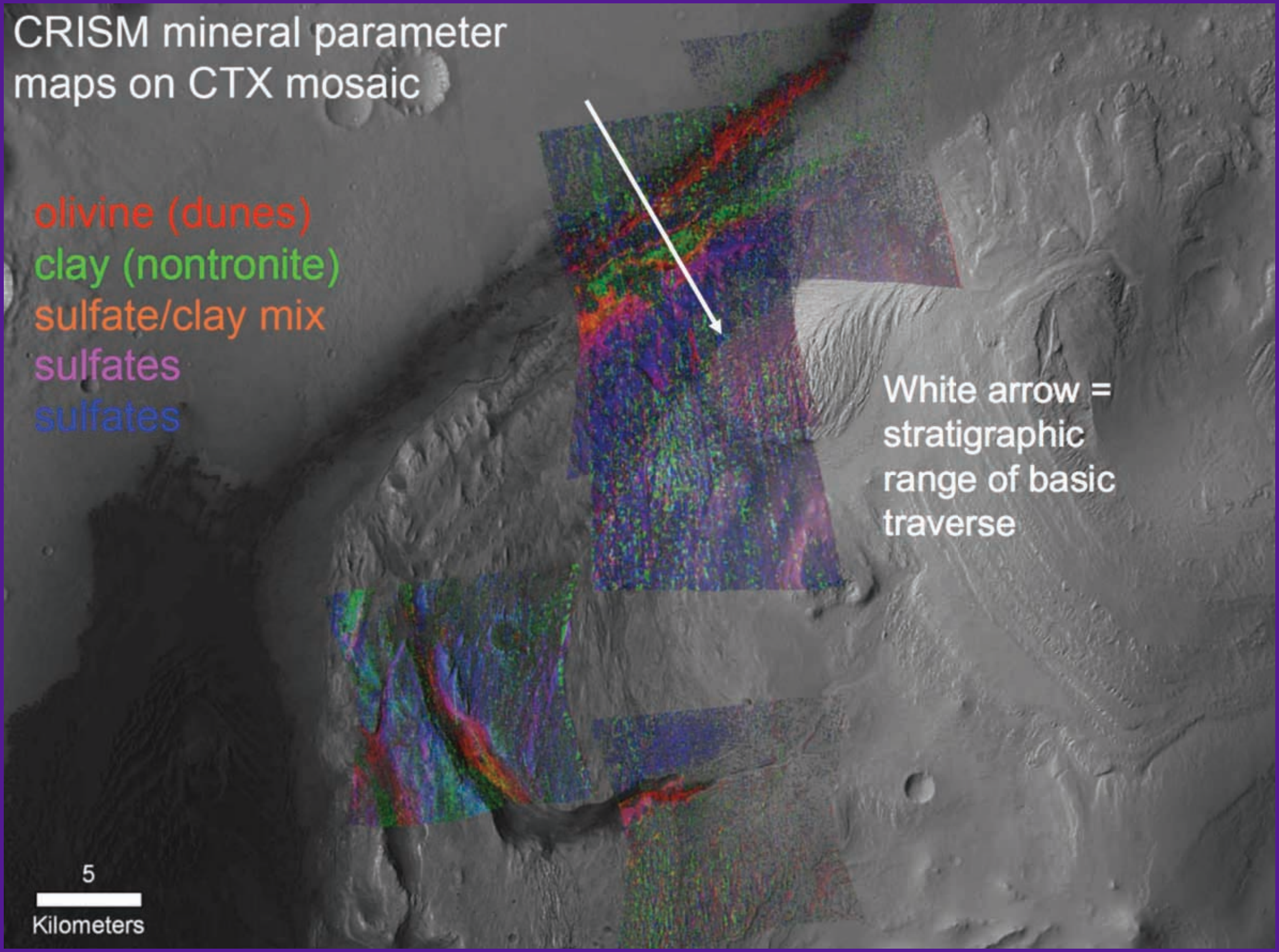


figure from Ralph Milliken

Marker "Beds" In Lower Mound Indicate Continuity of Strata Over Large Area (Milliken et al. 2010)

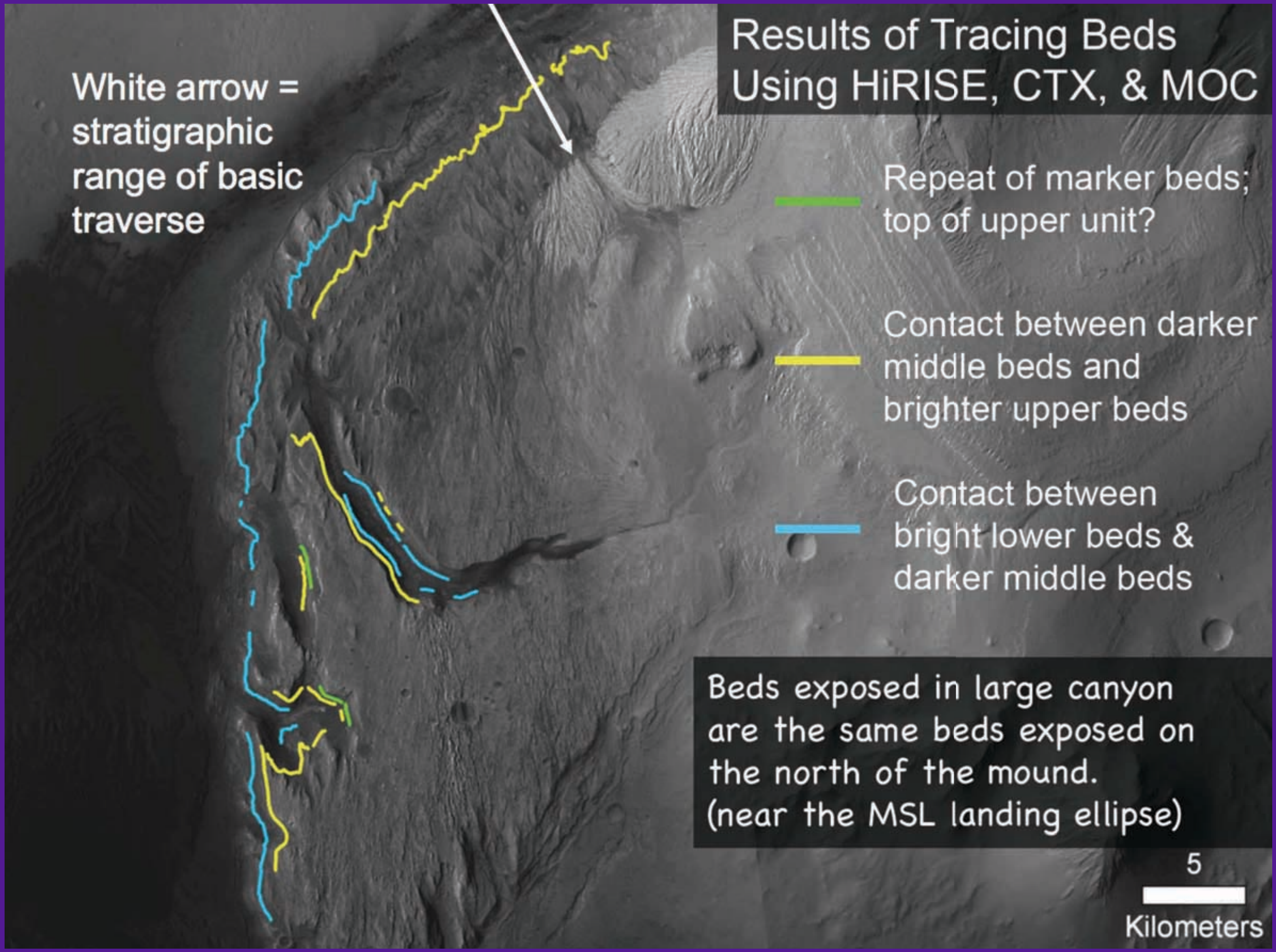
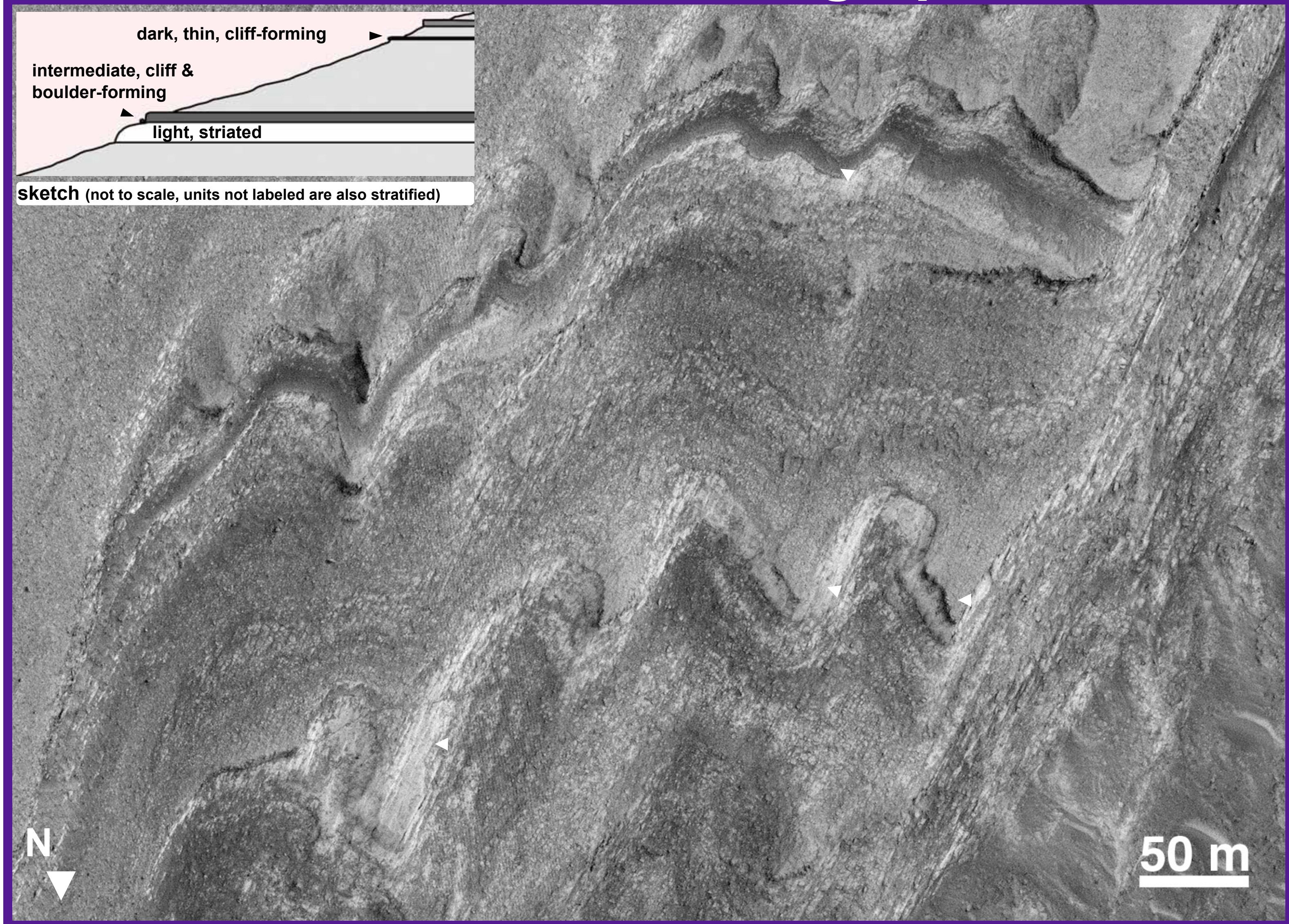


figure from Ralph Milliken

Example of the Diversity of Rock Materials in the Gale Mound Stratigraphic Record



Different strata exhibit differing thickness, erosional expression, and tone.

<u>For example:</u>

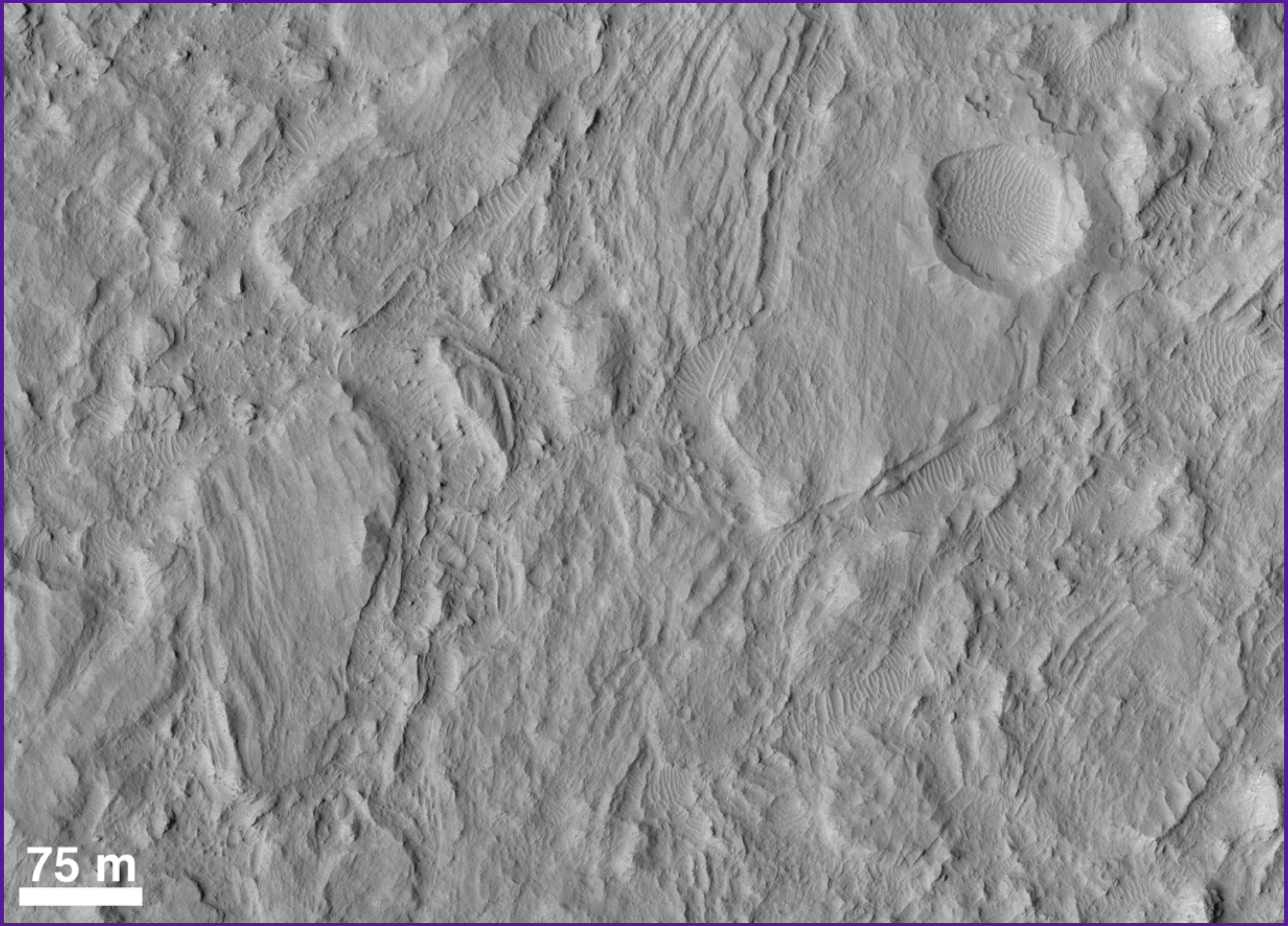
dark, thin, shelf & cliff-forming

intermediate, thicker, shelf & cliff- & boulder-forming

light slope-forming, striated

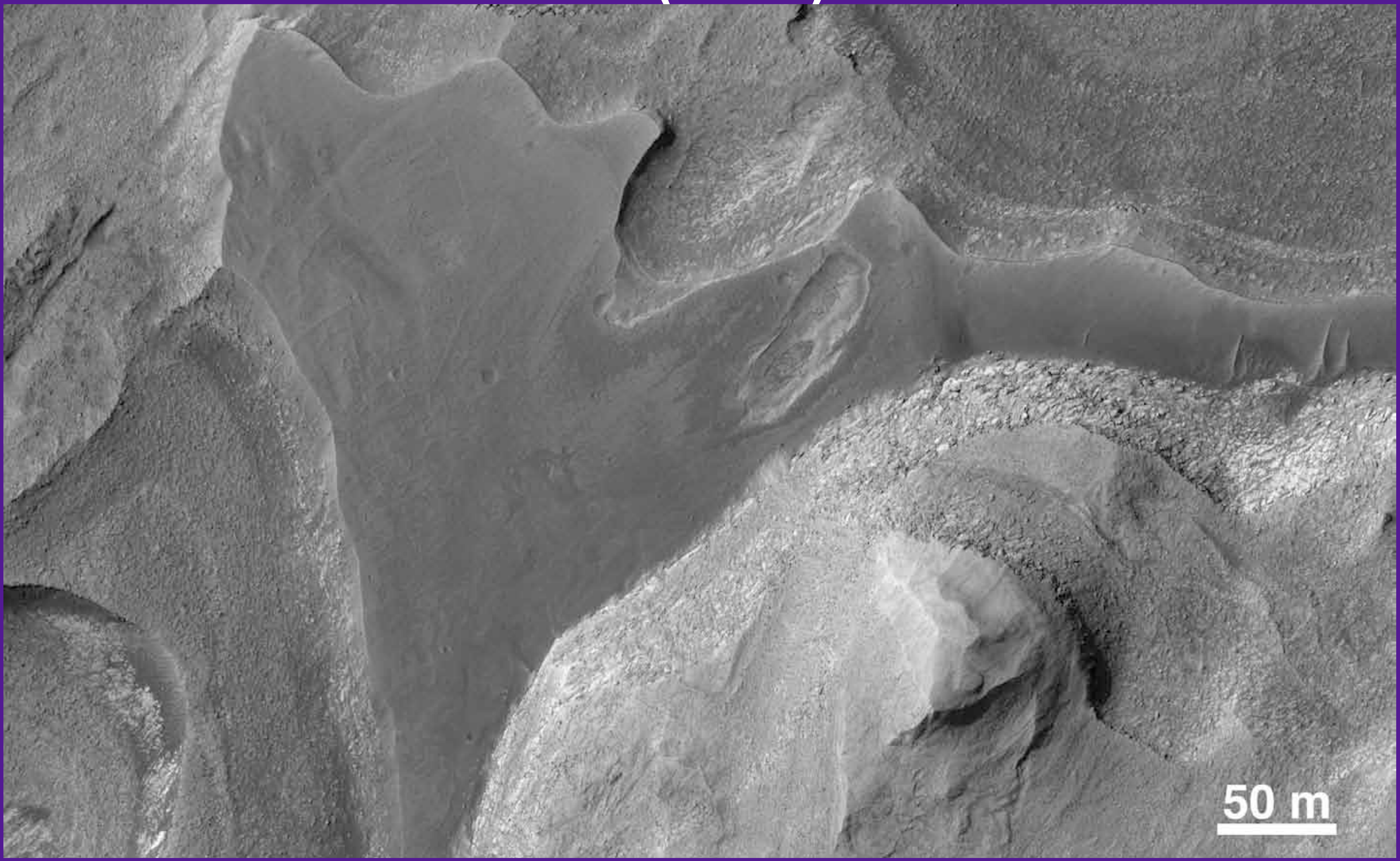
sub-frame of HiRISE ESP_012841_1750
(terrain slopes toward bottom of the page)

Diversity of Mound Materials Indicated via Erosional Expression of Upward-facing Strata in Large Blocks in Landslide Deposit



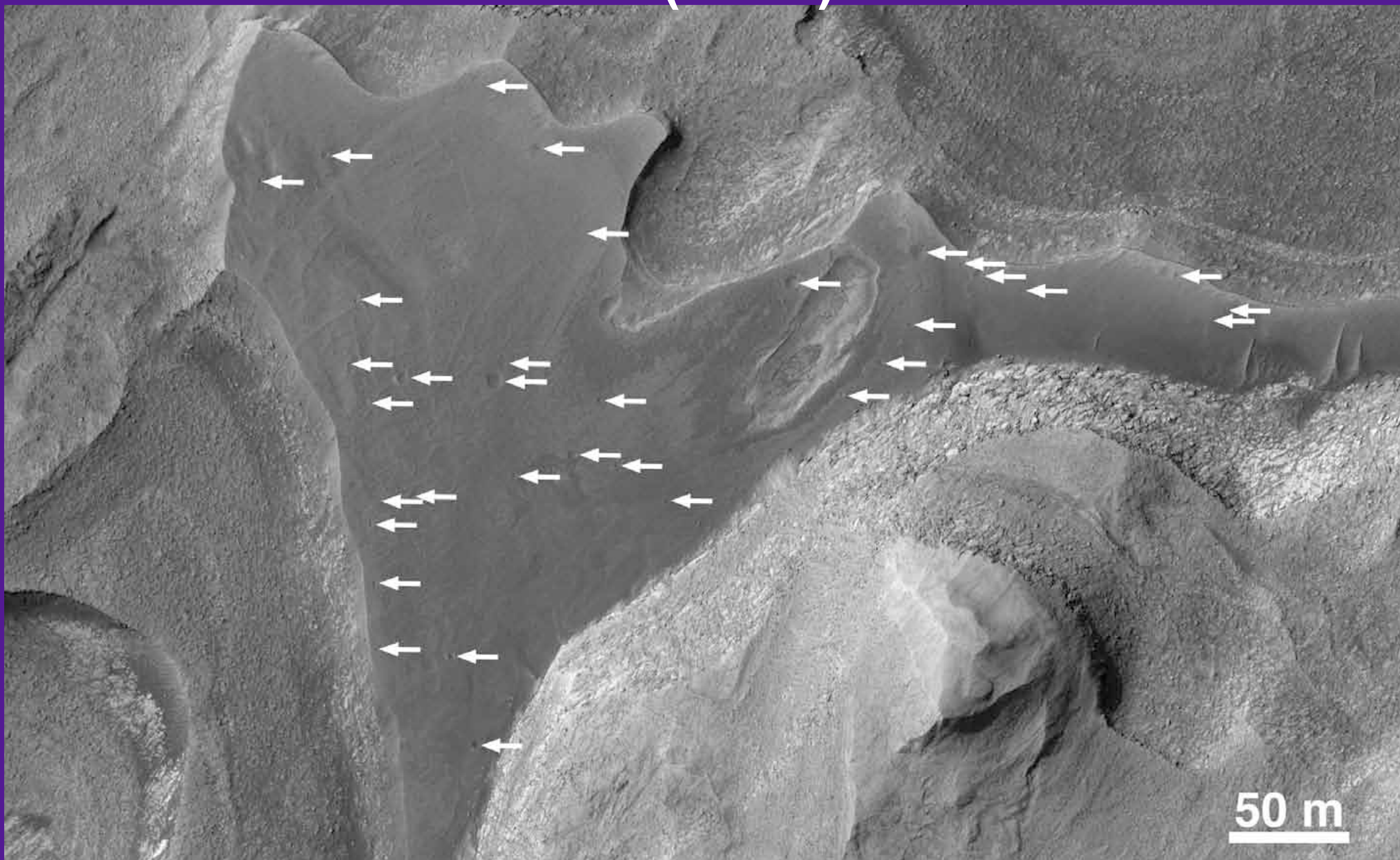
- sub-frame of HiRISE ESP_011562_1755
- materials are covered by a mantling of dust

Lower Mound Stratigraphic Diversity – the Milliken et al. (2010) "Marker Bed"



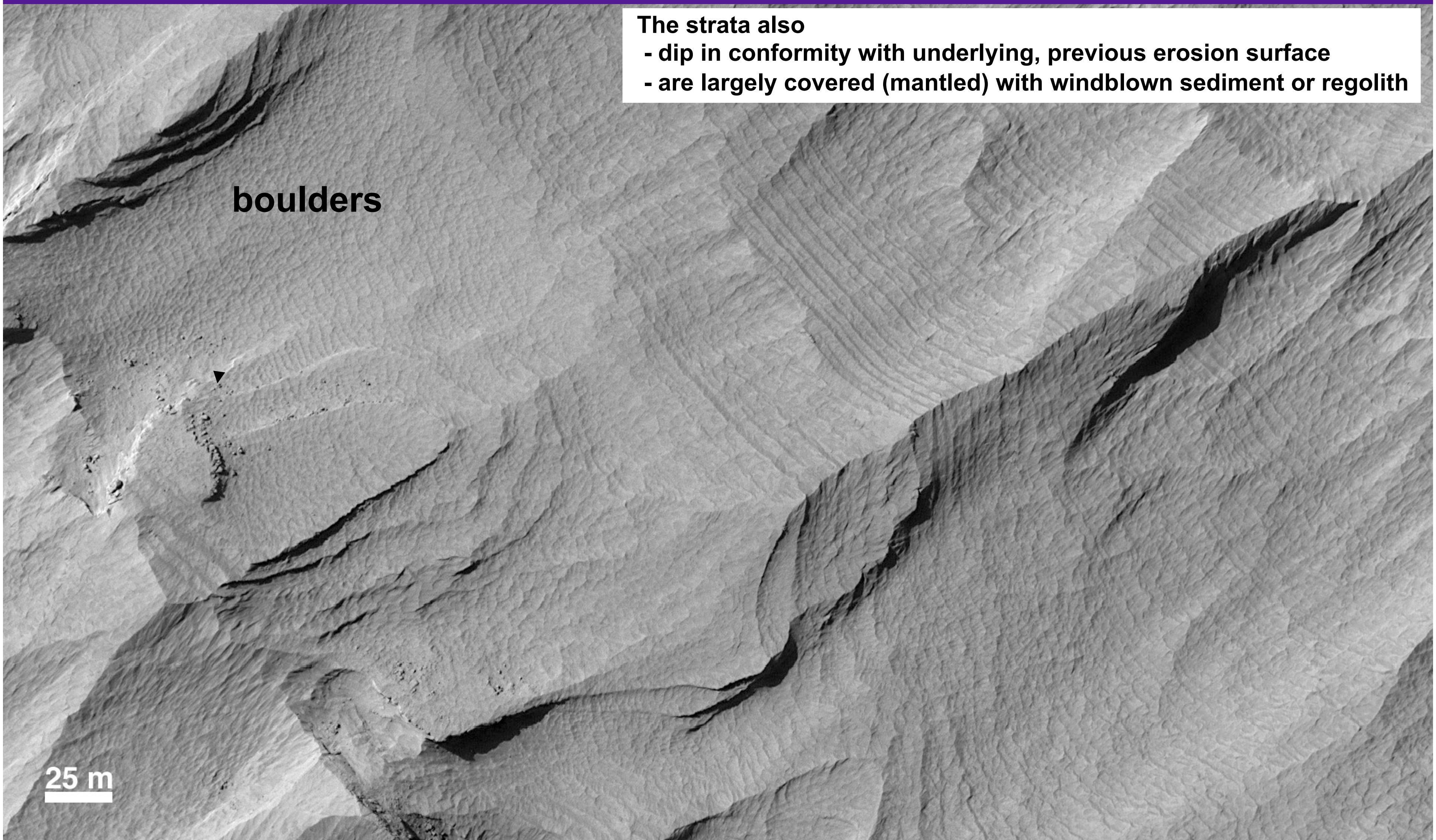
sub-frame of HiRISE PSP_009650_1755

Lower Mound Stratigraphic Diversity – the Milliken et al. (2010) "Marker Bed"



- sub-frame of HiRISE PSP_009650_1755
- arrows indicate small impact craters; the "marker bed" retains small craters longer than do the subjacent light-toned strata.

Mound Uppermost Strata have Cliff-Bench Erosional Expression and Produce Boulders -- the Material is Rock



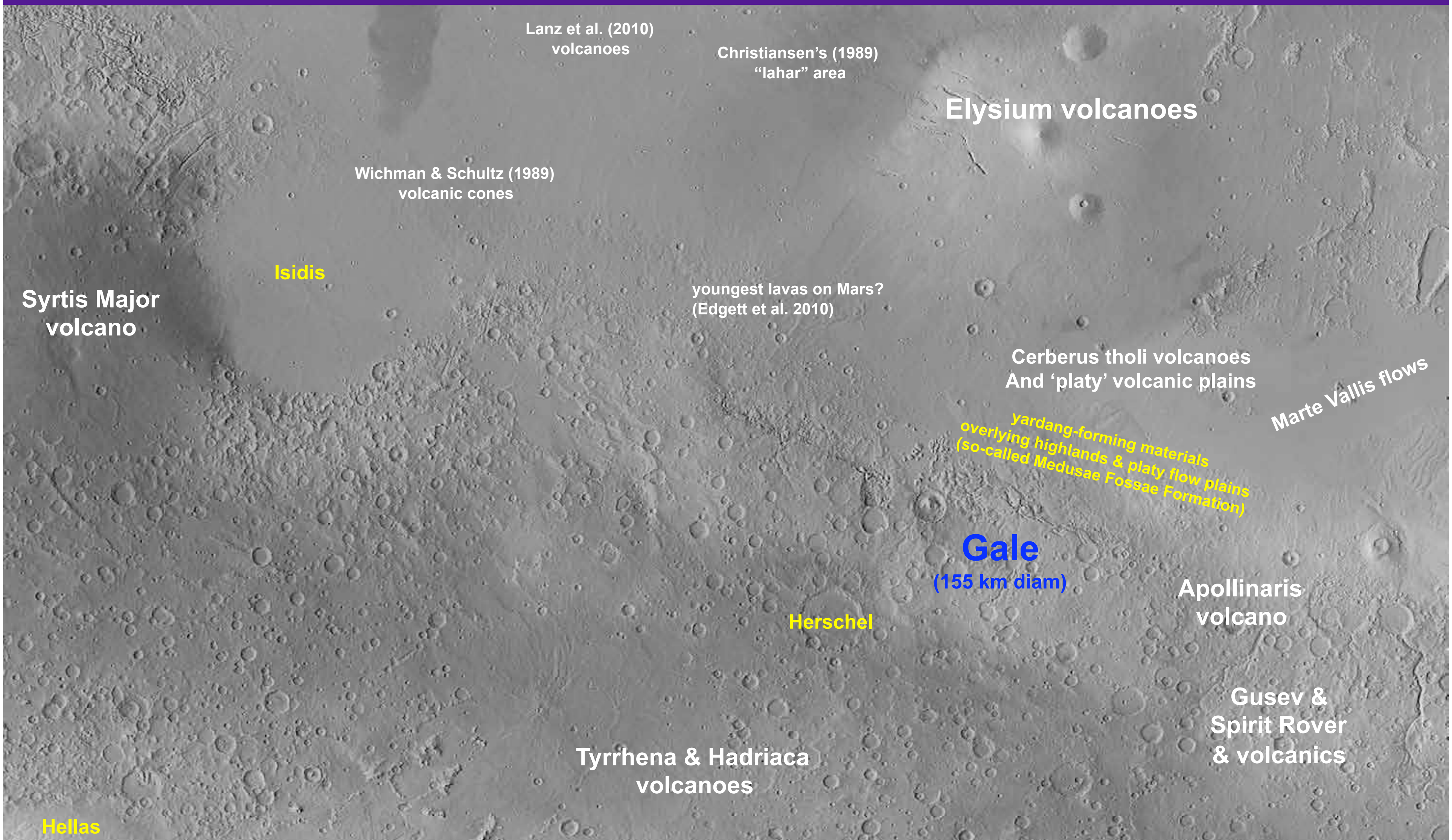
- sub-frame of HiRISE PSP_008002_1750
- terrain slopes downard toward upper right

Stratigraphy is a Record of Change

- Unknown is how much time is represented.
  - This is true for strata at all 4 candidate MSL field sites.
    - Stratum or stratal package thickness is not a linear proxy for time.
    - Without dating methods, a stratigraphic record does not necessarily tell us much about the duration of the events recorded.
      - Although, of course, some event durations can be estimated very well (e.g, an impact crater and ejecta emplacement occur very rapidly).

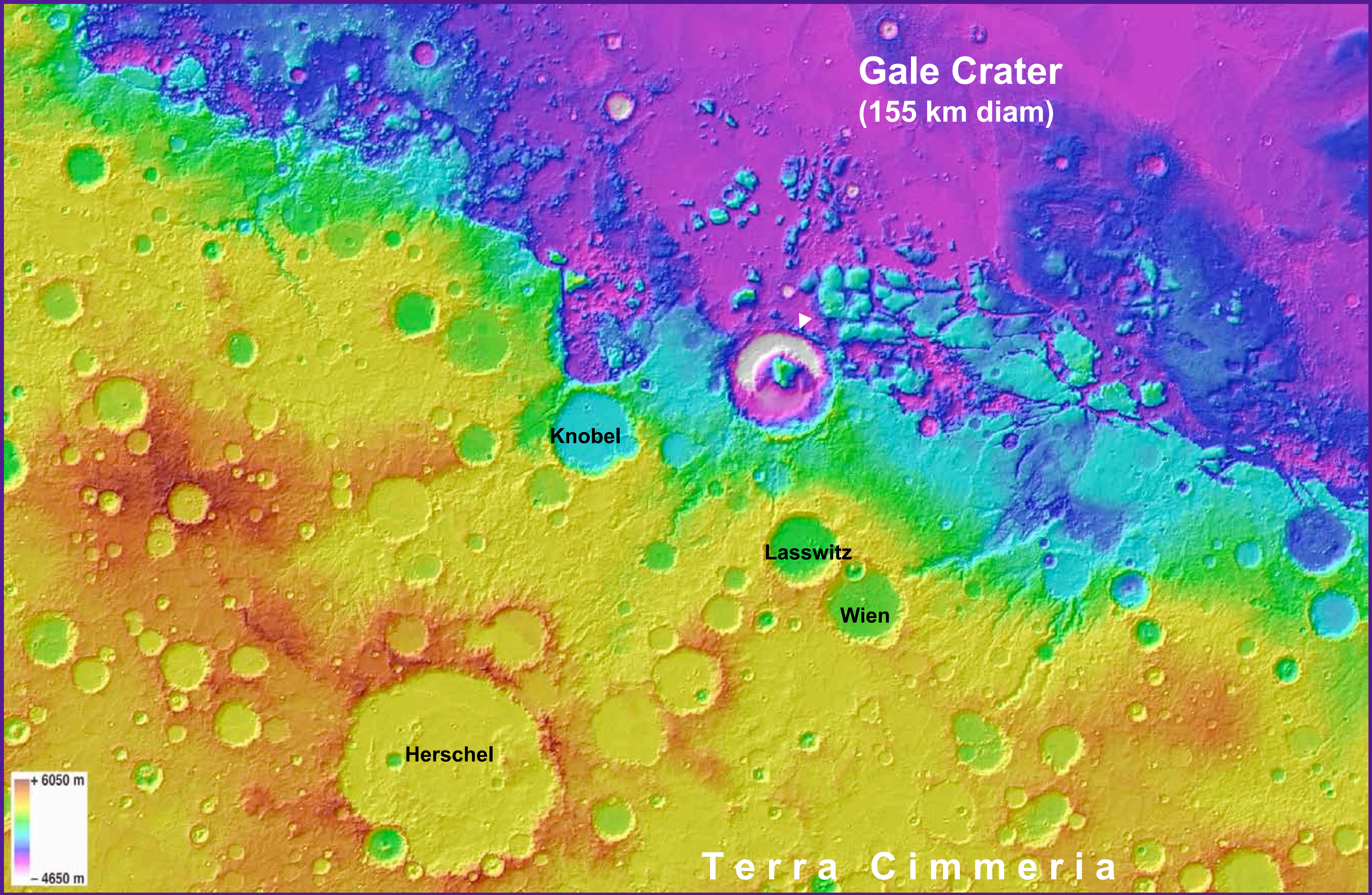
- BUT, strata tell us that changes occurred and the time-sequential order in which they occurred.
- AND (unless key strata have been removed by erosion), they can inform us about the transition that occurred between events.

Some of the Volcanic Landforms in Gale Region



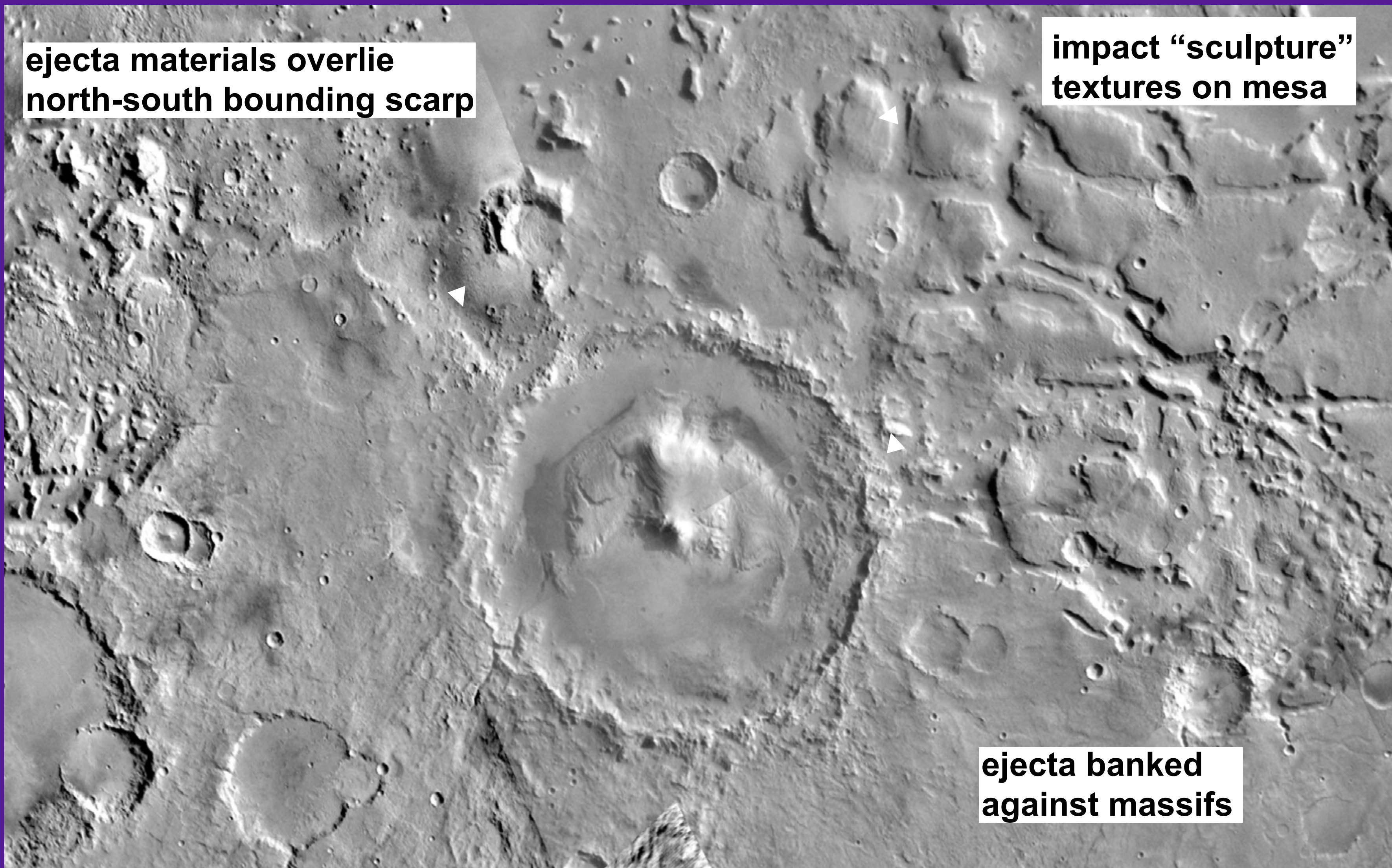
MOC wide angle red mosaic + MOLA topo as shaded relief, by MSSS

Gale is on the North-South Dichotomy Boundary. Gale Formed on a Slope; Northwest Rim Was Always Lower than Southeast Rim.



MOLA topography

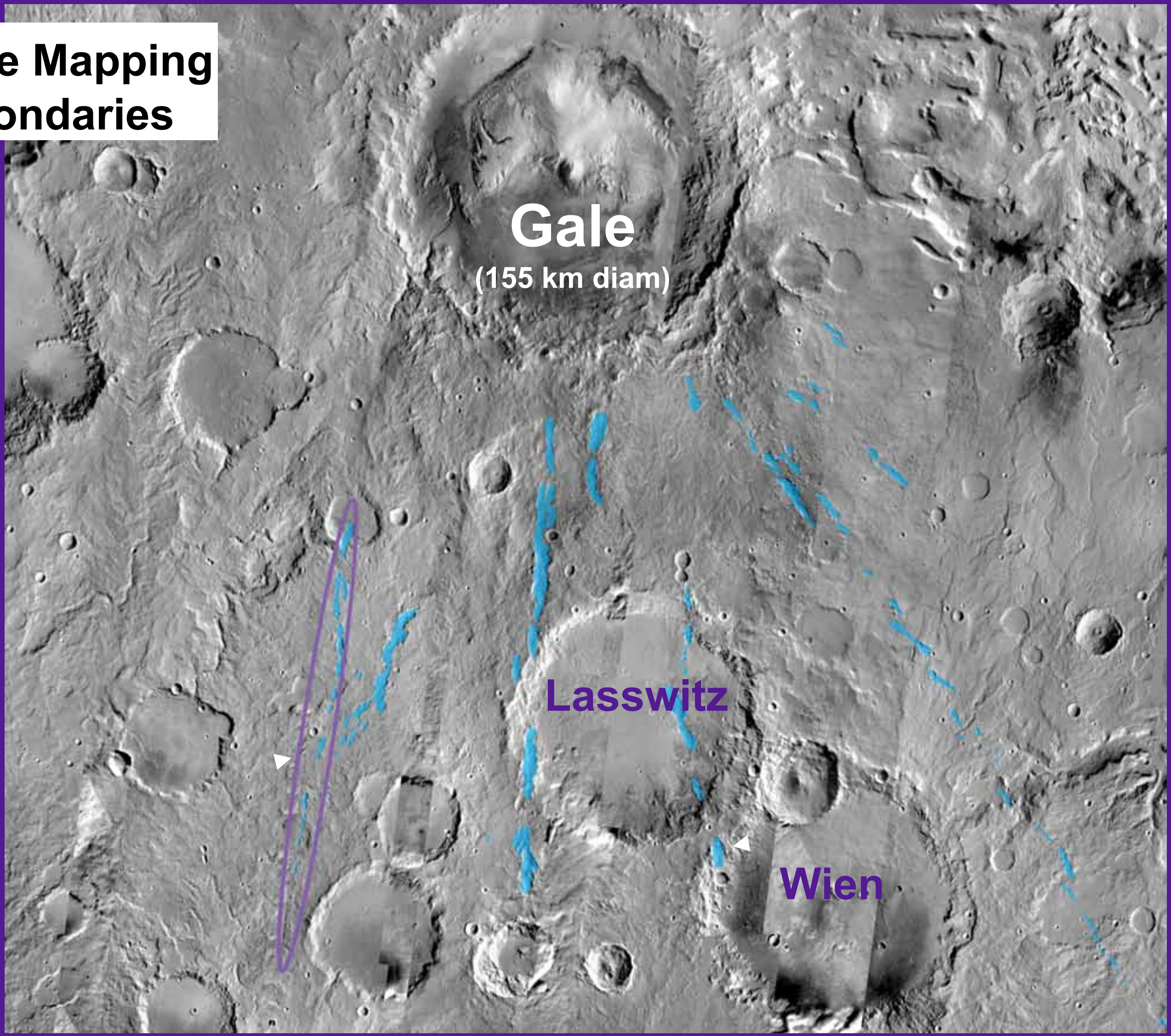
Gale Impact Occurred After Dichotomy Boundary Mesas, Troughs, etc. Formed in this Region



USGS Viking MDIM 2.1

Gale Formed After Lasswitz and Wien; Gale was a Late Arrival on the local Early Mars Scene

Approximate Mapping of Gale Secondaries



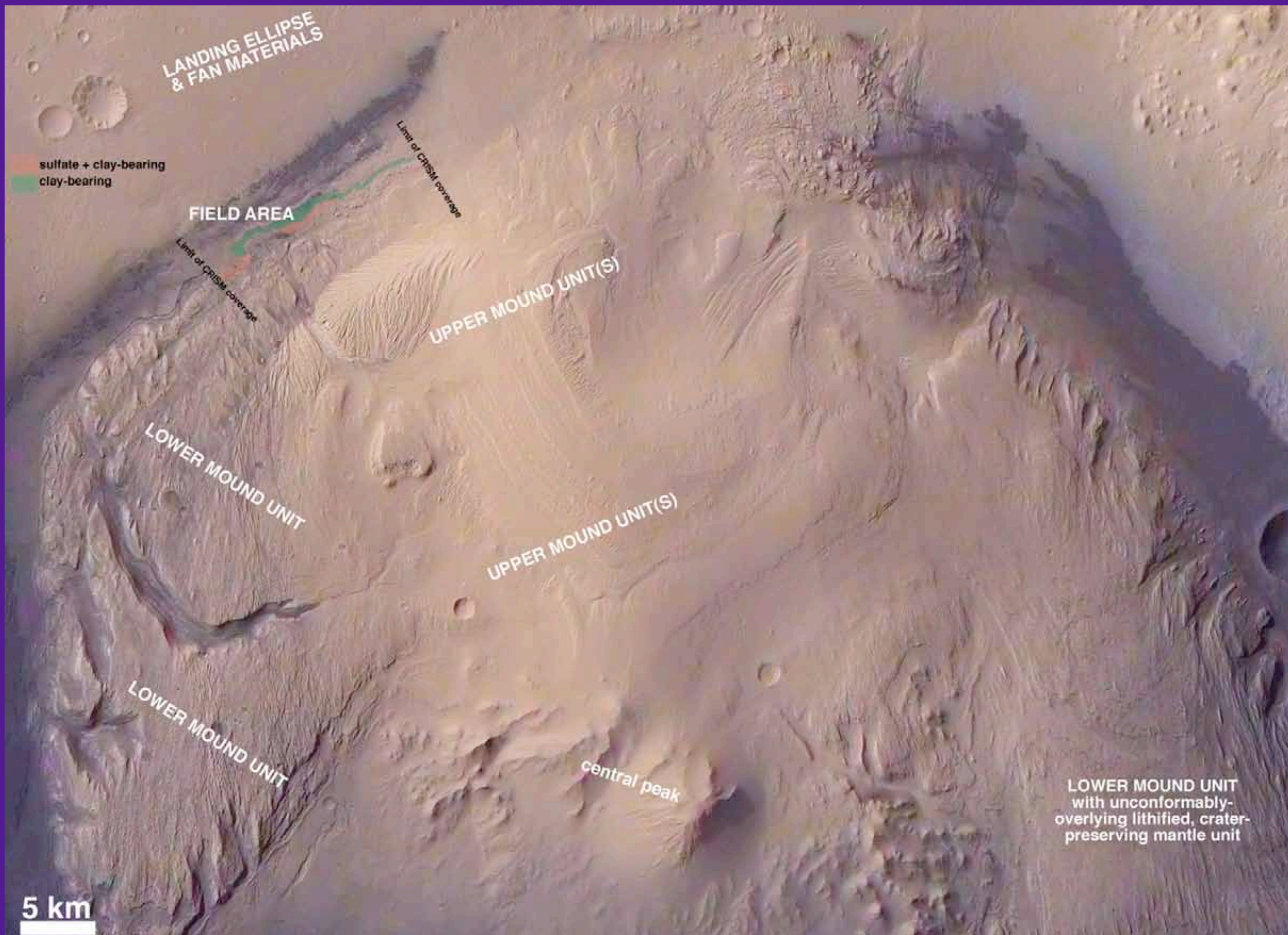
this group is probably not Gale secondaries

One Gale secondary is preserved on Wien rim; enough to establish age relation

THEMIS day IR (inverted DNs) + Viking MDIM 2.1

Some Features/Attributes of Gale's Mound

(with apologies that some text may be too small; I will point out what these say)



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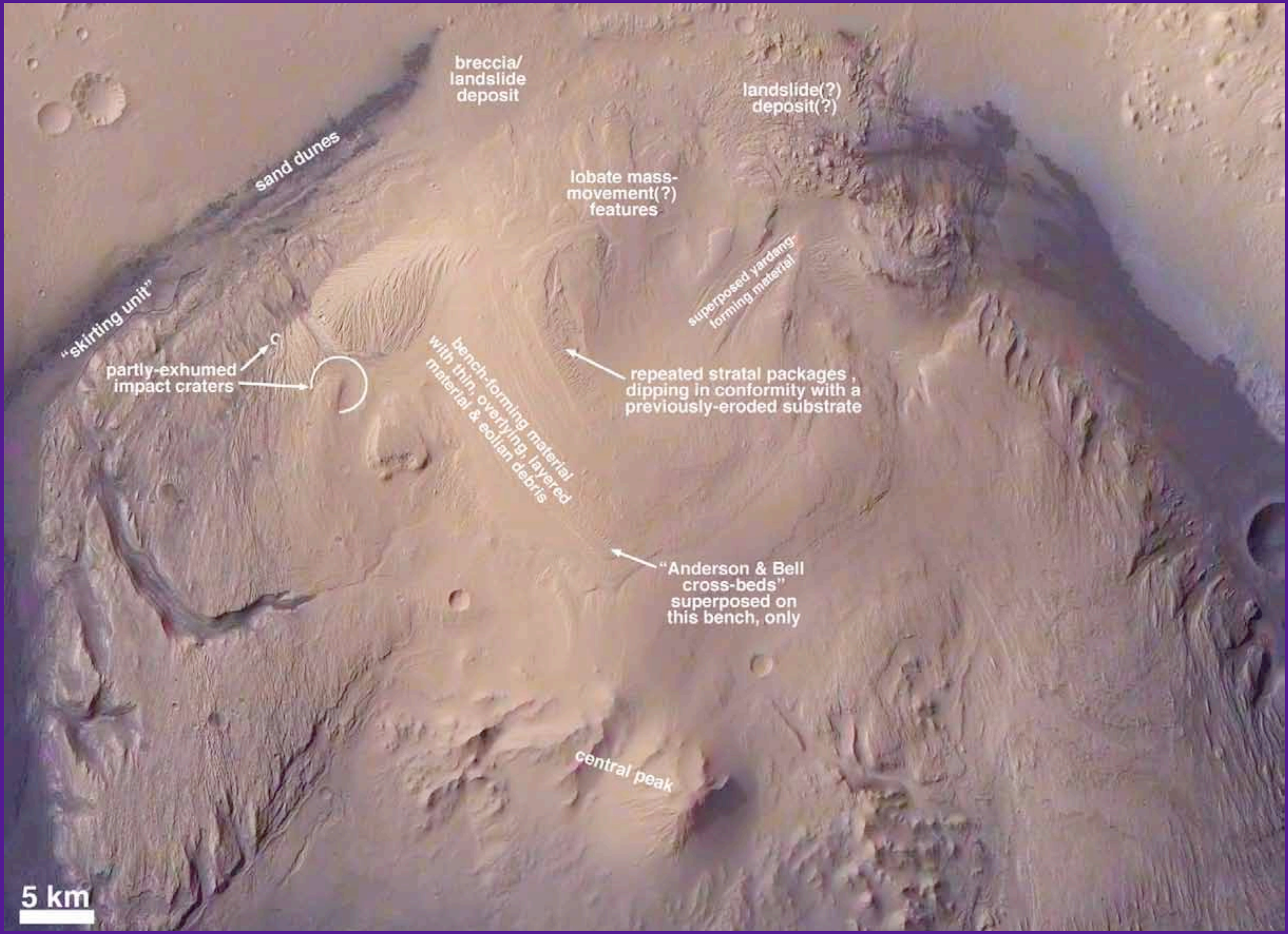
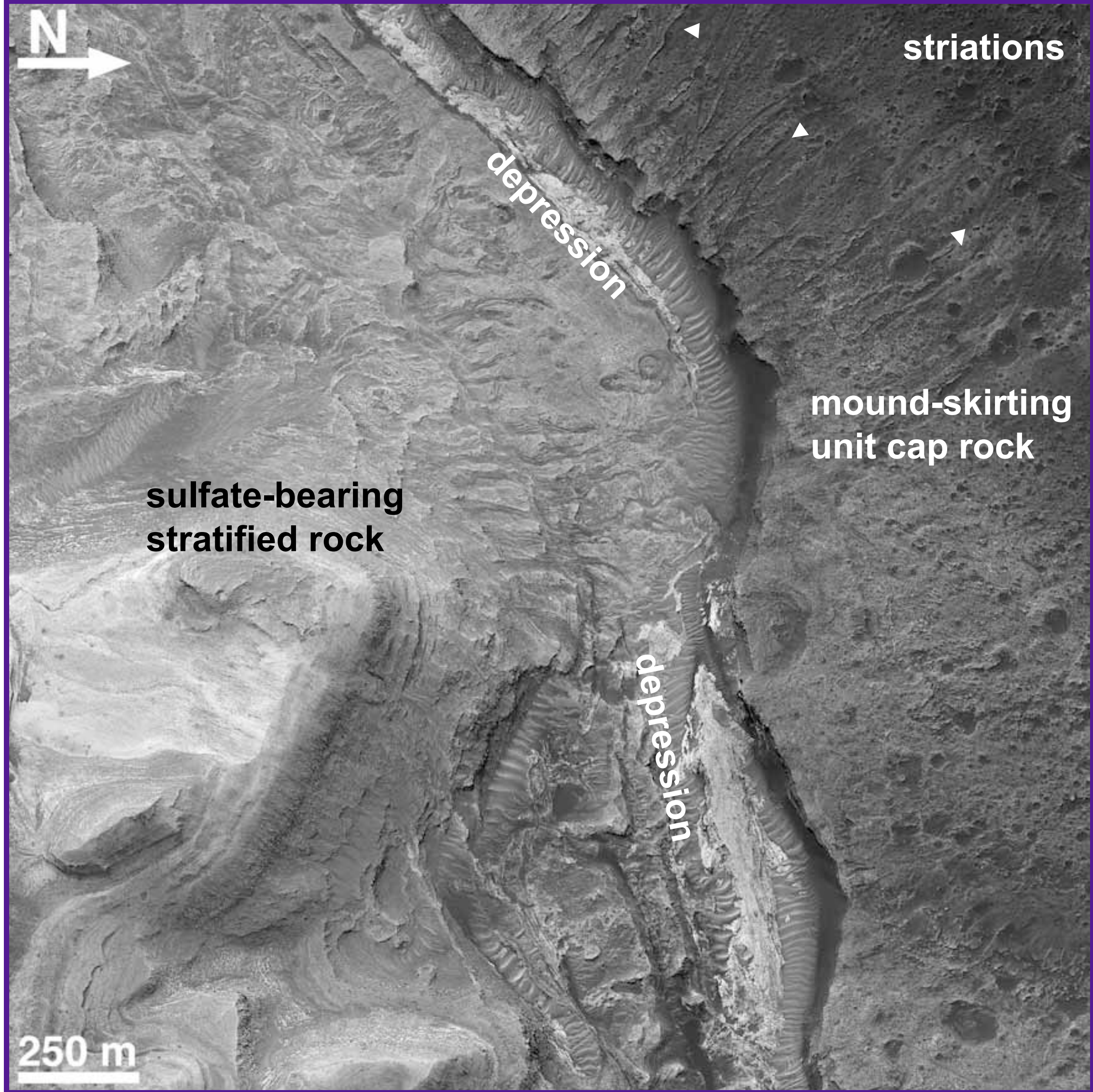
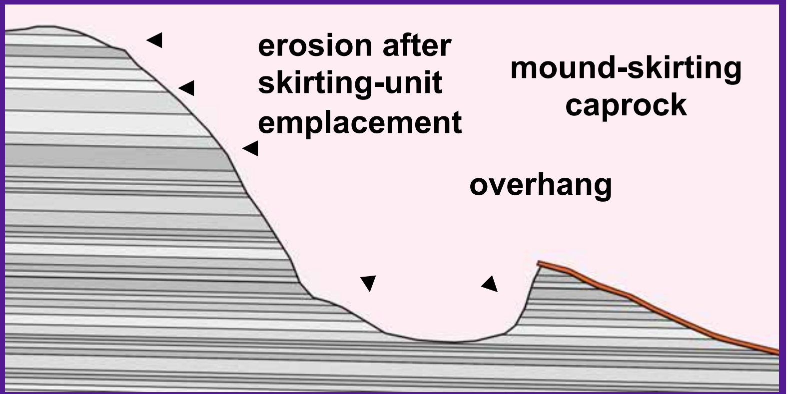


A Record of Global Importance: Transition from “Wet, Early” to “Dry, Present” Mars

- Rocks of the lower mound were eroded by liquid runoff (streams).
- These streams cut canyons and deposited the sediment they carried in their channels and in accumulations adjacent to the mound.
- Rocks higher in the mound stratigraphy were not cut by streams.
- The mound, therefore, likely includes a record of the transition of Mars from an early, “wet” Mars to the more modern, “dry” Mars.
- This transition, alone, is of global importance.

"Mound Skirting Unit" — Conglomerate(?) Composed of Sediment Shed from Mound During an Ancient Period of Erosion of Mound





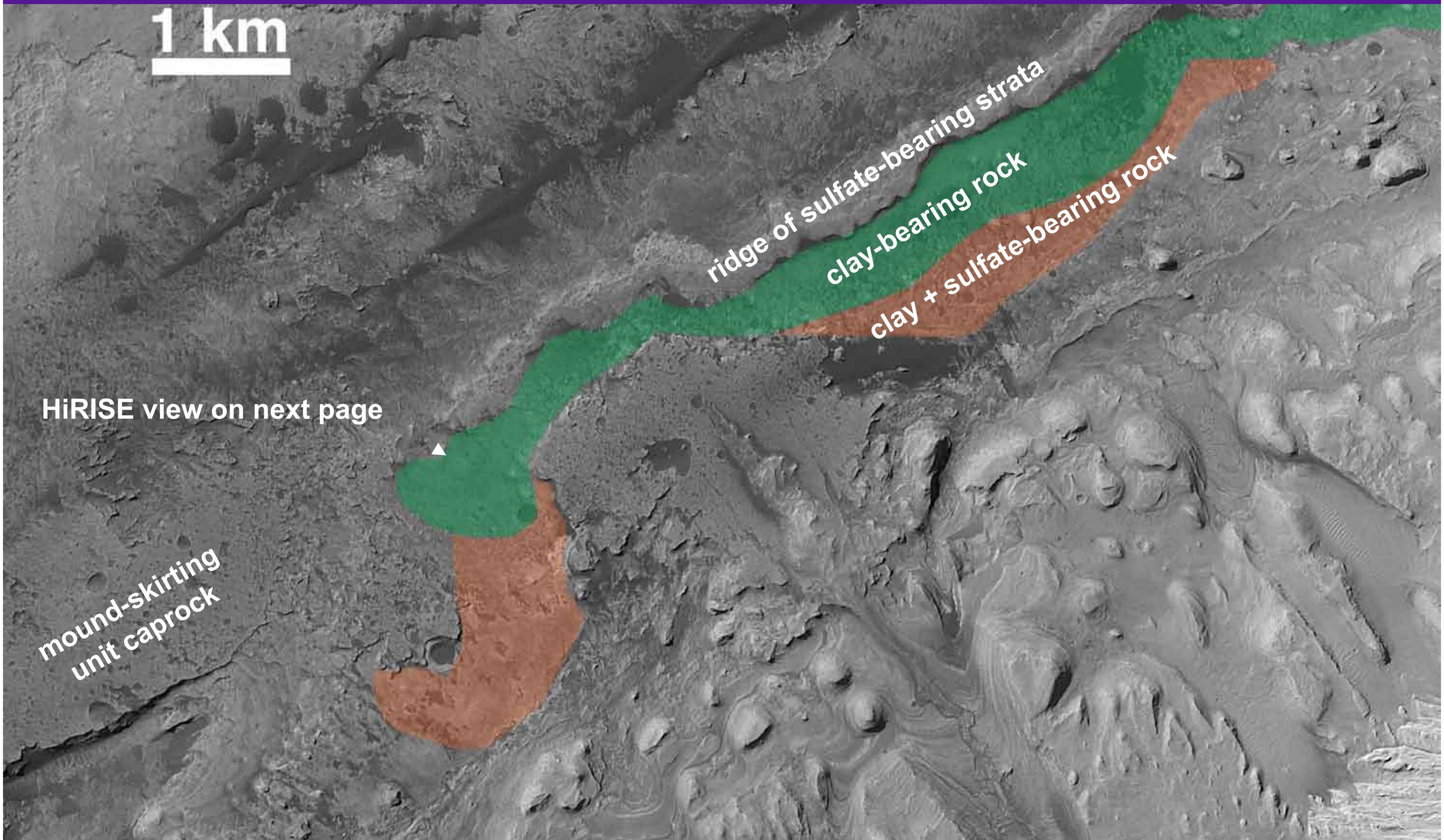
"Mound-skirting unit" forms thin cap-rock that lies unconformably on sulfate- and clay-bearing strata and dips away from the mound.

Striations may be remnants of channels or debris flows that transported material across the "skirting unit."

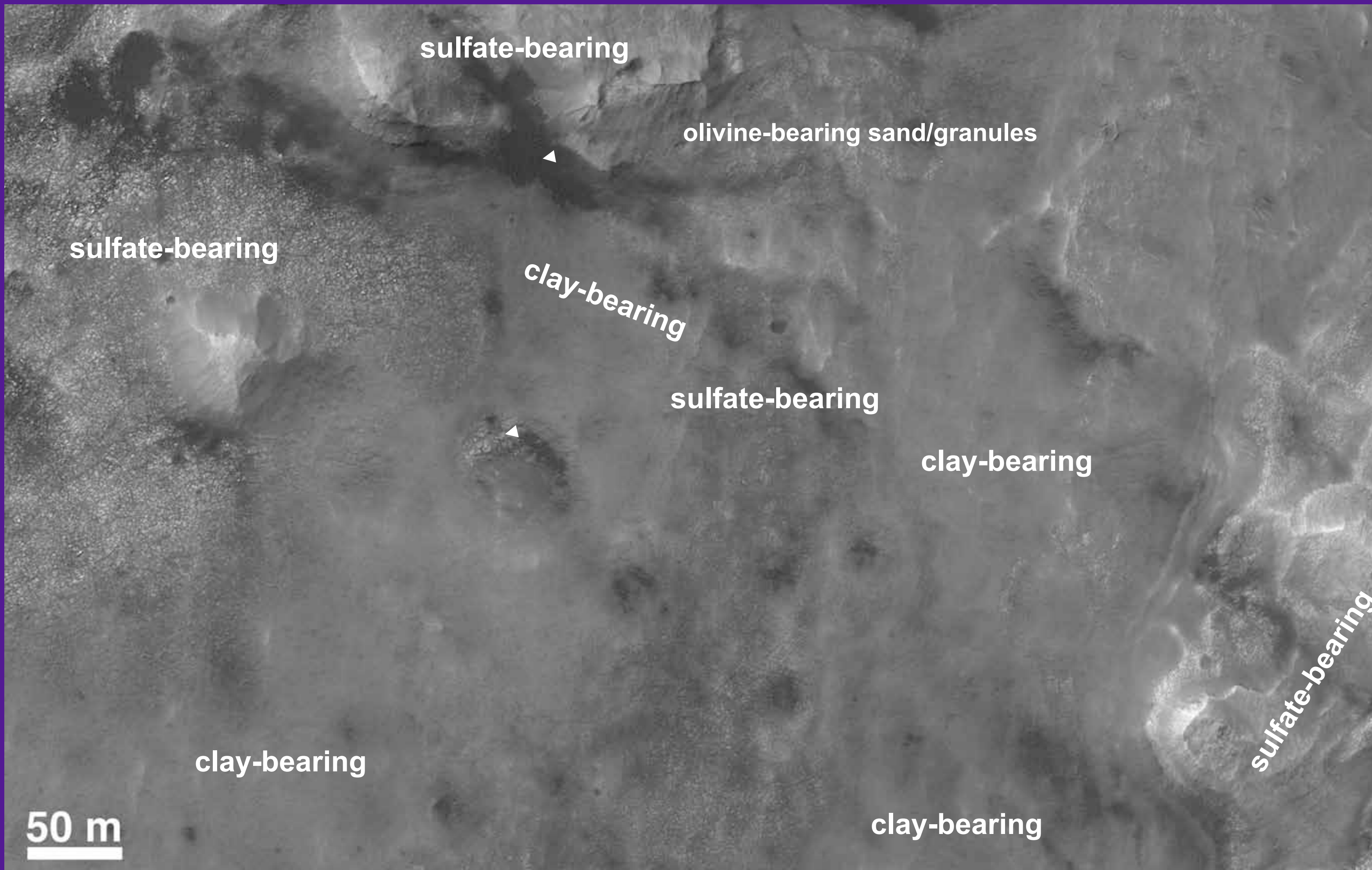
Material is here interpreted to be a conglomerate composed of clasts shed from an earlier phase of mound erosion.

- sub-frame of HiRISE ESP_012841_1750
- "mound-skirting unit" is term from Anderson and Bell (2010)
- strata in the sketch, above, are a "cartoon" representation, not actual strata

Clay-bearing Rock Exposure Detected From Orbit via CRISM is Broad, Planimetric Exposure of Stratum/a

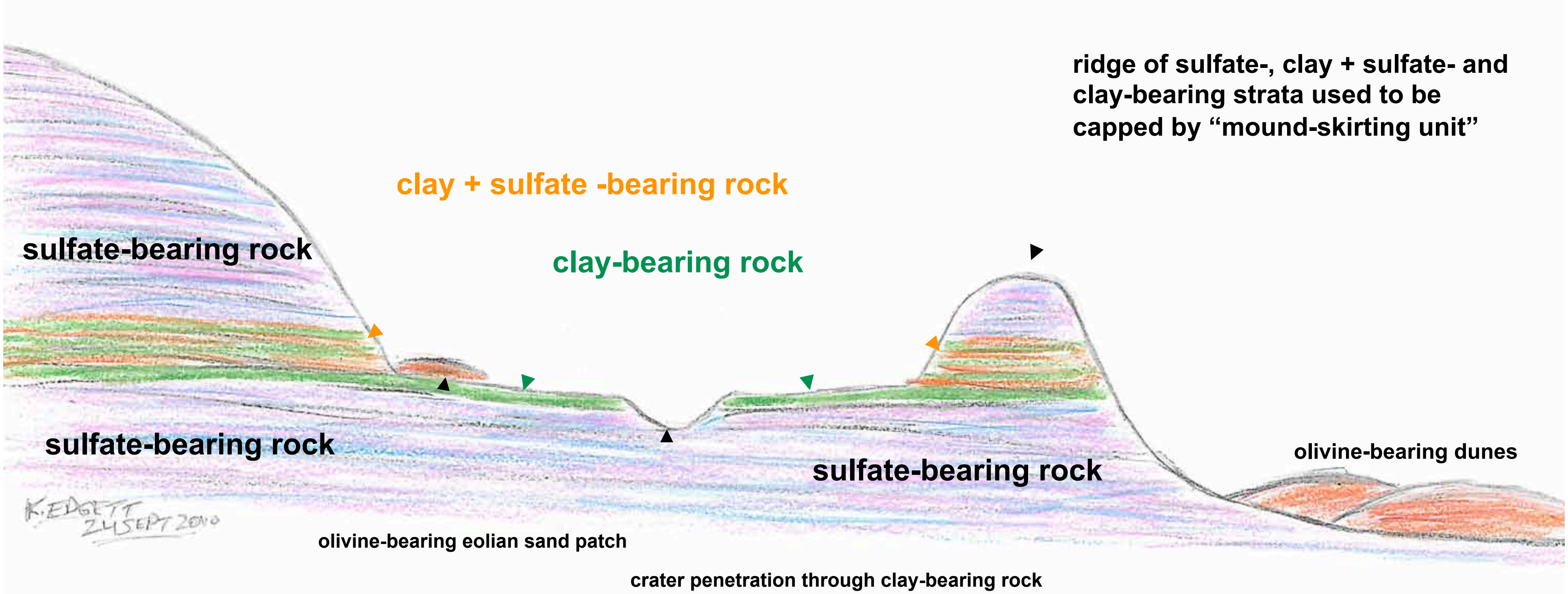


Clay-bearing Strata are Interbedded within Sulfate-Bearing Strata. Here is a Planimetrically-Broad Exposure of the Clay-Bearing material. It Exhibits a Smooth Texture at 25 cm/pixel, whereas the Sulfate-Bearing Rock is Broken and Rubbly as seen in planform.



sub-frame of HiRISE PSP_009716_1755

CRISM Detection of Clay-Bearing Stratum Results from Erosional Exposure of the Material in Broad, Planimetric Configuration



North ▶

cartoon/sketch not to scale

What Materials are in the Record? (1 of 2)

- Sediment from Local Sources
  - Clasts derived from erosion of Gale's rims, walls, and central peak.

(these are guaranteed to be present)

    - coarser (boulders, cobbles, pebbles) near source.
    - finer (sand, silt, clay-sized) away from source.
  - Sediment derived from erosion of earlier rocks that comprise the lower strata of the mound.

- Chemically-Precipitated Sediment

(not certain if present)
(but there are lots of sulfate-bearing rocks)

  - From dissolution of other rocks/minerals, transported in groundwater or streams.

What Materials are in the Record? (2 of 2)

- Sediment from Foreign Sources
  - Material that fell from the sky.

    (these are guaranteed to be present and perhaps dominant)

    - silt- and clay-sized impact-generated dust, eolian dust storm dust, and tephra.
    - rare, larger clasts occasionally emplaced ballistically from an impact event or delivery of impactors themselves from space.
  - Material transported over land.
    - stream sediment brought into the crater.
    - windblown sand/granules transported via saltation and traction.

Gale Mound Stratigraphy

- Records local, regional, and global…
  - changes in environment
  - changes in sediment sources and input processes
- On Earth, these would tie in with
  - climate change
  - tectonic change
- On Mars
  - this is mostly about climate change
  - and, depending on how much time is represented in the mound's geologic record,
    - it might show decreased tephra output with time
    - it might show decreased impact production of fines with time

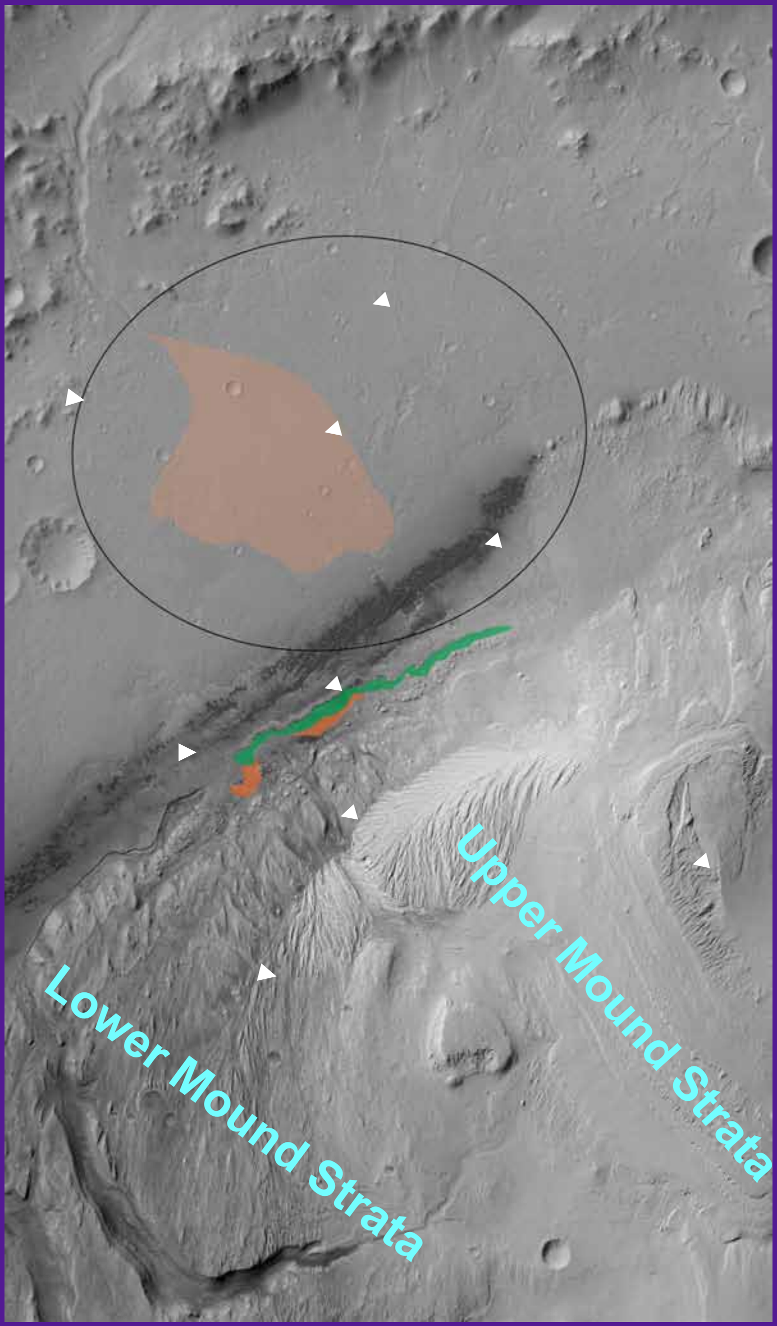
Landing Ellipse

25 km x 20 km

Field Area

- Primary Mission
- 1st Extended Mission

- later Extended phases



alluvium/alluvial fan sediments from crater wall

fan of sediment transported through channel

modern eolian dunes

lowermost strata

fluvial canyon, channel fill inverted and canyon widened

uppermost strata

Key CRISM detections in field area
clay-bearing material
sulfate + clay -bearing material

mosaic of sub-frames of CTX images: P18_008002_1748_XN_05S222W, P21_009294_1752_XI_04S222W, P22_009505_1753_XI_04S222W, P22_009716_1773_XI_02S223W

Landing Ellipse
25 km x 20 km

Field Area
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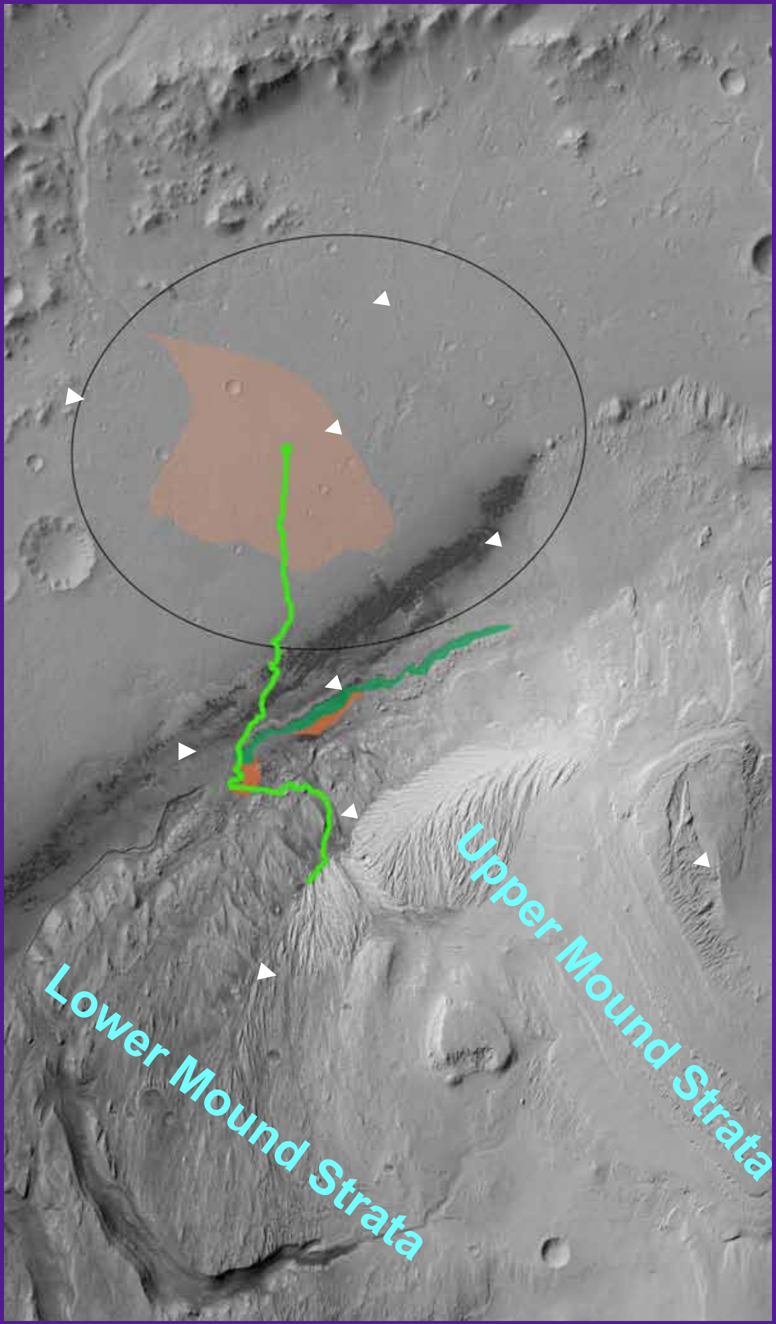
- 1st Extended Mission

- later Extended phases



alluvium/alluvial fan sediments from crater wall

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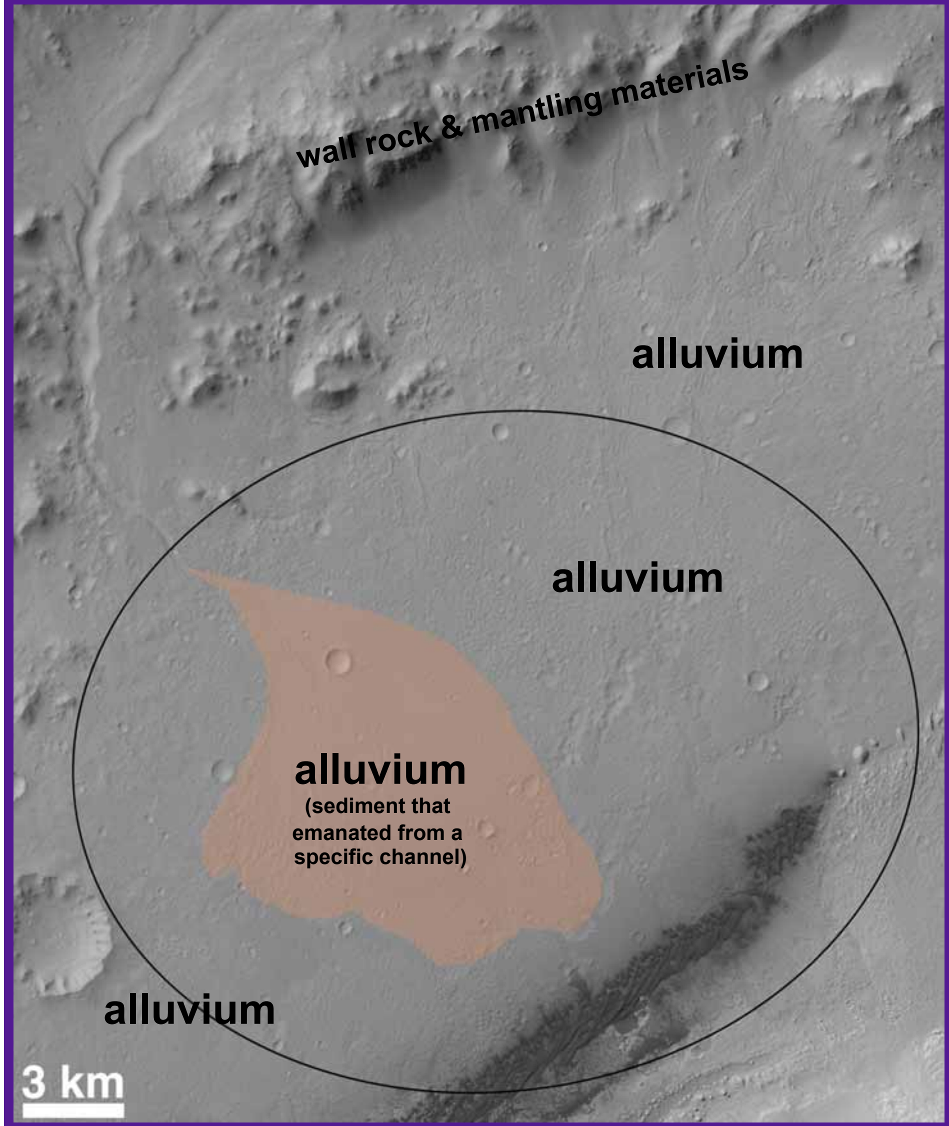
MSL Rover Science in the Landing Ellipse is Focused on Characterizing Gale Wall Rock



- Much of ellipse is covered by alluvium transported from Gale crater wall by fluvial and mass movement events.
- Preservation of many small craters tells us the alluvial material is relatively resistant to erosion, as might be expected if there are large, resistant clasts (e.g., boulders, cobbles, pebbles).
- Science in ellipse is <u>focused on characterizing candidate large clasts derived from Gale's north wall</u>.
- <u>The purpose</u>: To help investigators distinguish local (from Gale's walls and rims) sedimentary inputs to the stratigraphic sequence from foreign inputs (i.e., sources outside of Gale Crater).

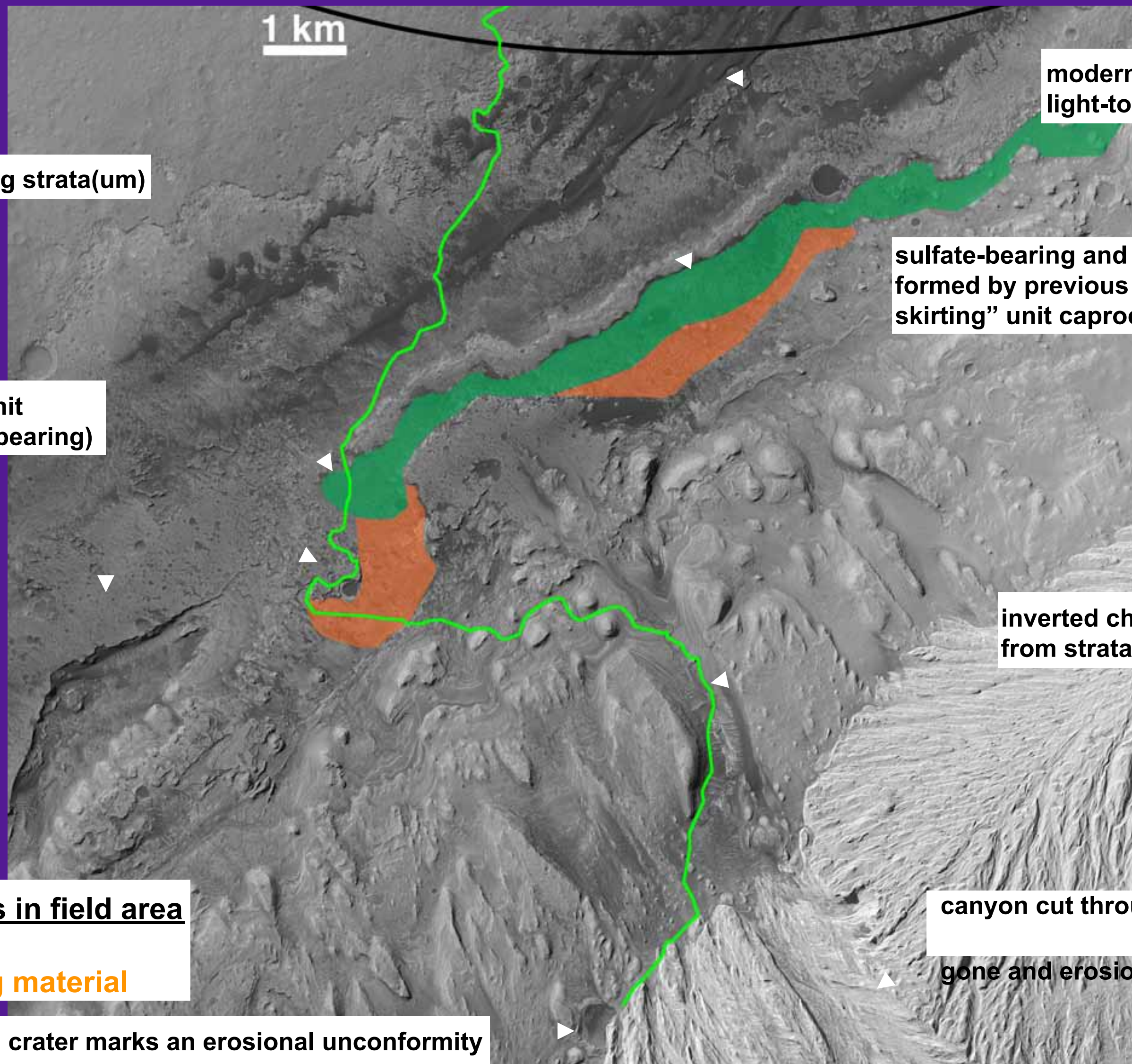
mosaic of sub-frames of CTX images: P18_008002_1748_XN_05S222W, P21_009294_1752_XI_04S222W, P22_009505_1753_XI_04S222W, P22_009716_1773_XI_02S223W

MSL Rover Science During Traverse to Mound Includes Characterization of Eolian Dune Sediment

- Modern, eolian dunes (responsive to modern winds--Hobbs et al. 2010; composition similar to olivine basalt + “high silica phases”; no genesis implied by the term “basalt”--Rogers & Bandfield 2009).
- Purpose: Determine sand/sediment composition to help pinpoint source: Derived from wall rock and alluvium, or derived from sedimentary rock that will be encountered later in the Mound stratigraphy?

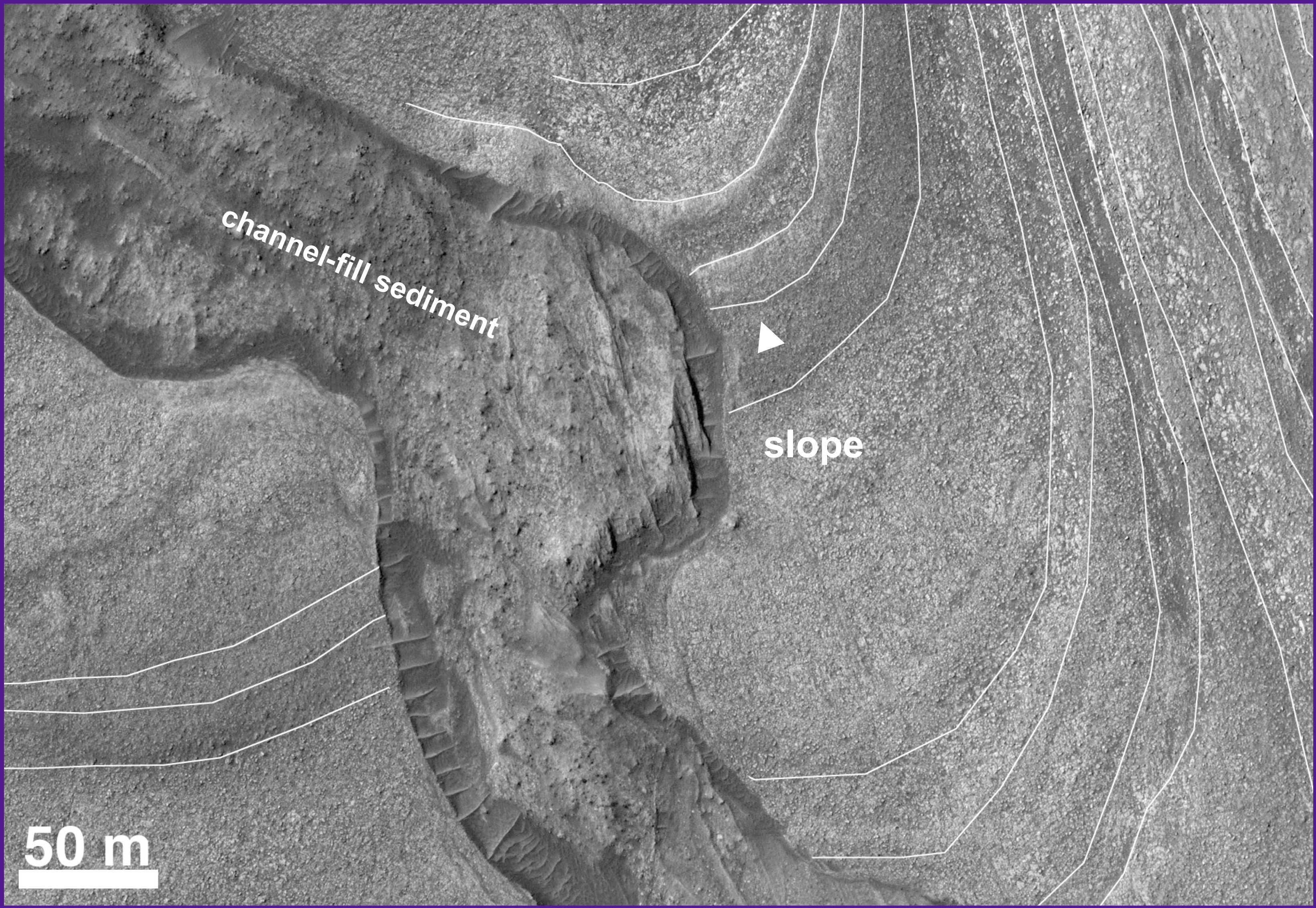
Candidate MSL Field Area in Gale

(green curve is a very notional traverse)



mosaic of sub-frames of CTX images: P18_008002_1748_XN_05S222W, P21_009294_1752_XI_04S222W, P22_009505_1753_XI_04S222W, P22_009716_1773_XI_02S223W

Sediment in the Remains of Channels Cutting the Lower Mound Rocks Provide "Preview" Samples of Material from Higher Up on the Mound, Possibly Including Material Otherwise No Longer Present in the Mound Stratigraphy.



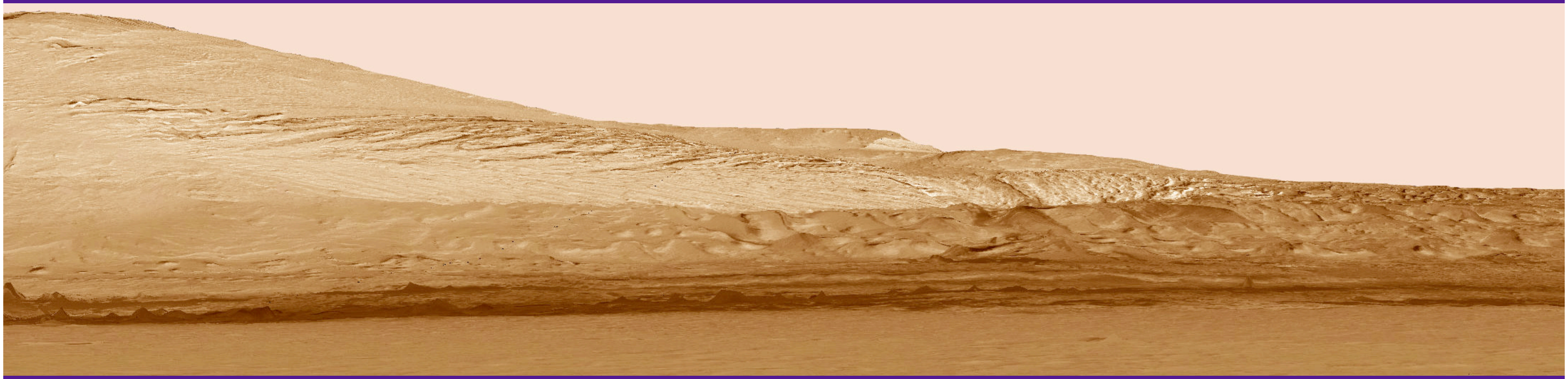
- sub-frame of HiRISE PSP_009294_1750
- white lines are a sketch of layering/bands in the mound bedrock

Conclusions (1 of 2)-- Examine one of the Thickest Exposed Stratigraphic Sequences in the Solar System

- Gale's mound is the last remaining record of a portion of early Mars history that has been otherwise erased from the region. This record has been lost from neighboring craters and terrain (e.g., Lasswitz).
- We have an opportunity to assess changing environments and habitability conditions on Mars over a very thick (5 km!) stratigraphic section.
- The stratigraphy might span across considerable time; it certainly appears to record conditions on the later part of the "early, wet" Mars <u>and</u> the transition to a more modern, "dry" Mars.
- With MSL we would start right after landing by examining some of the large clasts (rocks) in alluvium derived from Gale's wall, plus traverse to and examine modern eolian dune sands; these will help us become familiar with locally-derived sediments and provide information that might later help us distinguish between local and foreign sediment inputs.

Conclusions (2 of 2)-- Examine one of the Thickest Exposed Stratigraphic Sequences in the Solar System

- We would then examine the rocks of the lower part of the mound (and the mound-skirting unit and the channel fill materials shed from higher up on the mound).
- The lower mound strata include clay-bearing and sulfate-bearing sedimentary rocks. Water certainly had a role in their formation, diagenesis, and erosion.
- We will assess the events in the order that they occurred, looking at changes in climate, sedimentation, groundwater or lake chemistry, and habitability conditions over time.



Acknowledgements

- Unless otherwise noted, I take responsibility for all observations, interpretations, speculations, notions, and, most importantly, any *errors* you might find in this presentation package.
- Some figures were borrowed from previous presentations by Ralph Milliken, but he is not responsible for how I might have used or abused them.
- Communications over the past few years with Ralph Milliken, Dawn Sumner, Ryan Anderson, John Grotzinger, Linda Kah, Mike Malin, Tanya Harrison, David Shean, Megan Kennedy, and Liliya Posiolova, have helped me refine this story.
- David Shean and Tanya Harrison assisted with production of some of the figures that are derived from digital elevation models/topographic data sets.

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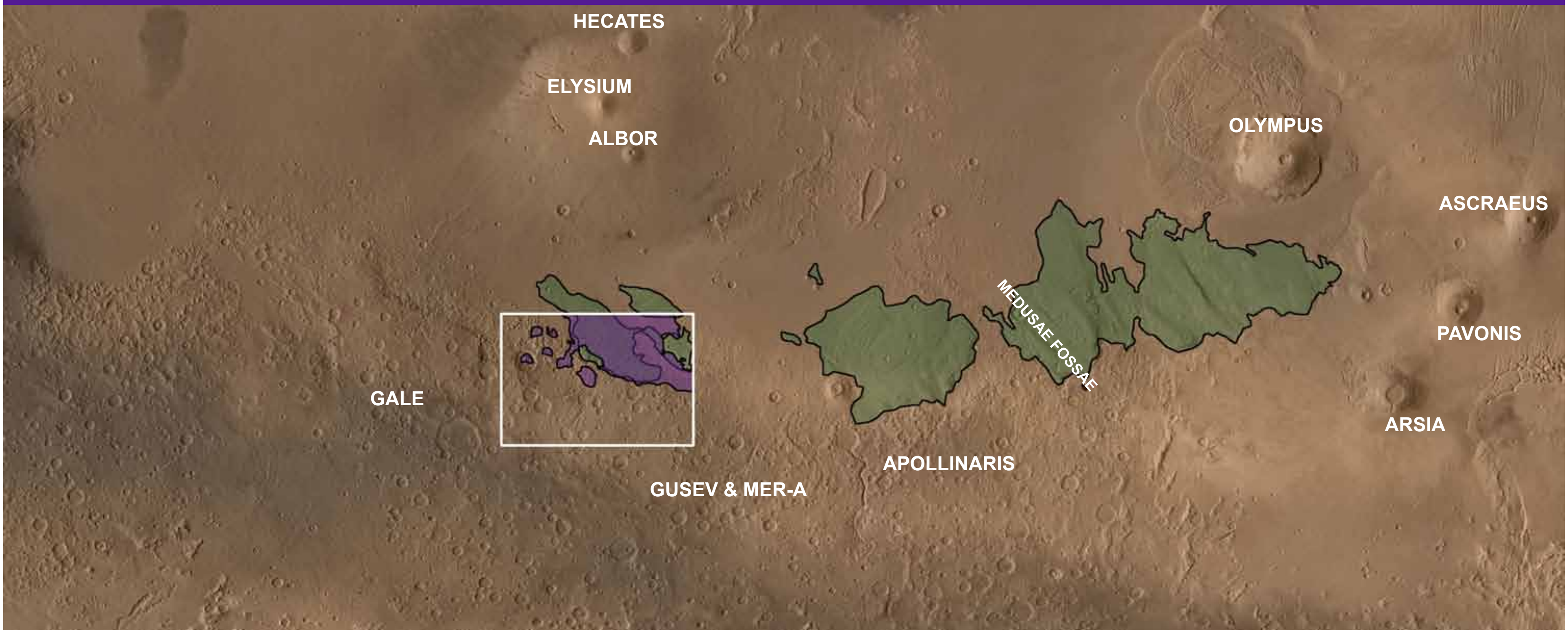
Appendix

- This presentation for the 4th MSL Landing Site Workshop on 27 September 2010 was designed to be a 30-minute talk with time for questions and answers.
- Thus, some material had to be cut from the the presentation I would have liked to have given.
- I have included some of those “cut” materials on the following pages, so that readers of this material, when presented online, have access to the additional information.

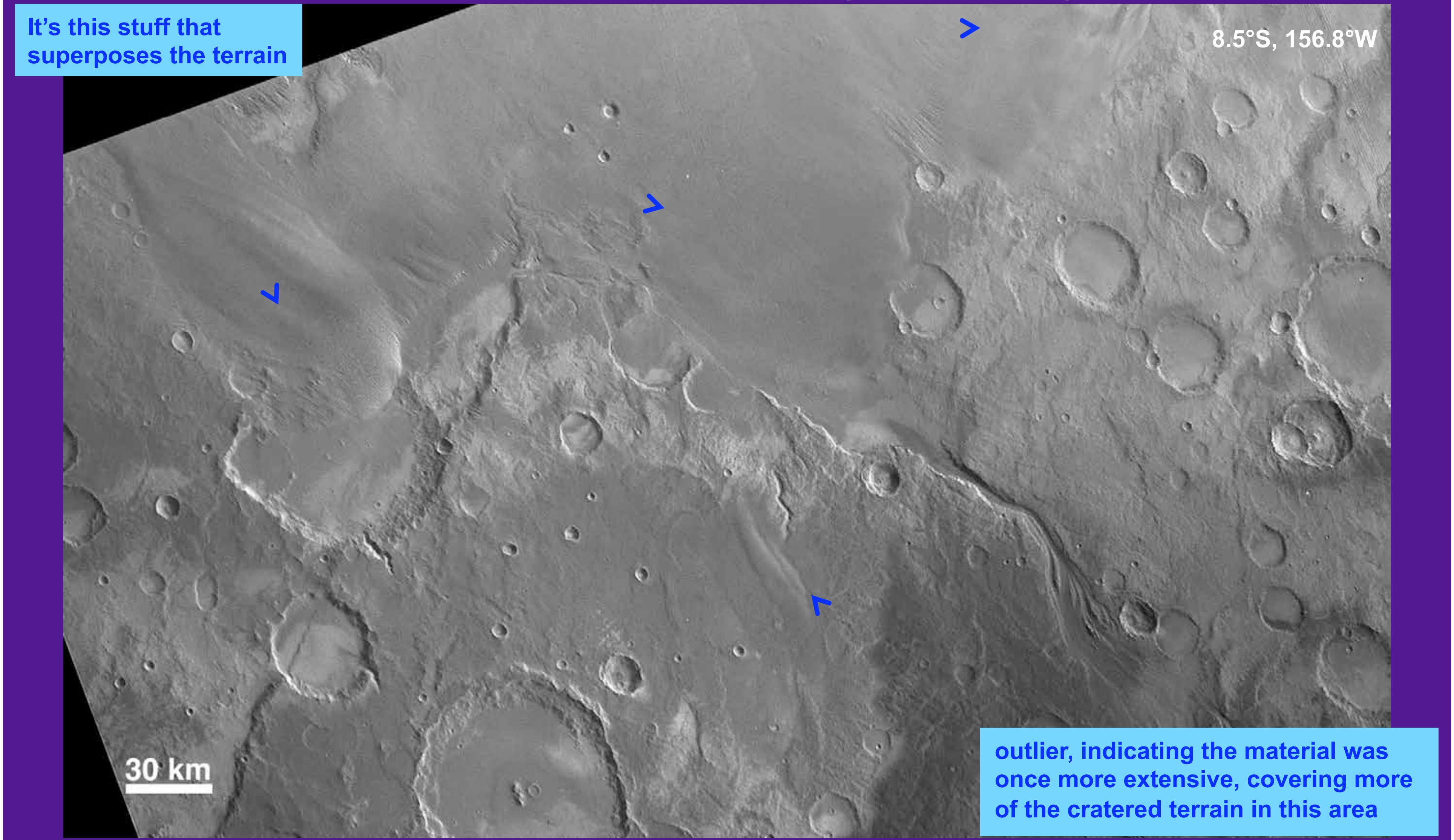
The Medusae Fossae Formation Issue



- Green shows “traditional” mapping of “Medusae Fossae Formation” material (e.g., Scott and Tanaka 1986; Greeley and Guest 1987).
- Purple shows recent, ***preliminary*** mapping by Zimbelman (2010).
- Some investigators have suggested Gale mound is outlier of “Medusae Fossae Formation”material (Scott and Chapman 1998; Hynek et al. 2003; Zimbelman 2010).

Base map made by MSSS for National Geographic (2001) using MOC wide angle images and MOLA topography.

The Yardang-forming Material known as “Medusae Fossae Formation” Was Once a More Extensive and Straddles the North-South Dichotomy Boundary

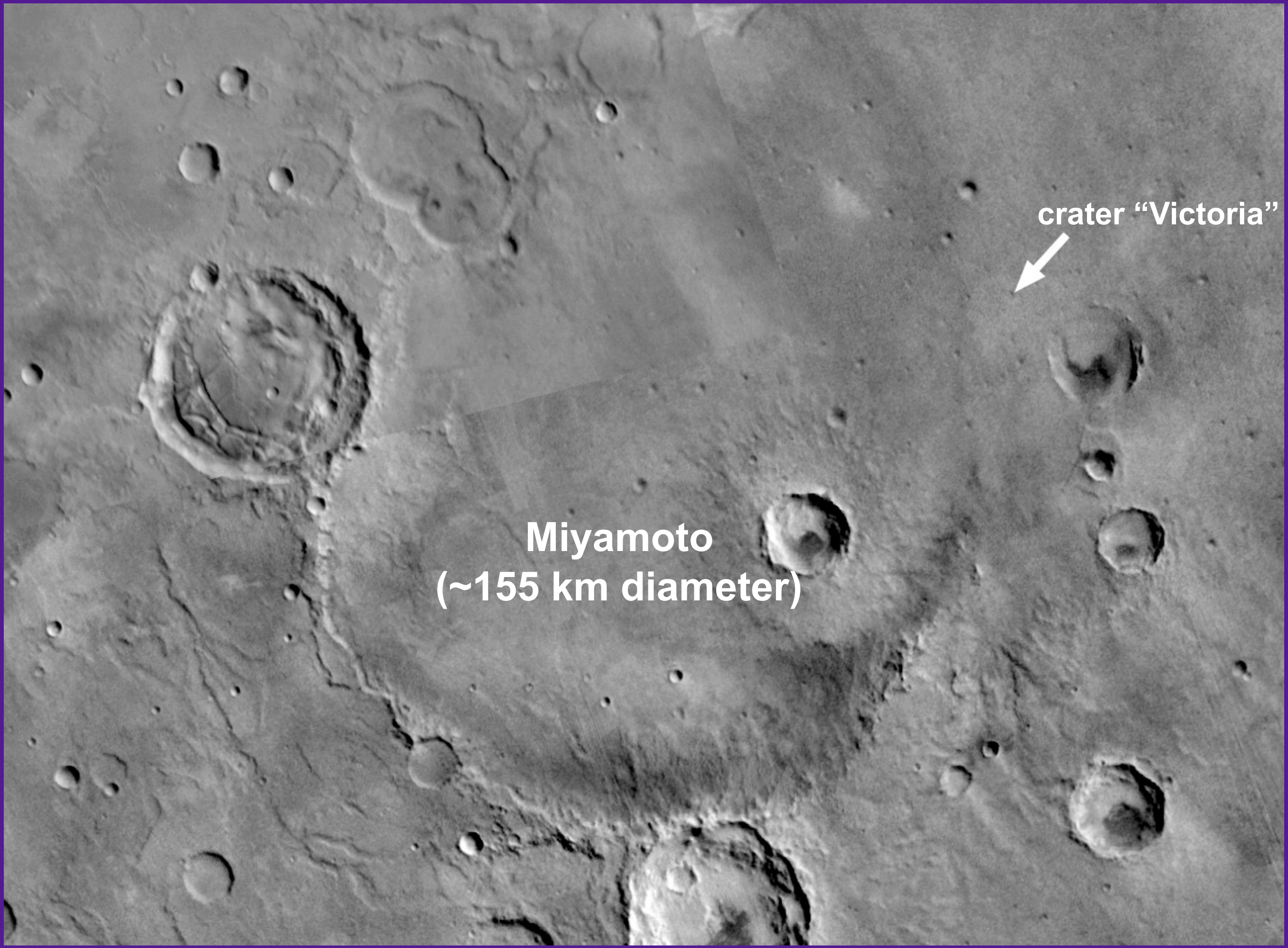


Mosaic of Viking 1 images 637A75, 637A76, 637A78

Gale Mound & “Medusae Fossae Formation”

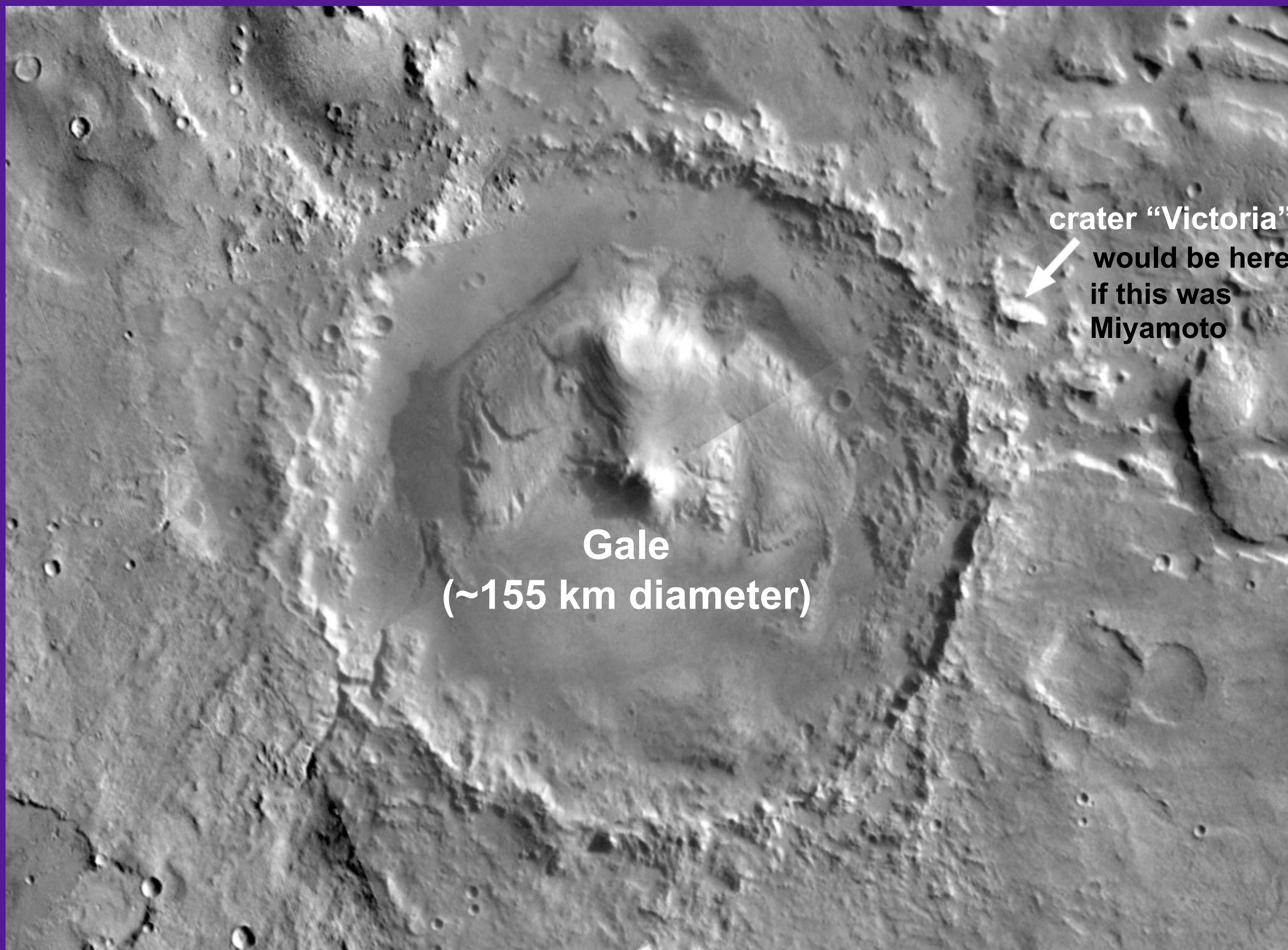
- The prevailing view, for > 2 decades, has been that the “Medusae Fossae Formation” is largely composed of massive amounts of tephra, in some cases deposited as ignimbrites erupted from vents now hidden by the materials.
- That view is challengable, given the variety of new observations made in this decade (e.g., inverted channels and fans in the material), but, so far, the people working on this topic have not been writing about challenges to the Viking-era view.
- Is the Gale Mound part of the “Medusae Fossae Formation”?
  - Not likely. It shows considerably more complexity. Compare Gale’s mound with Nicholson’s mound.
  - Some suggest some of the Gale strata could be MFF. But it doesn’t matter, anyway, because…
    - This is **not a testable hypothesis** without detailed field examination of the entire extent of the “MFF” as well as the entire Gale mound.
    - Without that extensive field work, it is also **not a testable hypothesis** that the “MFF” is largely composed of tephra.

Miyamoto Crater, Near the MER-B field site, is an eroded crater of about the same size as Gale. Like Gale, it formed on a slope. It’s north and northeast wall/rim are buried beneath the Meridiani Planum bedrock. Consider the rock type and groundwater story for the MER-B field site.



USGS Viking MDIM 2.1

Gale (to compare with Miyamoto and location of MER-B field site (near Victoria) in previous slide.



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