TERBY CRATER: MSL LANDING SITE CANDIDATE

Second Landing Site Workshop
October 23-25, 2007

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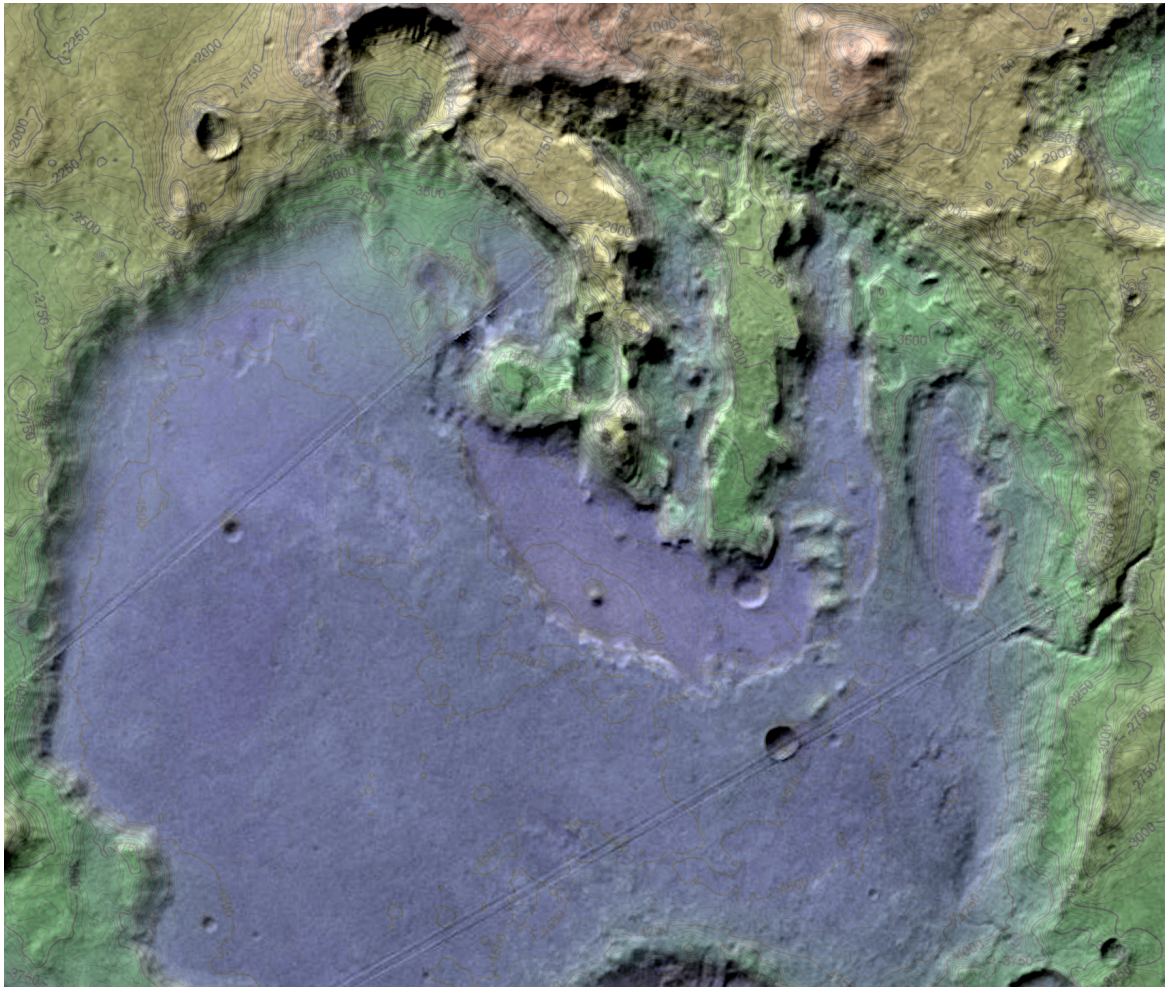
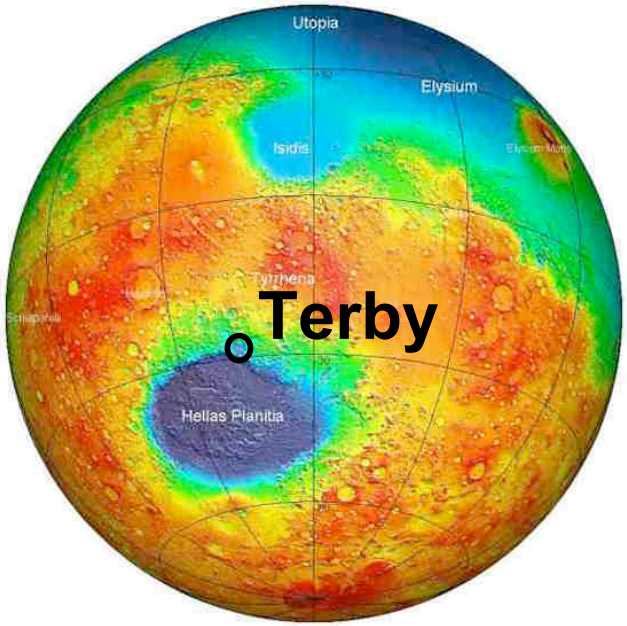
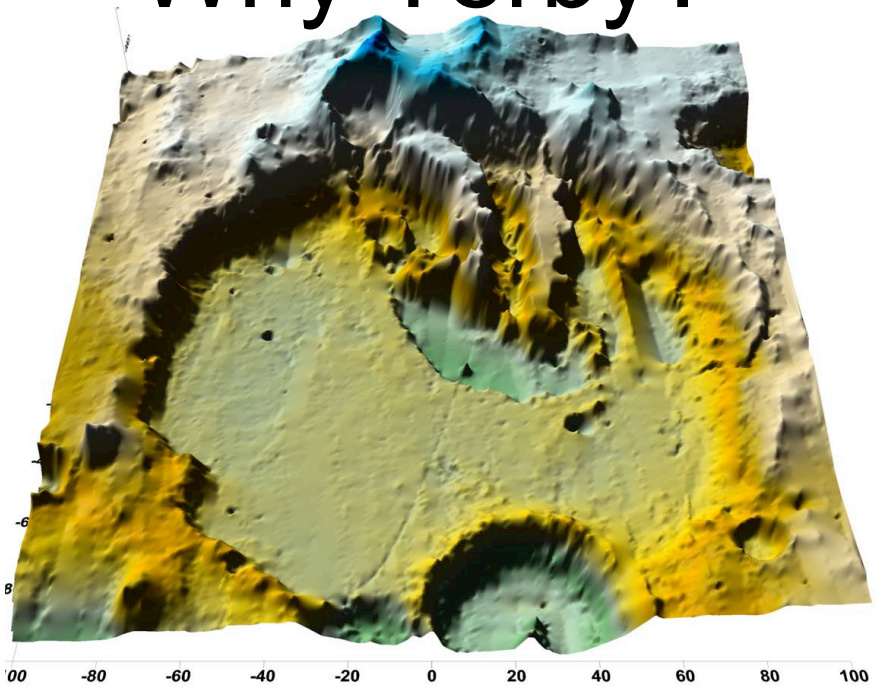
Terby Crater

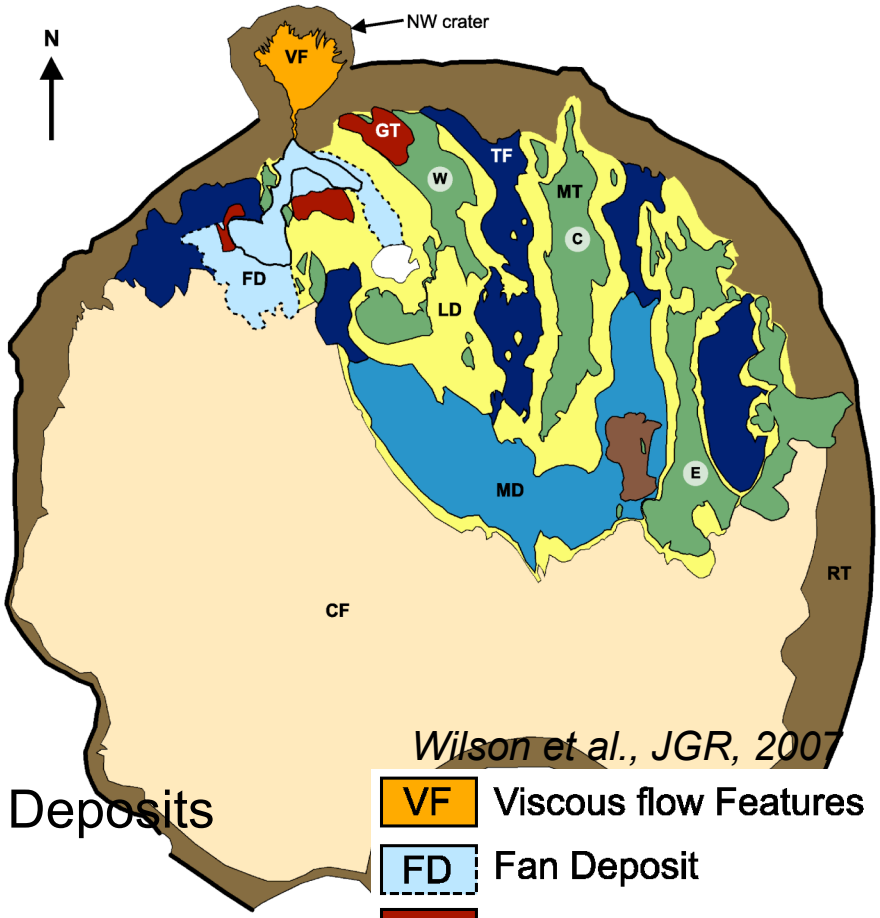




- D ~165 km
- Noachian [*Leonard and Tanaka*, 2001; *Wilson et al.,* 2007]
- 28°S, 287°W
- Elevation Range: 0 to -5000 m
- Diverse assemblage of terrains and geologic processes

Why Terby?

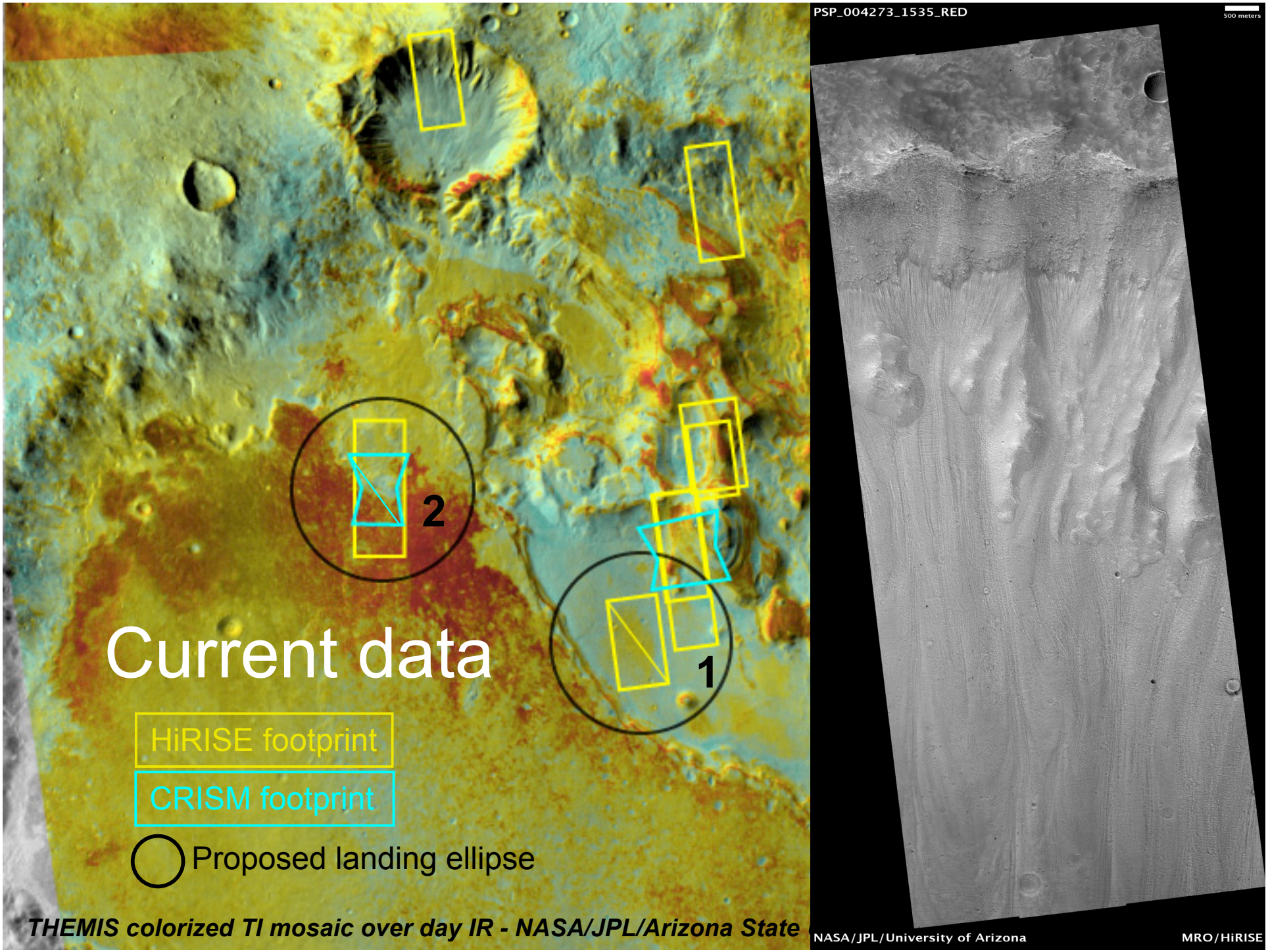


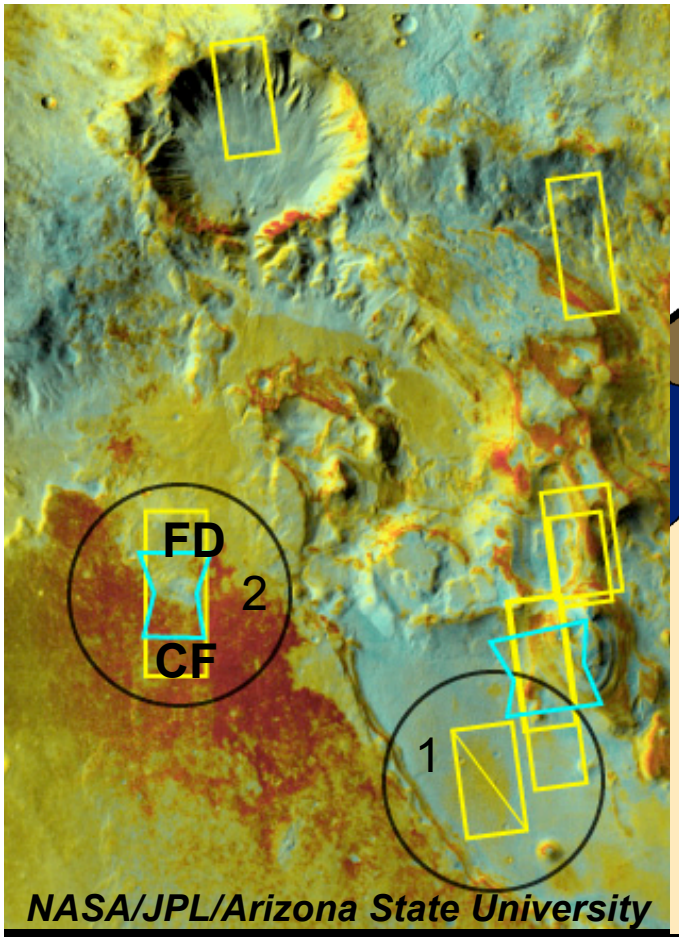


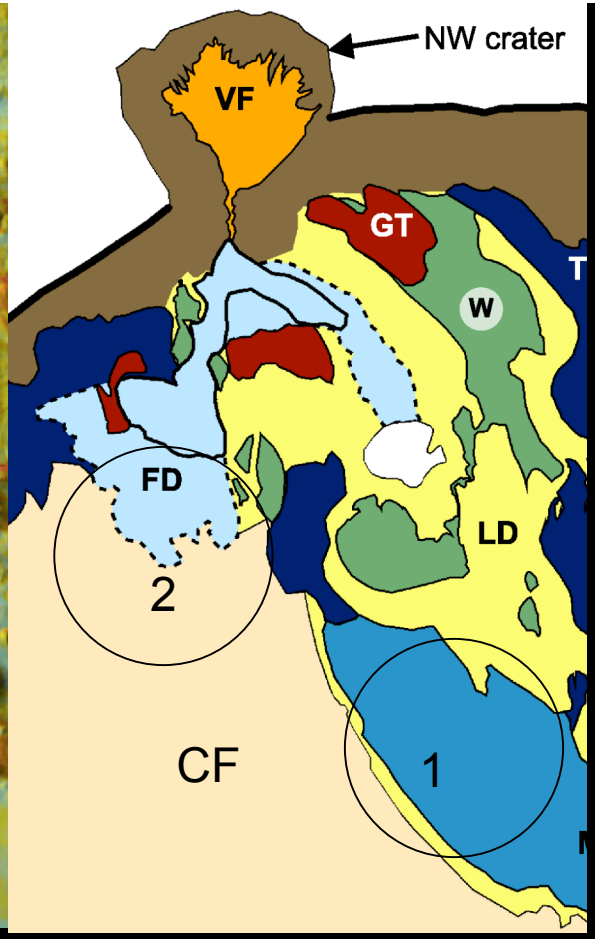
Wilson et al., JGR, 2007

- Evidence for past habitability: Layered Deposits
  - Up to ~2.5 km stratigraphic section
  - Consistent with lacustrine origin
  - STRONG Fe/Mg clay and hydrated signature
- Fluvial/Alluvial processes: Alluvial fans formed from episodic releases of melt water from NW crater (VF), dissected rim, sinuous channels
- Depressions, eskers, scoured caprock, avalanche
- "Ancient" bedrock – rim materials
- Well-studied regional context
- Representative of craters in circum-Hellas region

VF	Viscous flow Features
FD	Fan Deposit
GT	Grooved Terrain
TF	Trough Floors
MD	Moat Deposit
CF	Crater Floor deposit
MT	Mesa Tops
LD	Layered Deposits
RT	Rough Terrain
	Avalanche deposit


2
1
Current data
HiRISE footprint
CRISM footprint
Proposed landing ellipse
THEMIS colorized TI mosaic over day IR - NASA/JPL/Arizona State
PSP_004273_1535_RED
500 meters
NASA/JPL/University of Arizona
MRO/HiRISE





Landing Ellipse 1: Moat Deposit

- Very flat
- Elevation: -5km
- Possibly more elliptical (NW/SE orientation)
- No HiRISE image

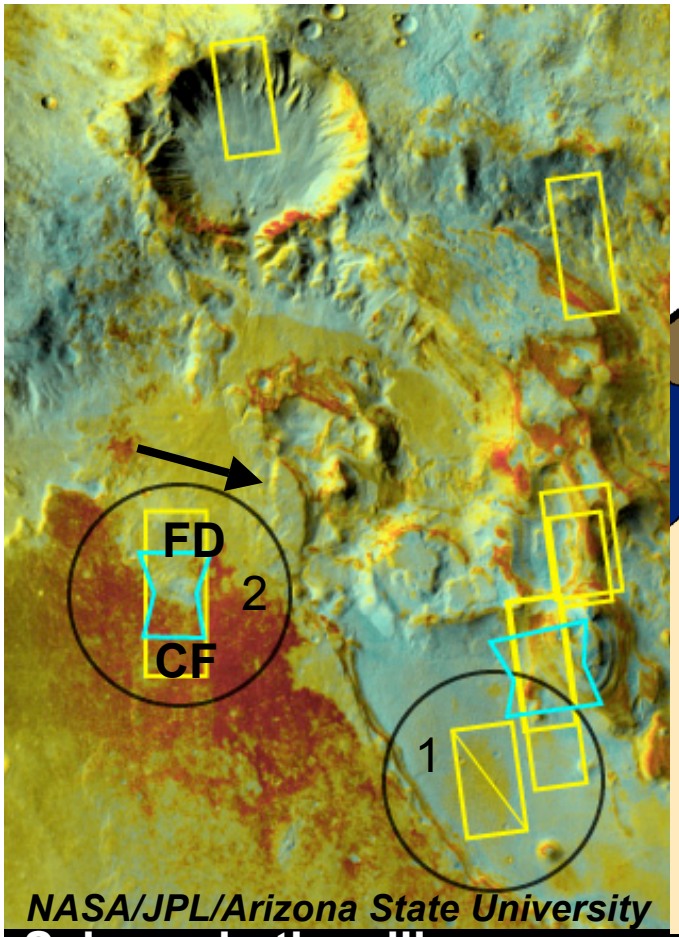
Science in the ellipse:

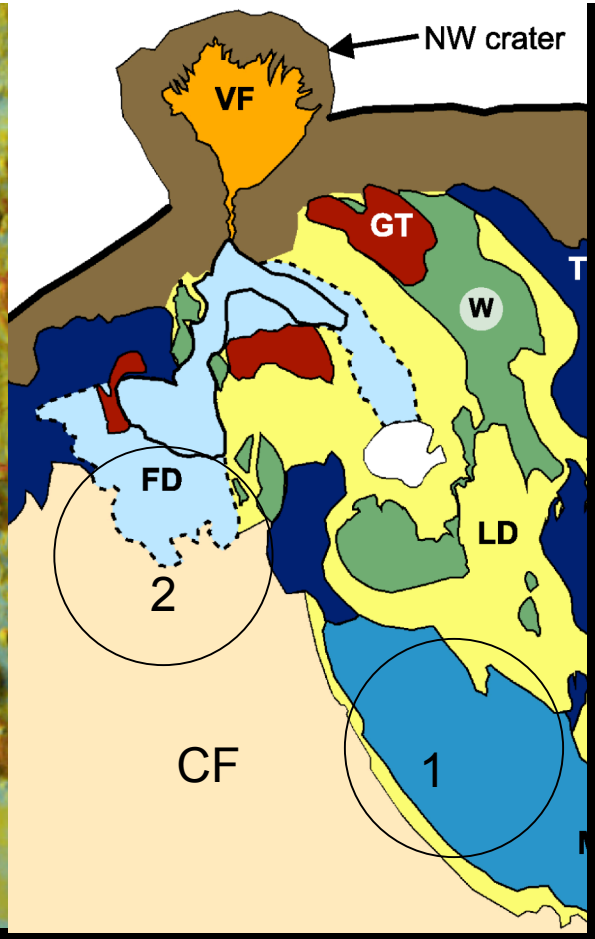
- LD in benches (2.5 km), CF (400 m), mounds
- esker like ridges

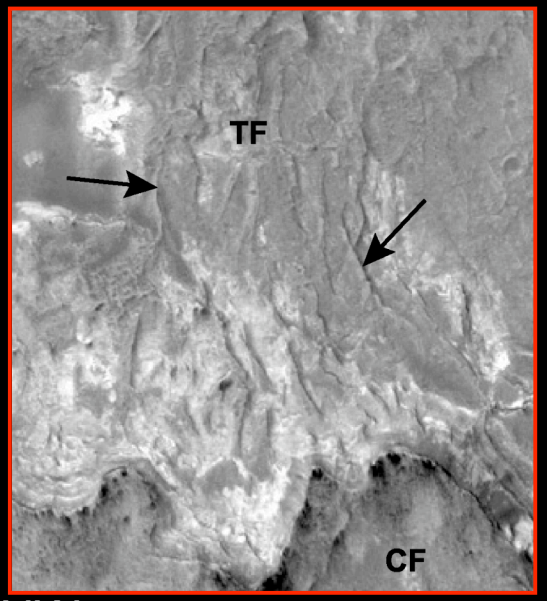
Science outside ellipse:

- Access to ancient wall rock, stratigraphy of layered benches

Landing Ellipse 2: CF/FD boundary







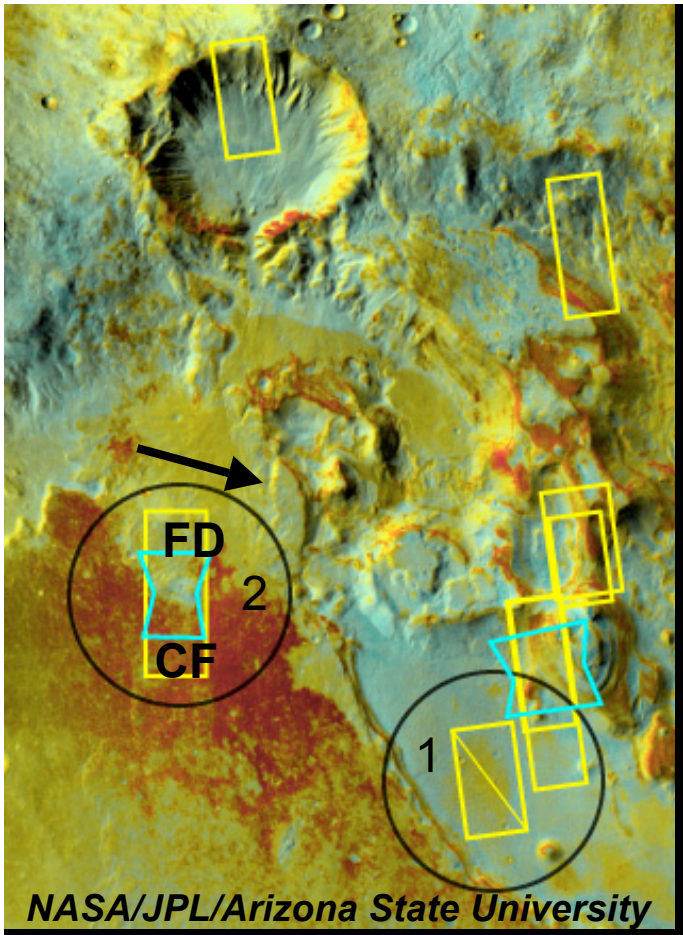
Science in the ellipse:

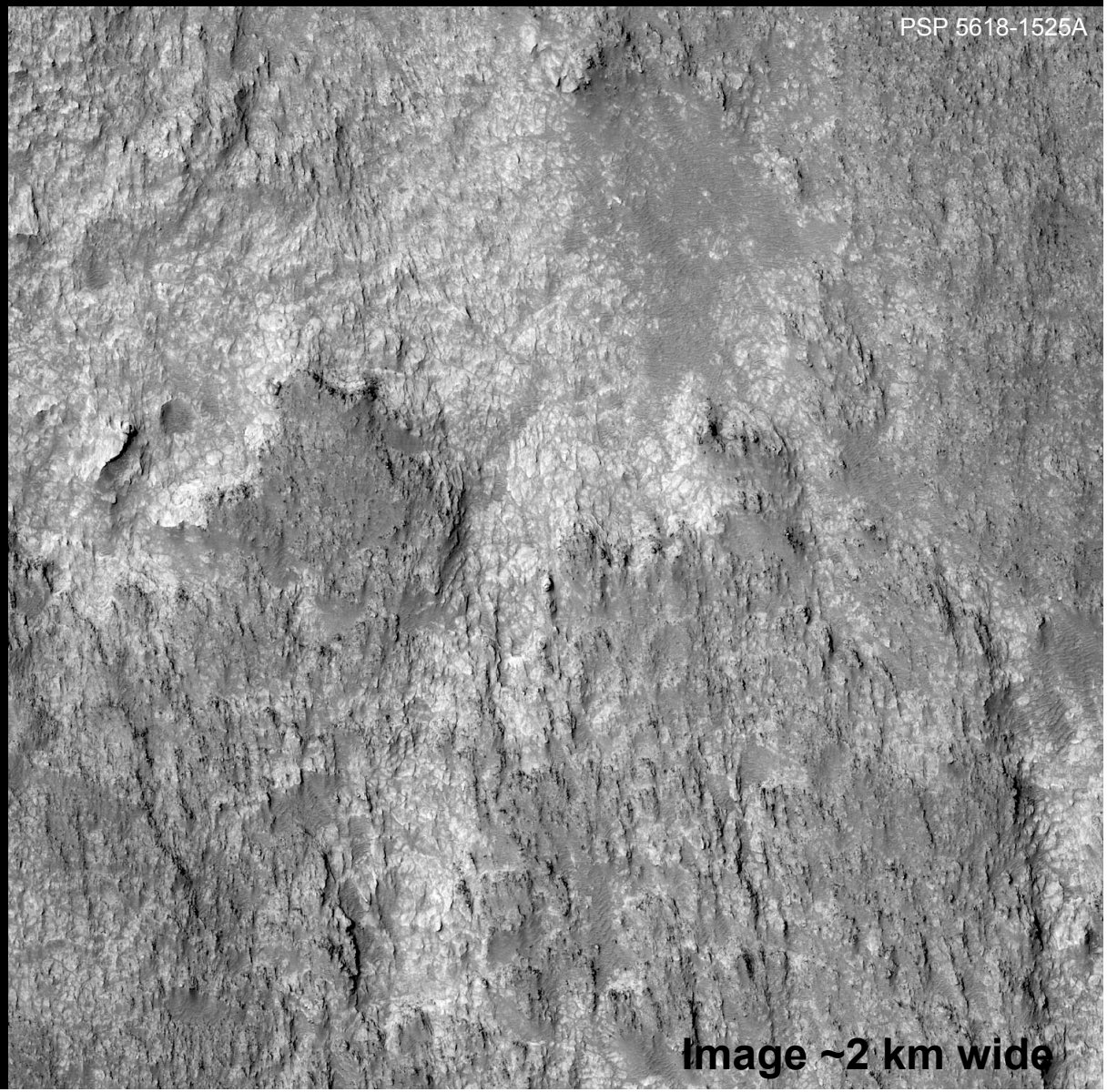
- LD in bench dissected by fan deposit, LD in CF
- Hesperian alluvial fan (2 depositional periods)
  - Incorporated light-toned material from layered benches, NW crater wall rock, ice-rich materials
  - mid-latitude processes

Science outside the ellipse:

- Grooved terrain (GT) associated (fluidized ejecta from NW crater?), ice processes recorded on northwestern TF (late Noachian to Hesperian)

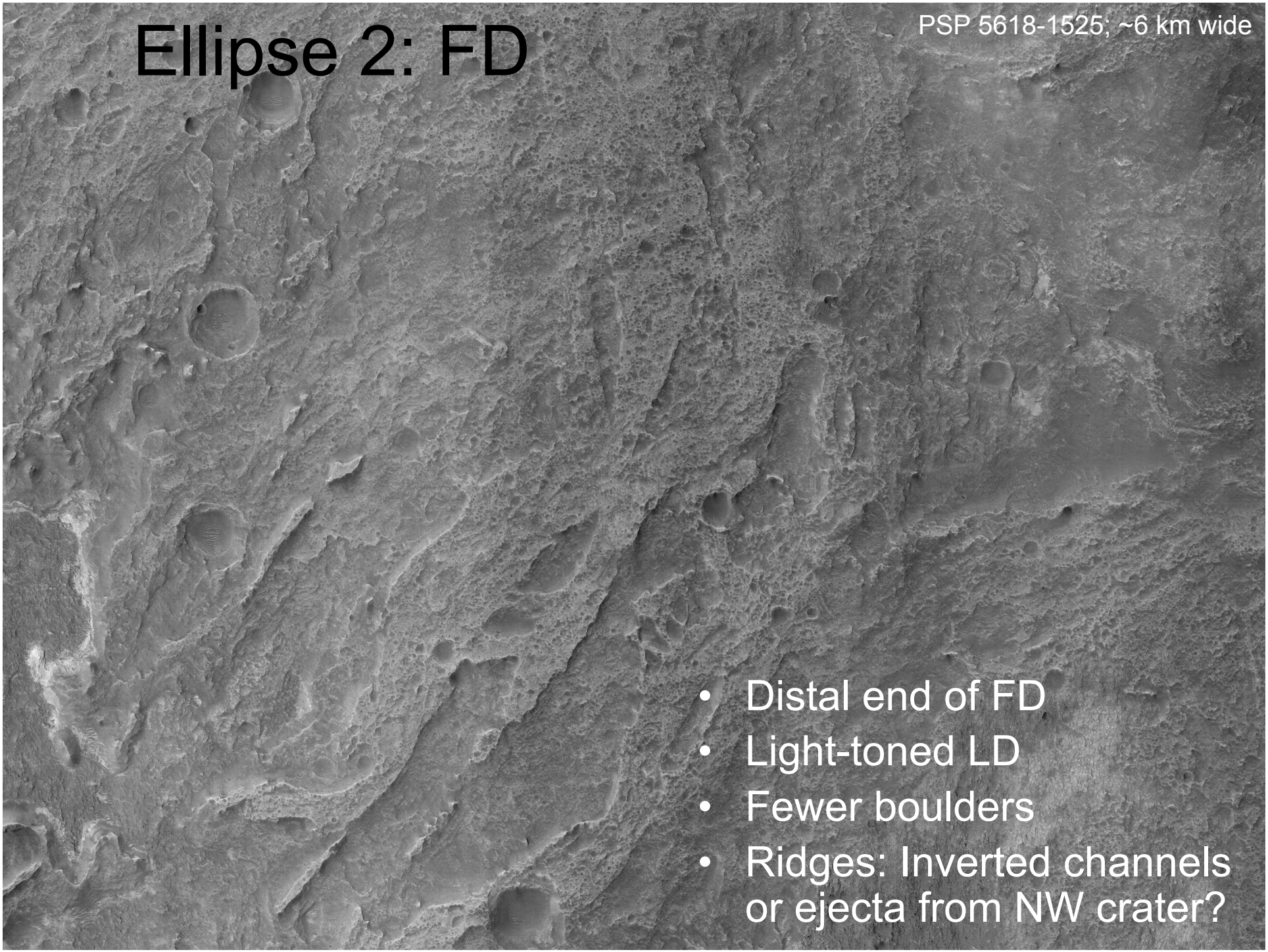
Ellipse 2: CF





- N/S texture
- Boulder lag (high TI)
- Smooth light-toned deposits

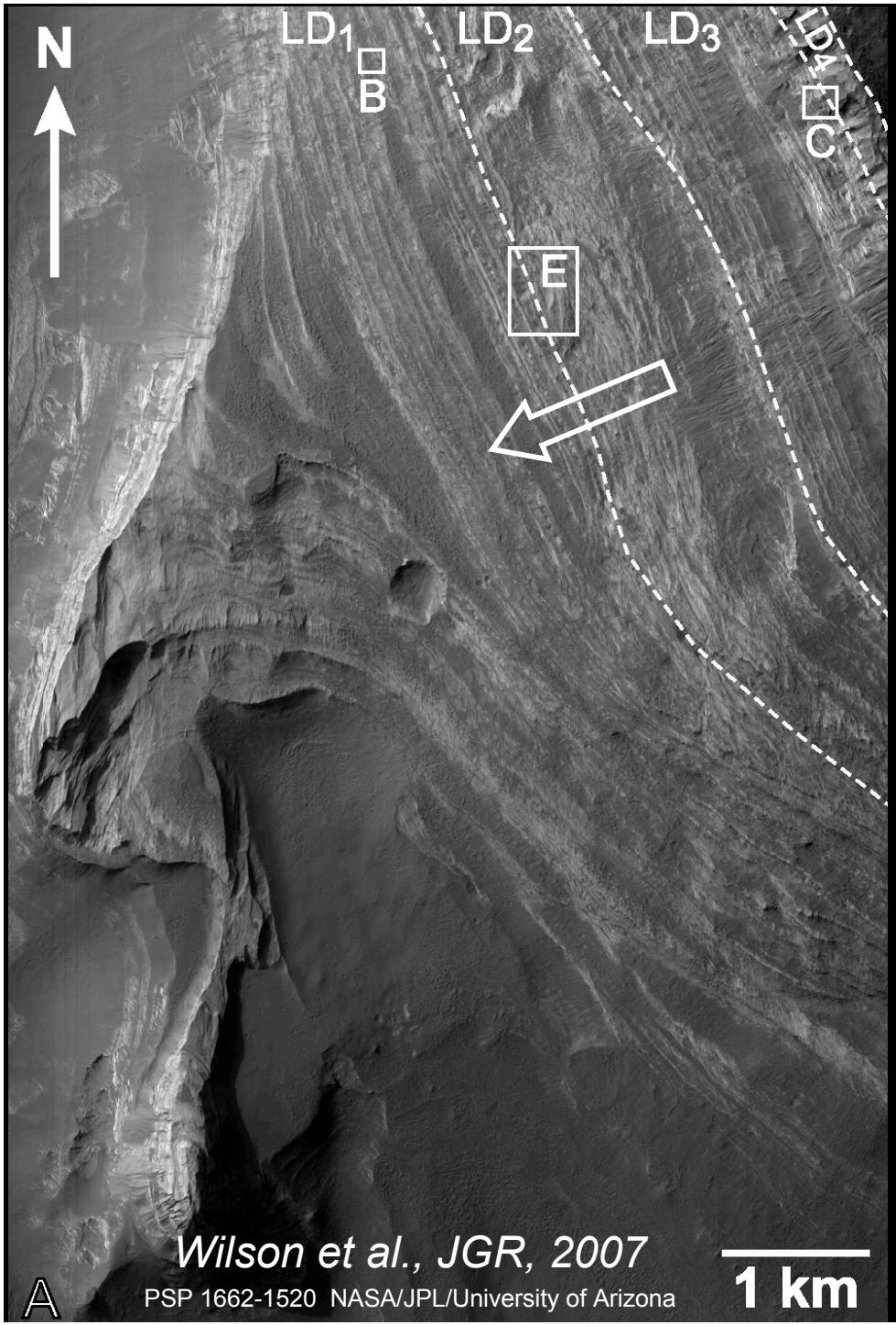
Ellipse 2: FD



- Distal end of FD
- Light-toned LD
- Fewer boulders
- Ridges: Inverted channels or ejecta from NW crater?

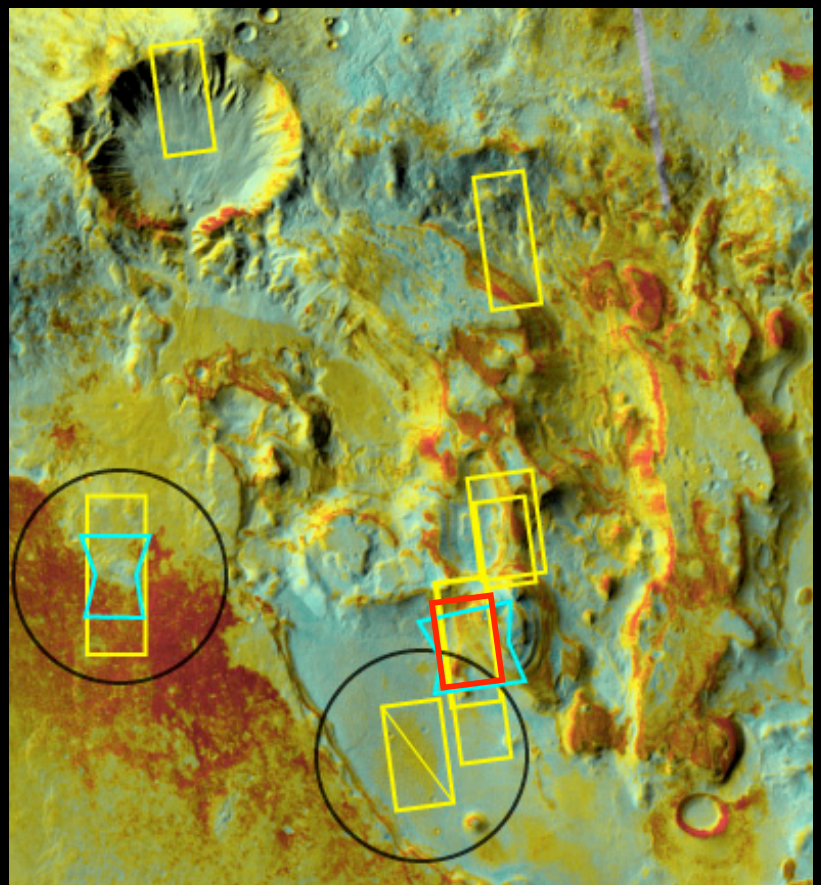
Nature of the Layered Deposits

- **Light- and intermediate-toned**
- **Indurated and fine-grained**
  - **Based on appearance, steep scarps, ease of erosion, TI, preservation of faults, fractures, folds (?) and contacts**
- **Laterally continuous (km scale)**
- **Consistent thicknesses (km scale)**
- **Fe or Mg-rich clay and hydrated signature (CRISM)**
- **Scalloped texture – aeolian deflation**
- **Mid to Late Noachian** [Ansan et al., 2005; Mest and Crown, 2005, Wilson et al., 2007]



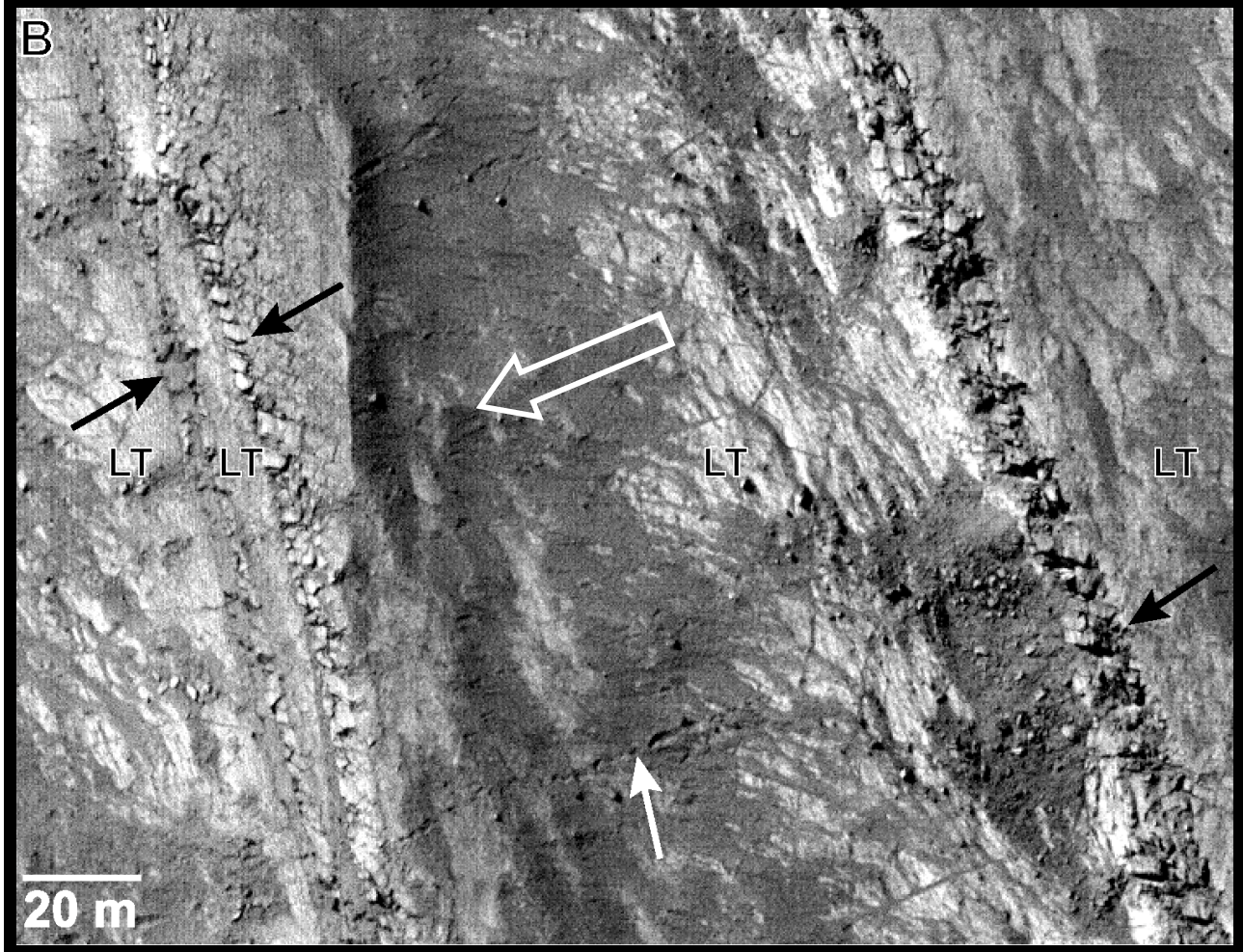
Stratigraphy

- 4 sub units
- Probable correlation across troughs

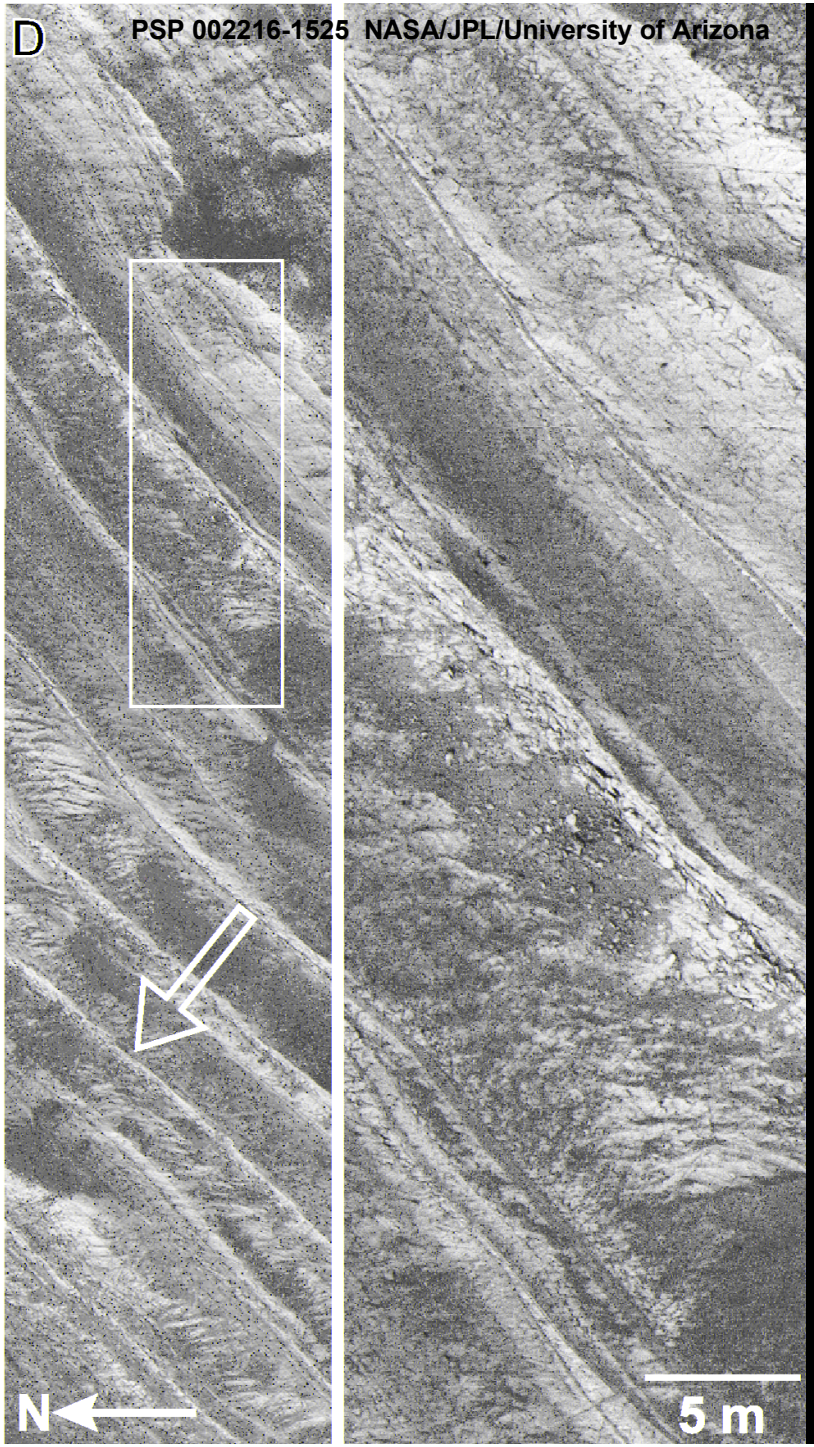


Stratigraphy: Sub units 1 (LD_1) and 3 (LD_3)

HiRISE PSP 1662-1520 NASA/JPL/University of Arizona



- Characterized by thin (~1-25 m thick) intermediate-toned layers interbedded with thicker (~100 m) light-toned beds
- Fine-grained intermediate-toned layers weather along meter-scale joints, produces boulders



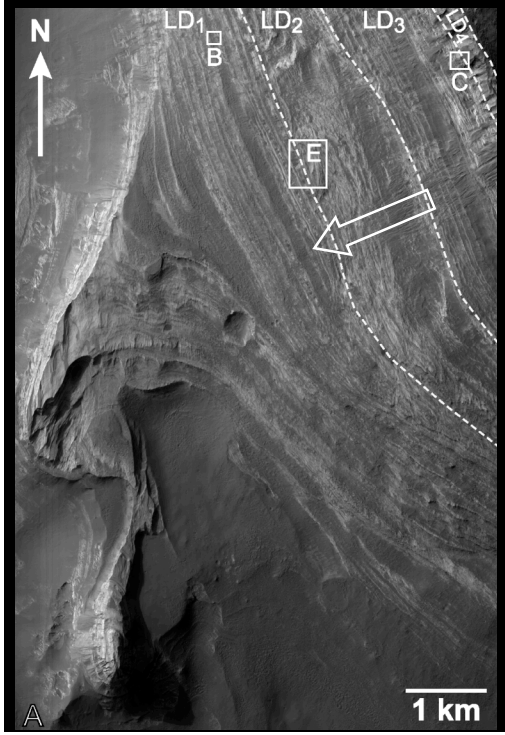
Stratigraphy: Sub unit 1 (LD_1)

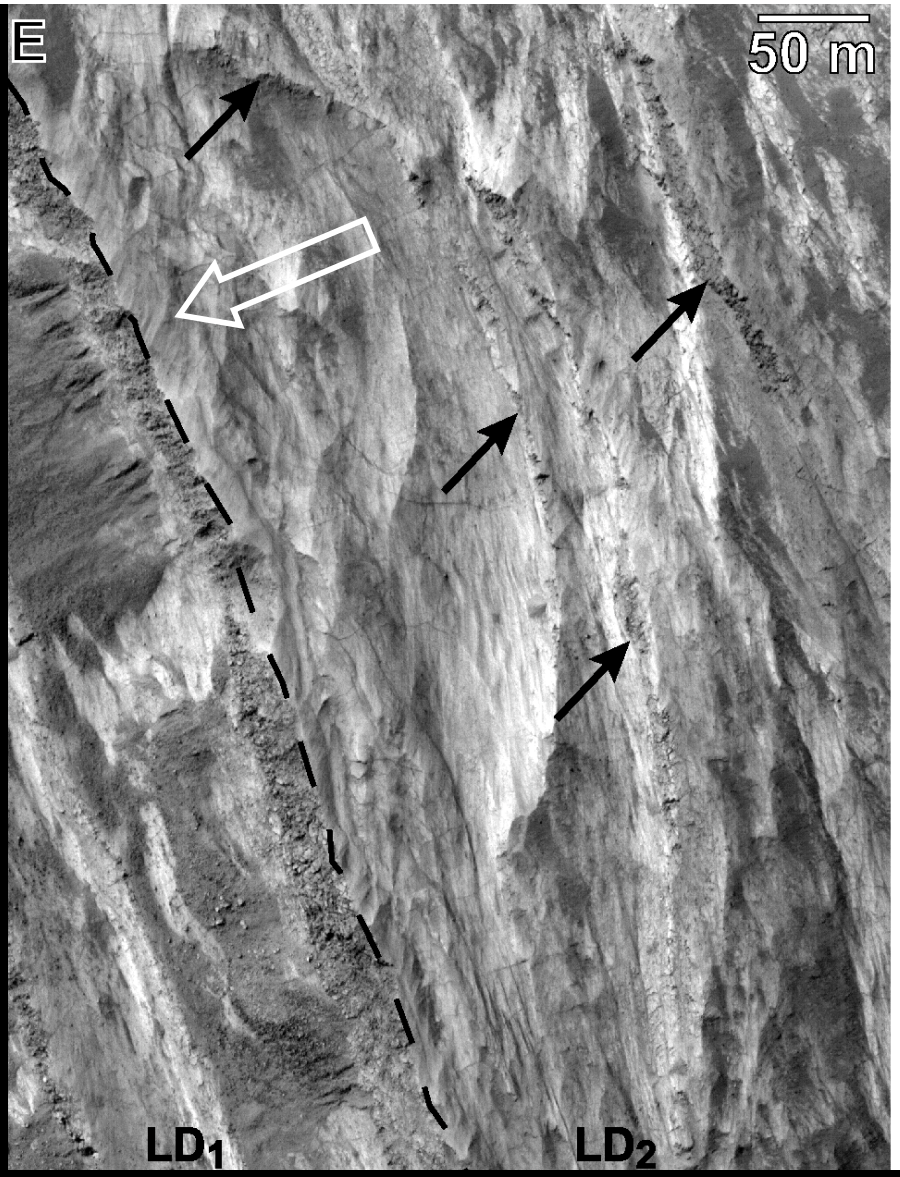
- HiRISE image from northern edge of mesa
- Sub meter-scale, continuous layers/laminations
- Deposition from suspension
- Tone variations: differences in composition (grain size), cementation or induration

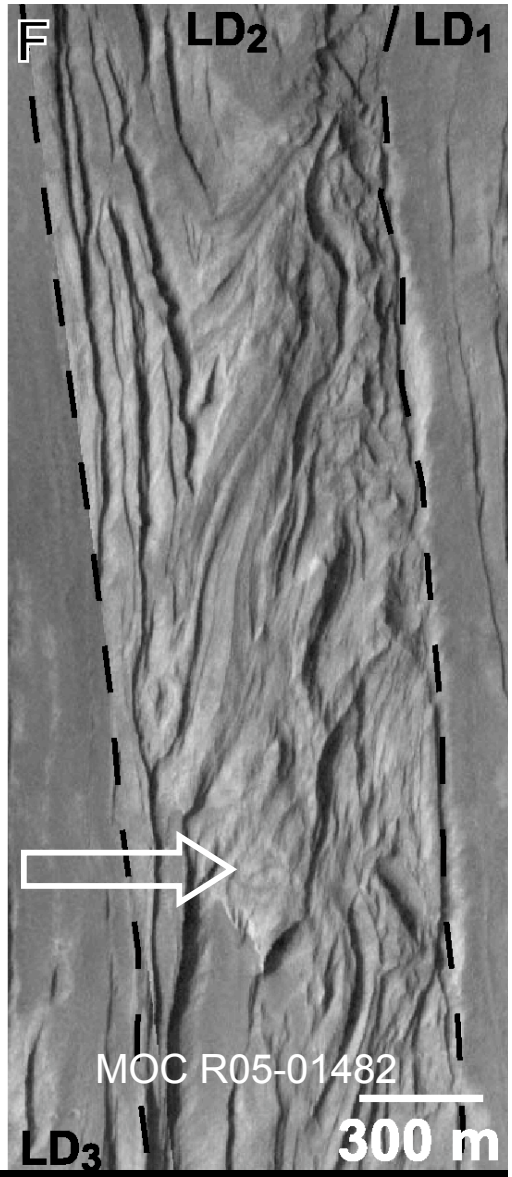
Wilson et al., JGR, 2007

Sub unit 2 (LD_2)

PSP 002216-1525
NASA/JPL/University of Arizona

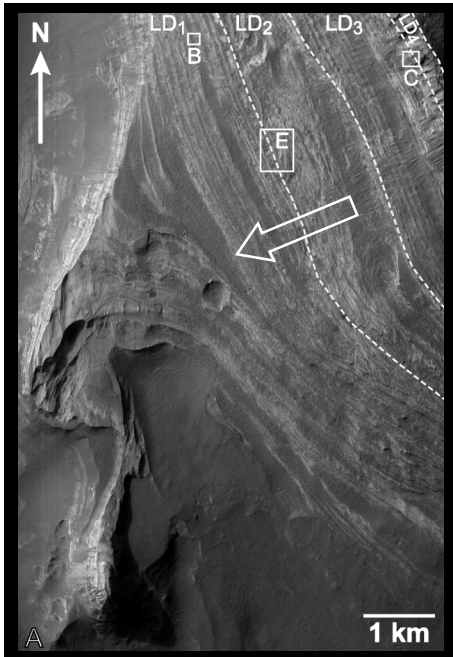


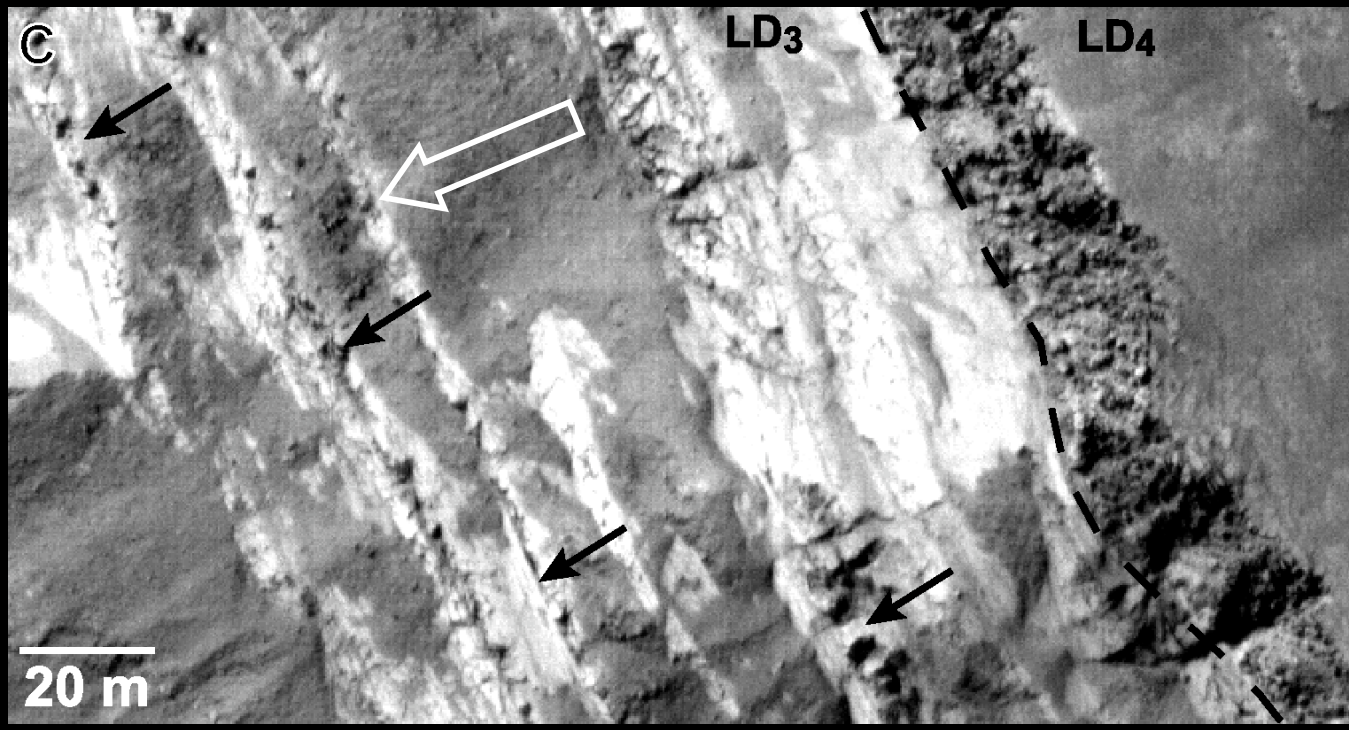




- ~ 400 m thick; light-toned, irregular, non-horizontal, discontinuous, possibly folded beds of variable thicknesses
- Change in depositional environment
- Appearance and scale consistent w/ soft sediment deformation

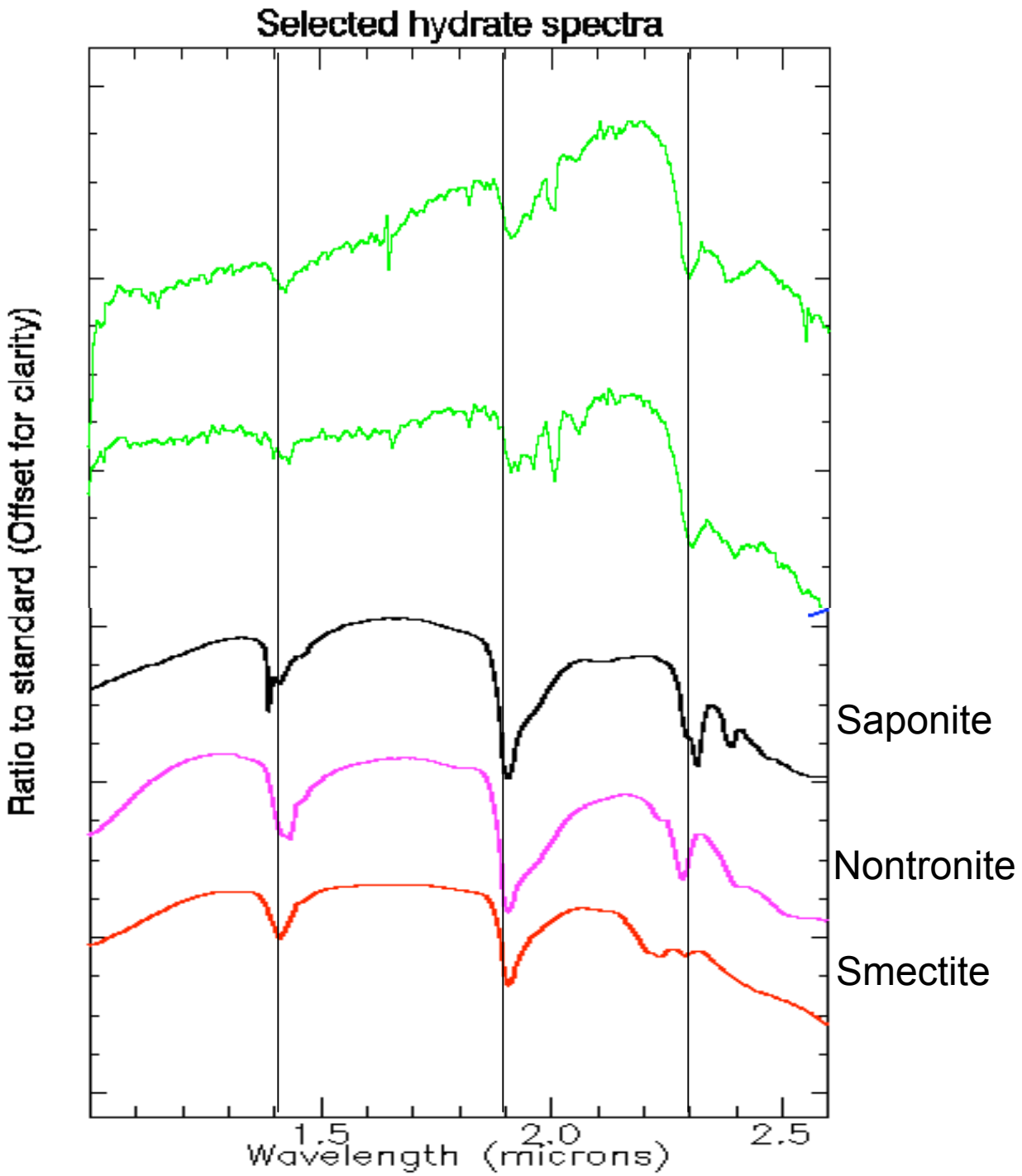
Stratigraphy: Sub unit 4 (LD_4)

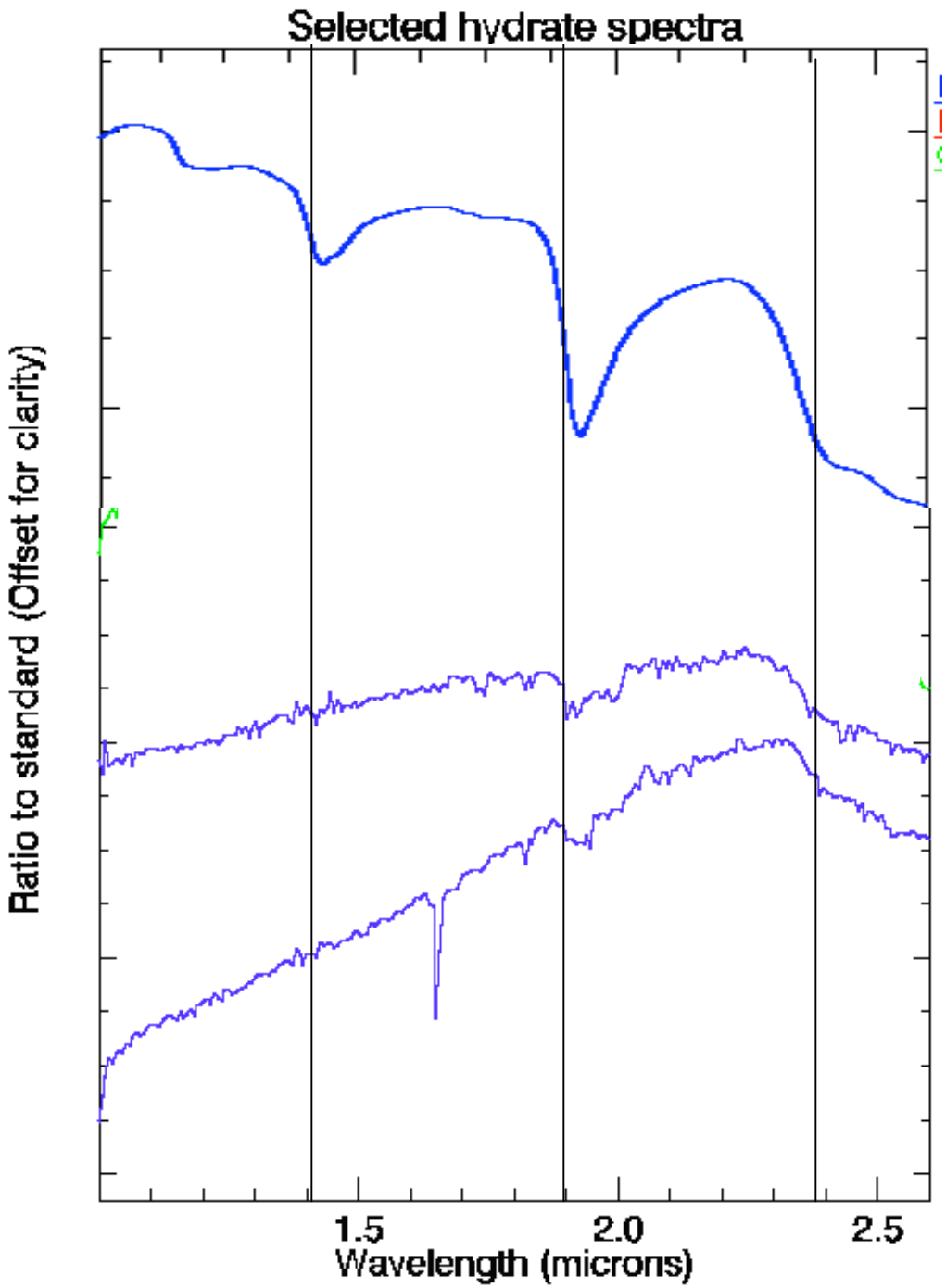




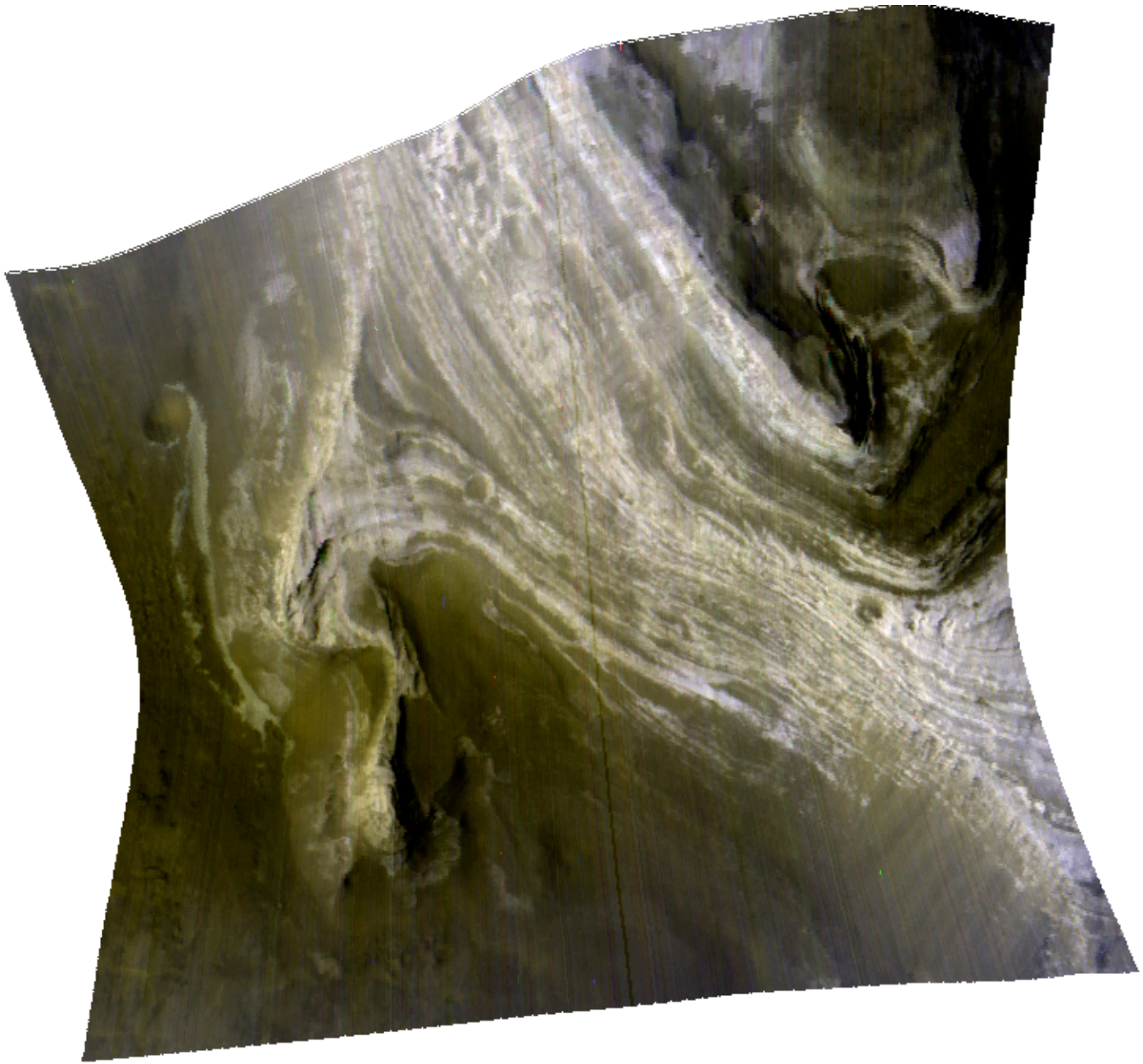
LD_4 (top)

- ~100 m thick
- Package of light-toned LD “sandwiched” between dark–toned, rubbly, clay-rich layers
- Weathering non-uniformly, producing boulders
- Thickness (~5-15 m) of boulder-rich layers varies along strike

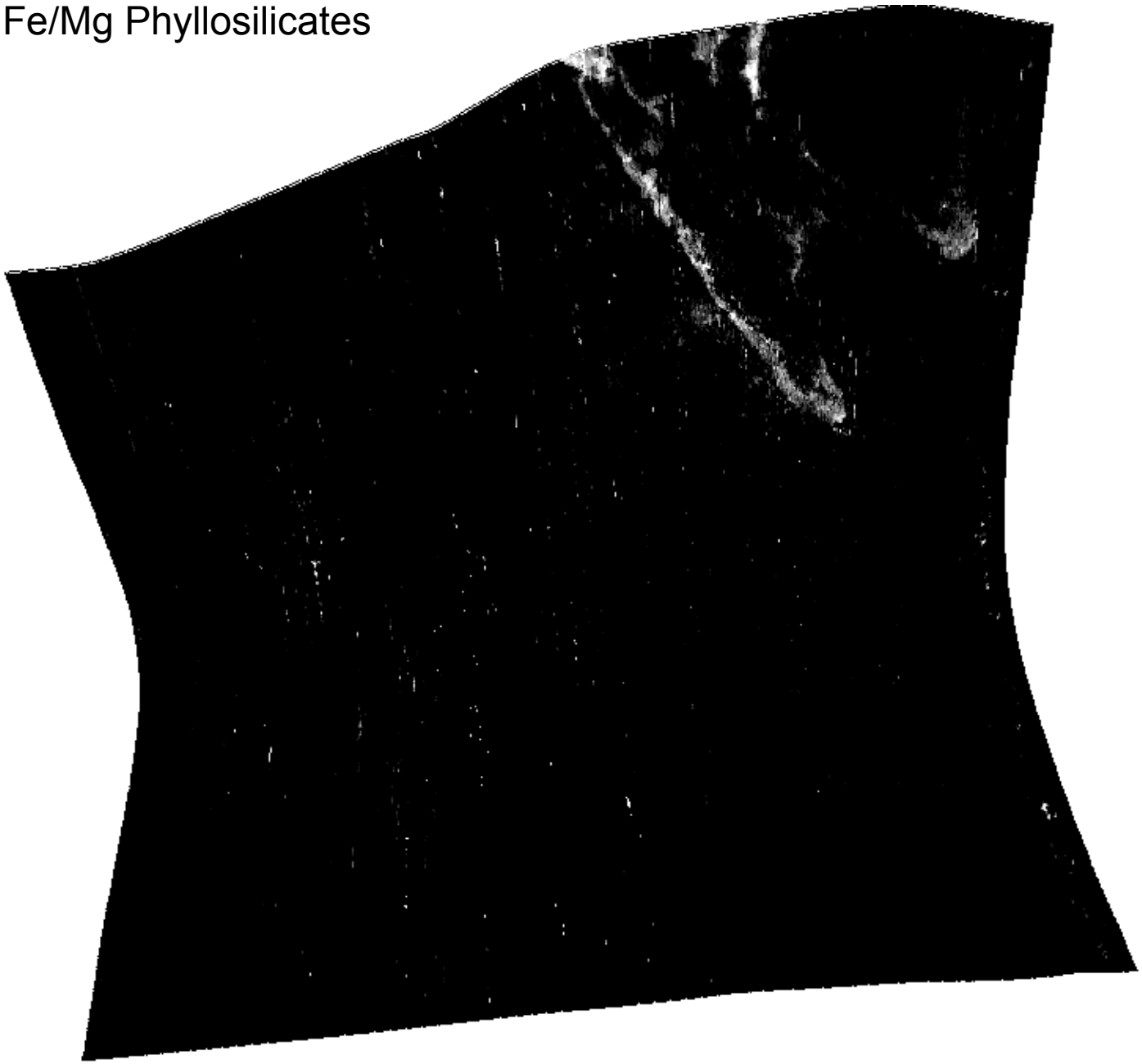

Selected hydrate spectra
Ratio to standard (Offset for clarity)
1.5
2.0
2.5
Wavelength (microns)
Saponite
Nontronite
Smectite



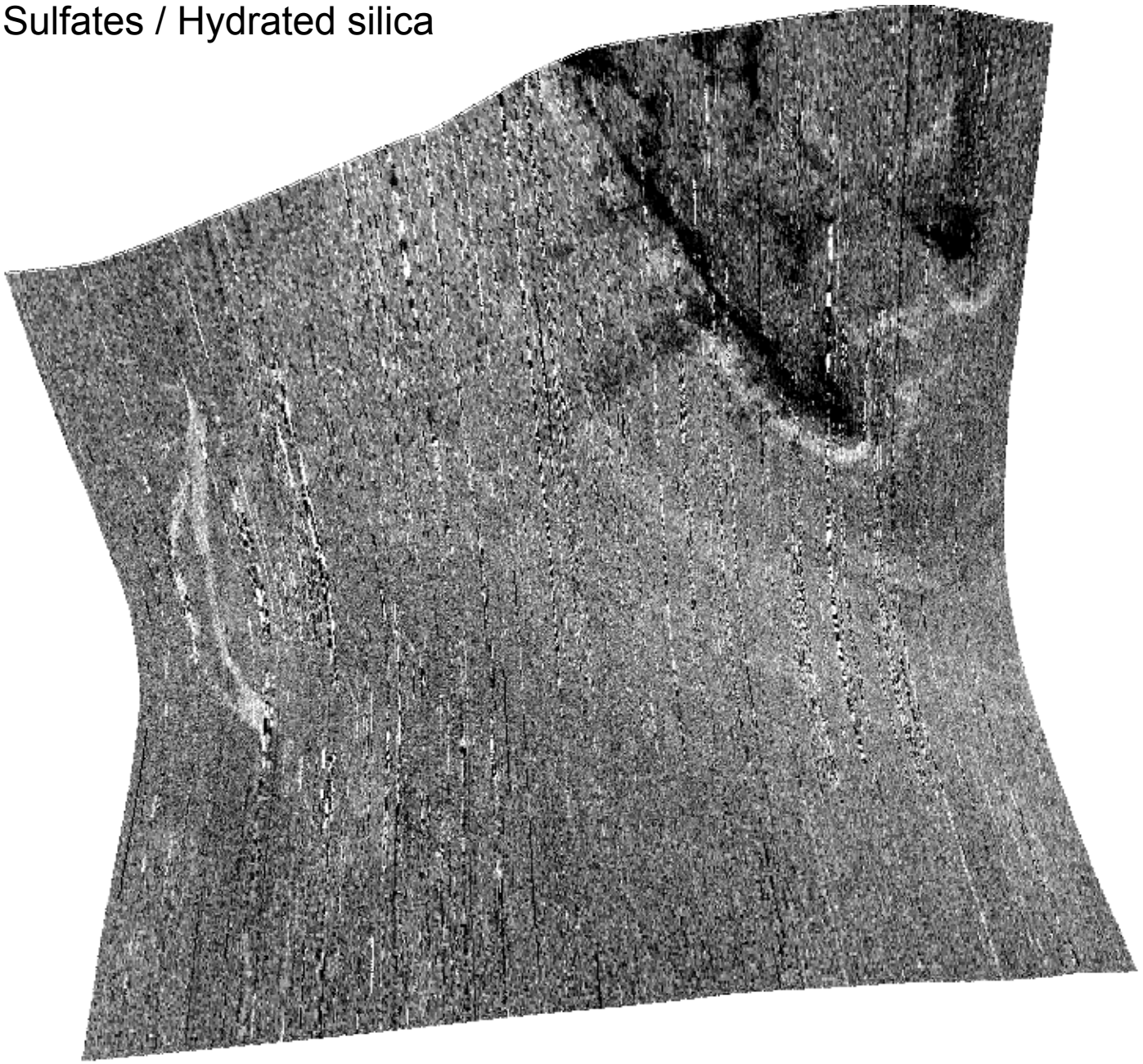
Polyhydrated
Mag. Sulf.



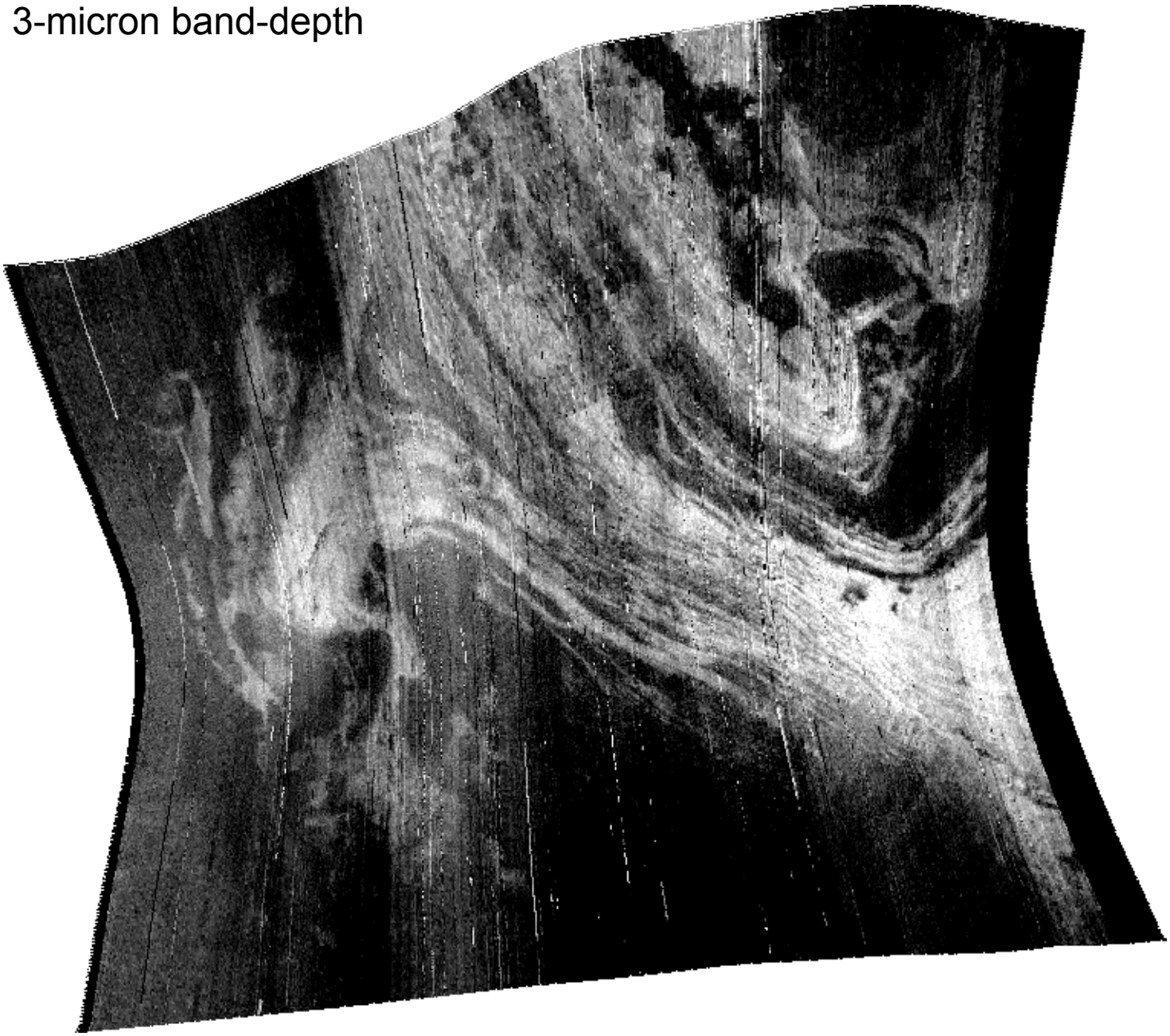
Fe/Mg Phyllosilicates



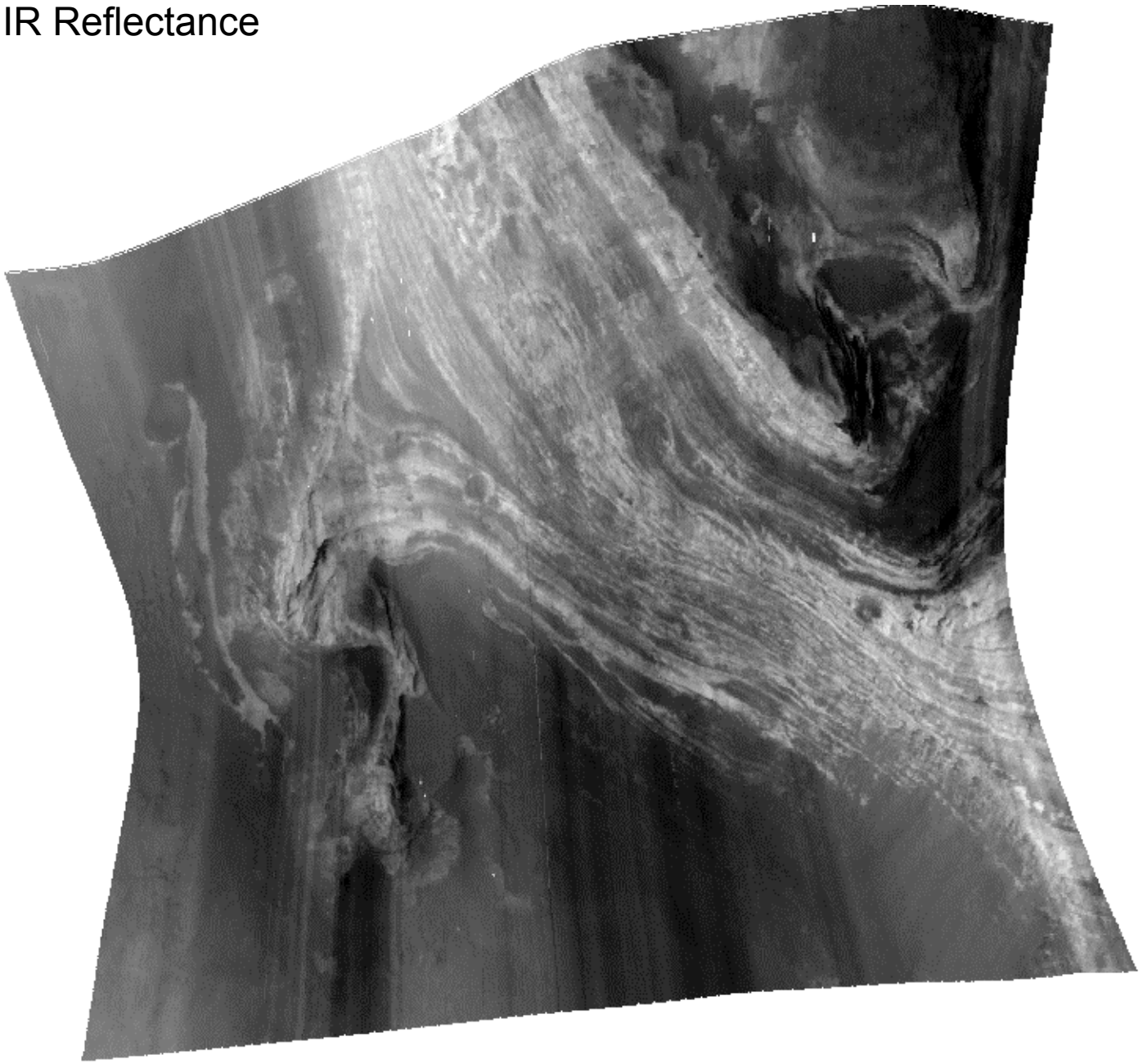
Sulfates / Hydrated silica

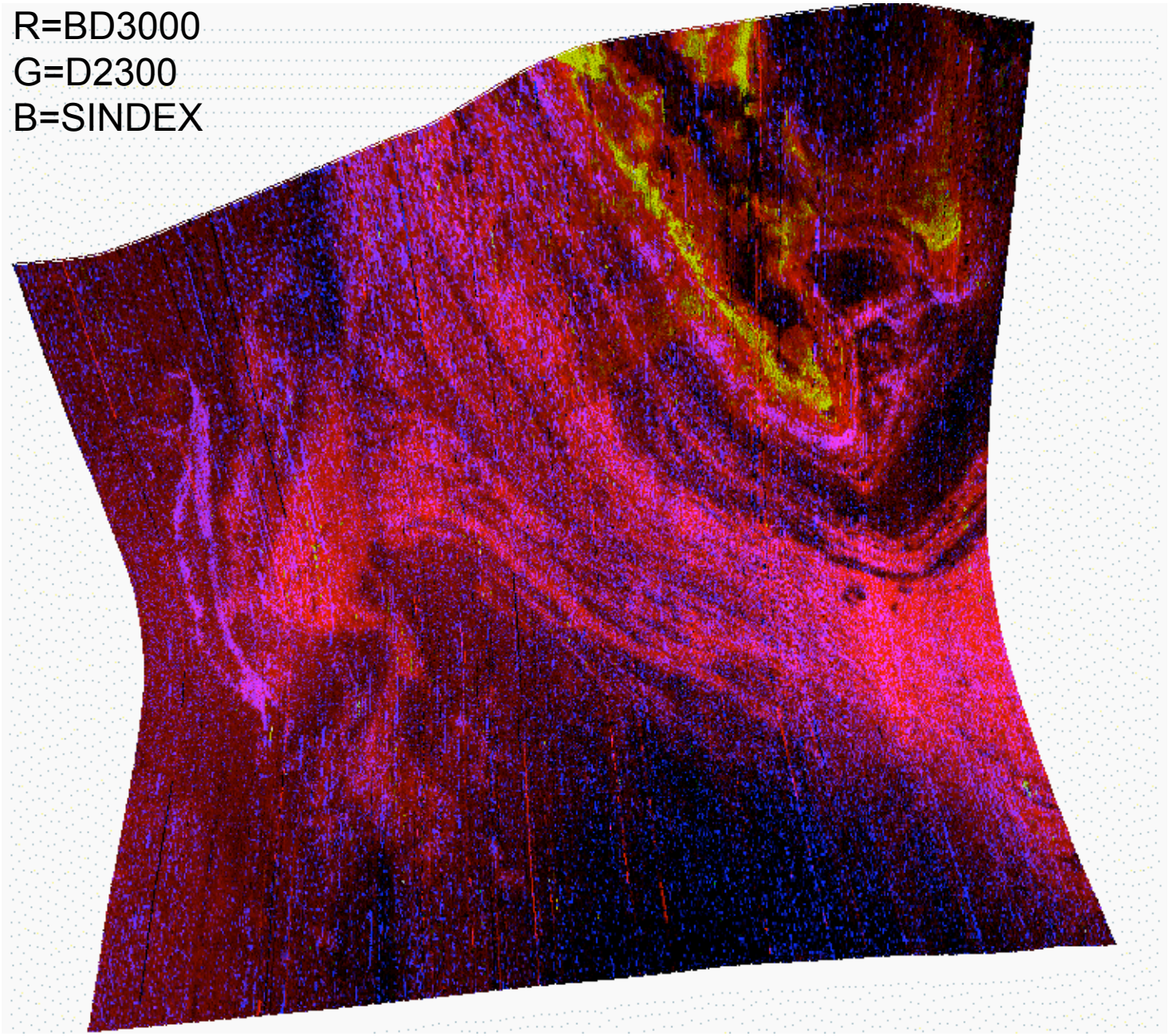


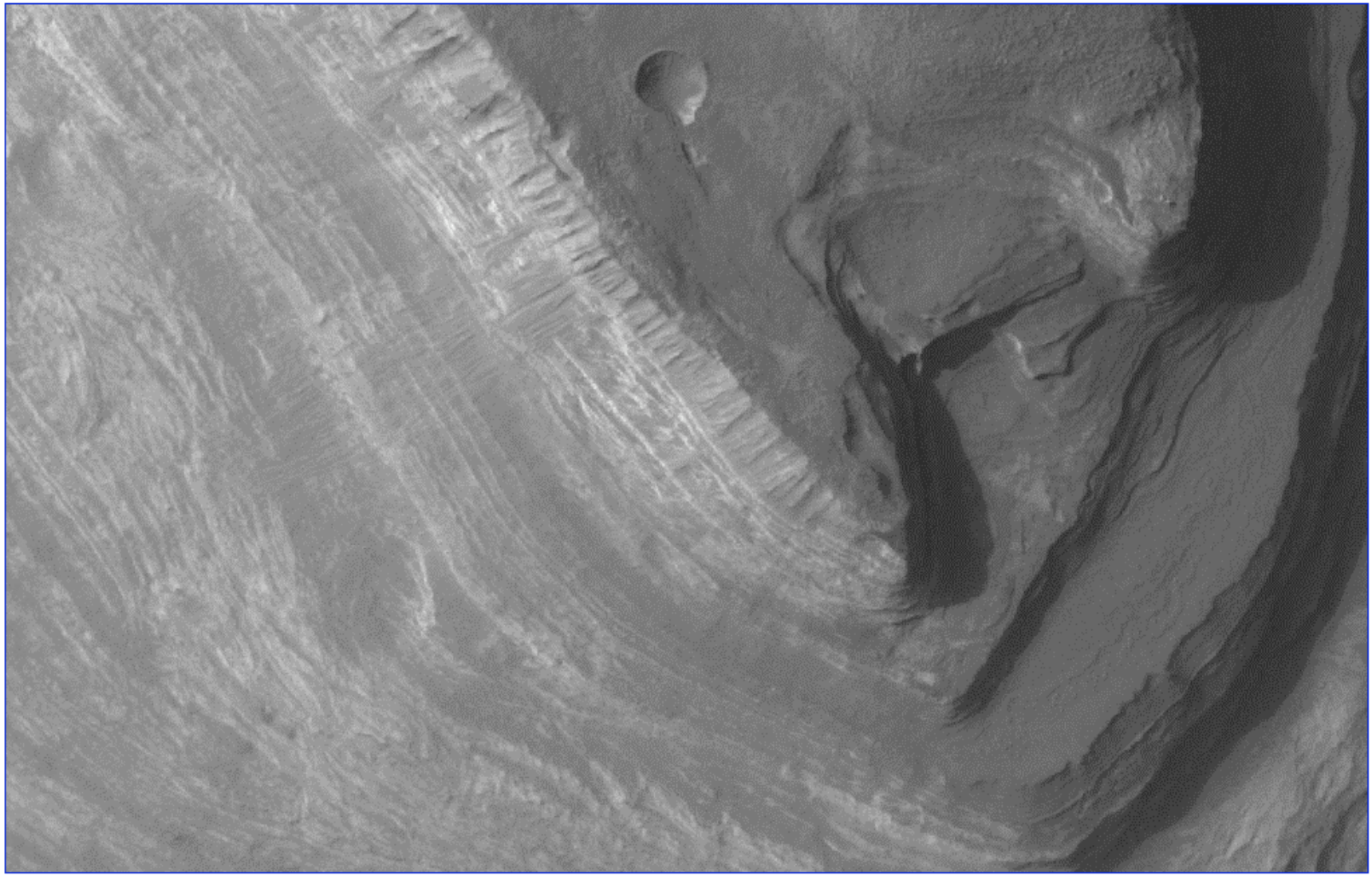
3-micron band-depth



IR Reflectance

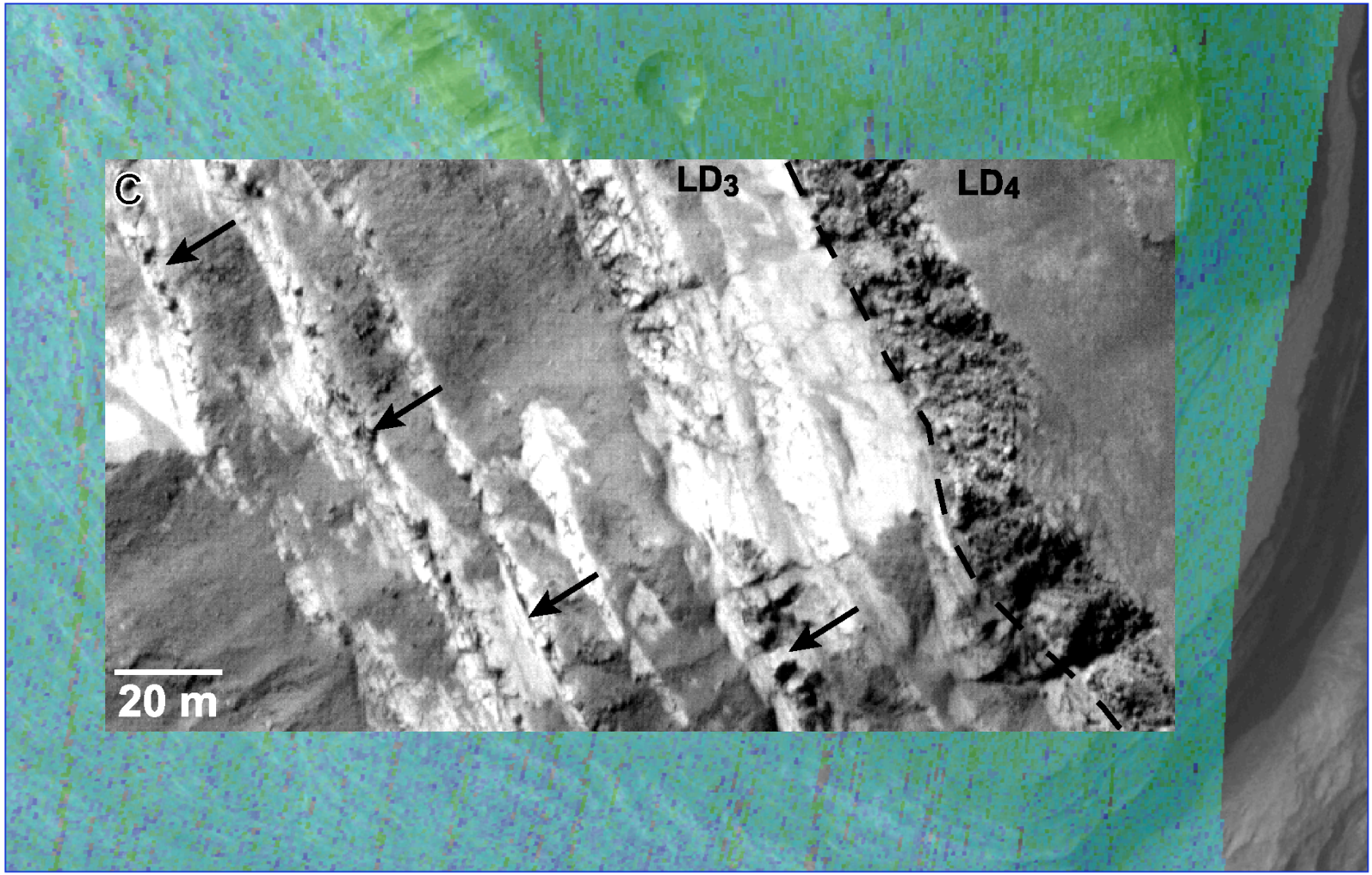



R=BD3000
G=D2300
B=SINDEX

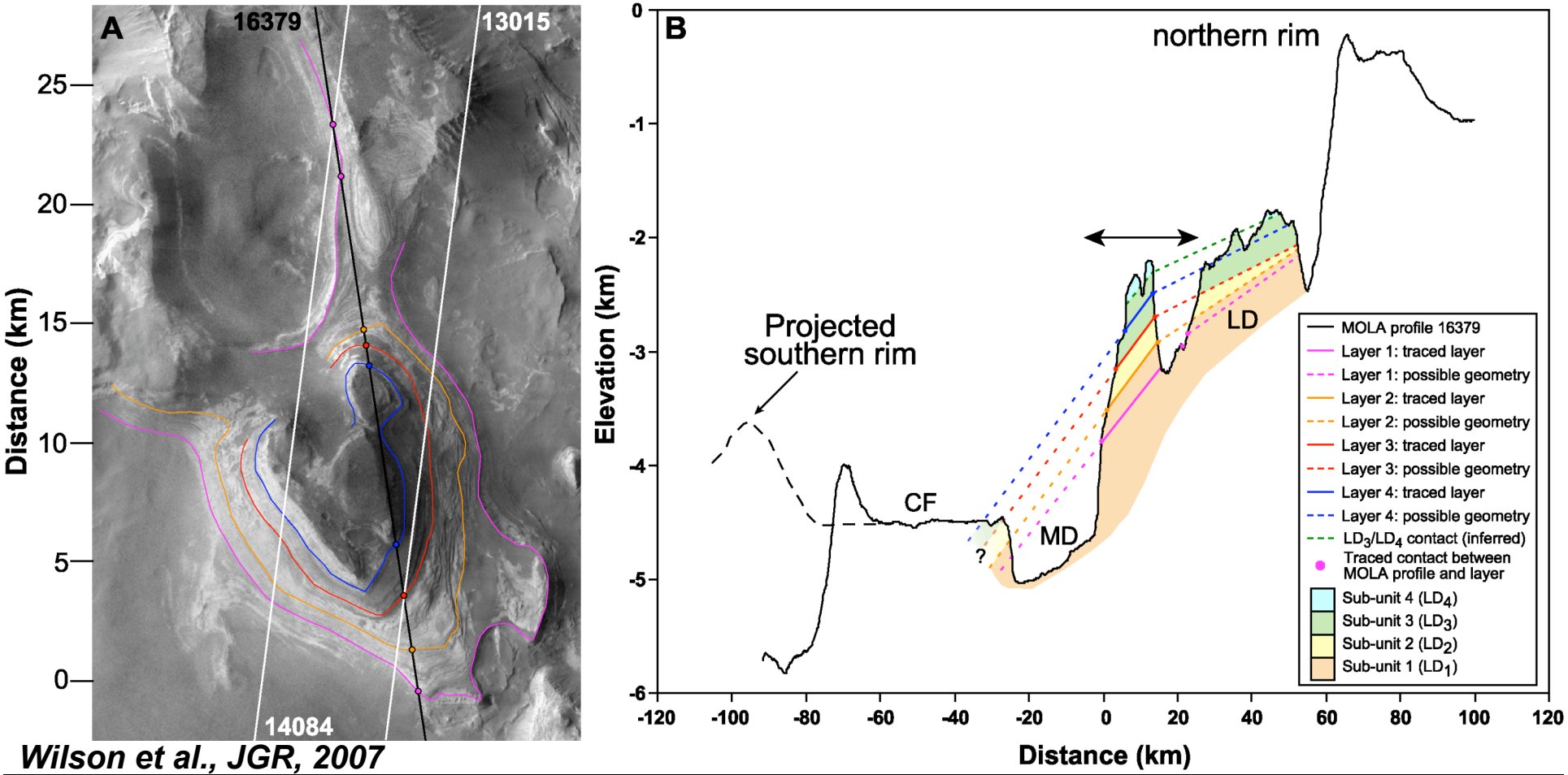


0 0.4 0.8 1.6 Kilometers

N
W E
S


C
LD3
LD4
20 m
Hydrate
Fe/Mg-Phyllosilicate
Km
0 0.250.5 1 1.5 2
N
W
E
S

Original Depositional Geometry of the Layered Deposits

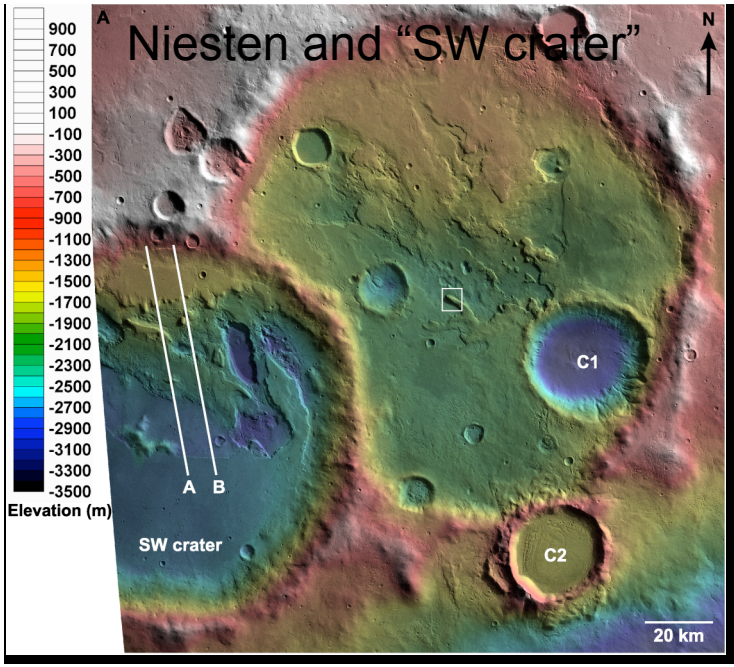


Wilson et al., JGR, 2007

- Maker beds and MOLA tracks provide consistent picture of bedding sloping at ~3 degrees southward along track (similar geometry of LD in Niesten, SW crater)
- If layers were projected across moat deposit (MD), most would intersect the 400 m layered sequence exposed along north-facing scarp

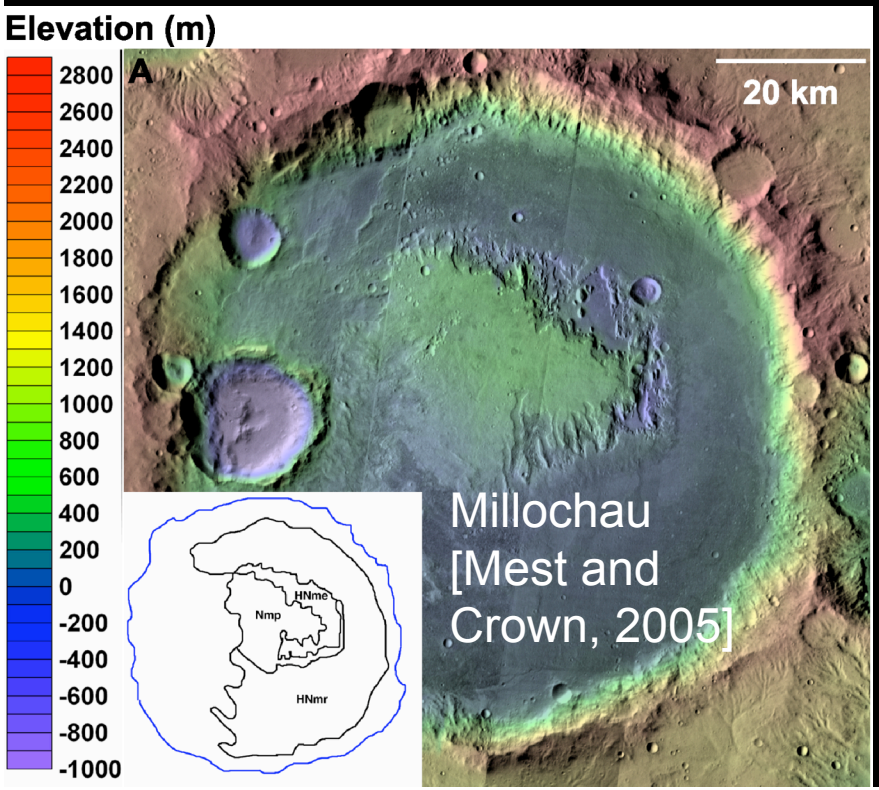
Origin of the Layered Deposits

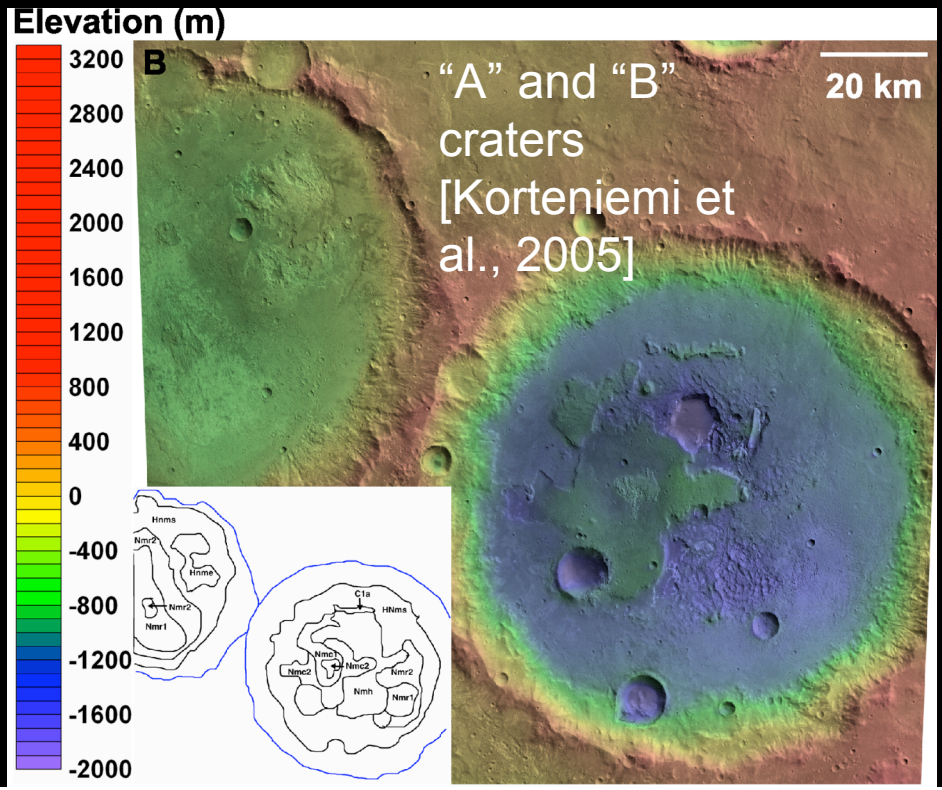
Process	Problem	
Volcanic flows or intrusions	Fine grained, repetitive nature, erodable	X
Mass wasting	Fine grained, repetitive nature, lack of source	X
Volcanic Airfall	Repetitive nature, consistent thickness, induration of layers, lack of obvious proximal volcanic source.	X
Glacial	Faults, absence of glacial flow and internal collapse features, layers of regular thickness	X
Fluvial	Geometry not consistent with prograding fan, lack of course grained material, consistent thickness and no obvious source	X
Aeolian Dunes	Fine grained, lack of cross-bedding	X
Lacustrine	**Nature, geometry and mineralogy consistent with deposition in fluid moderated by an environmental cycle (climate or seasons)**	**O**
Loess	**Fine-grained, terrain conforming and cliff-forming, need upslope winds, might be rhythmically layered**	**O**



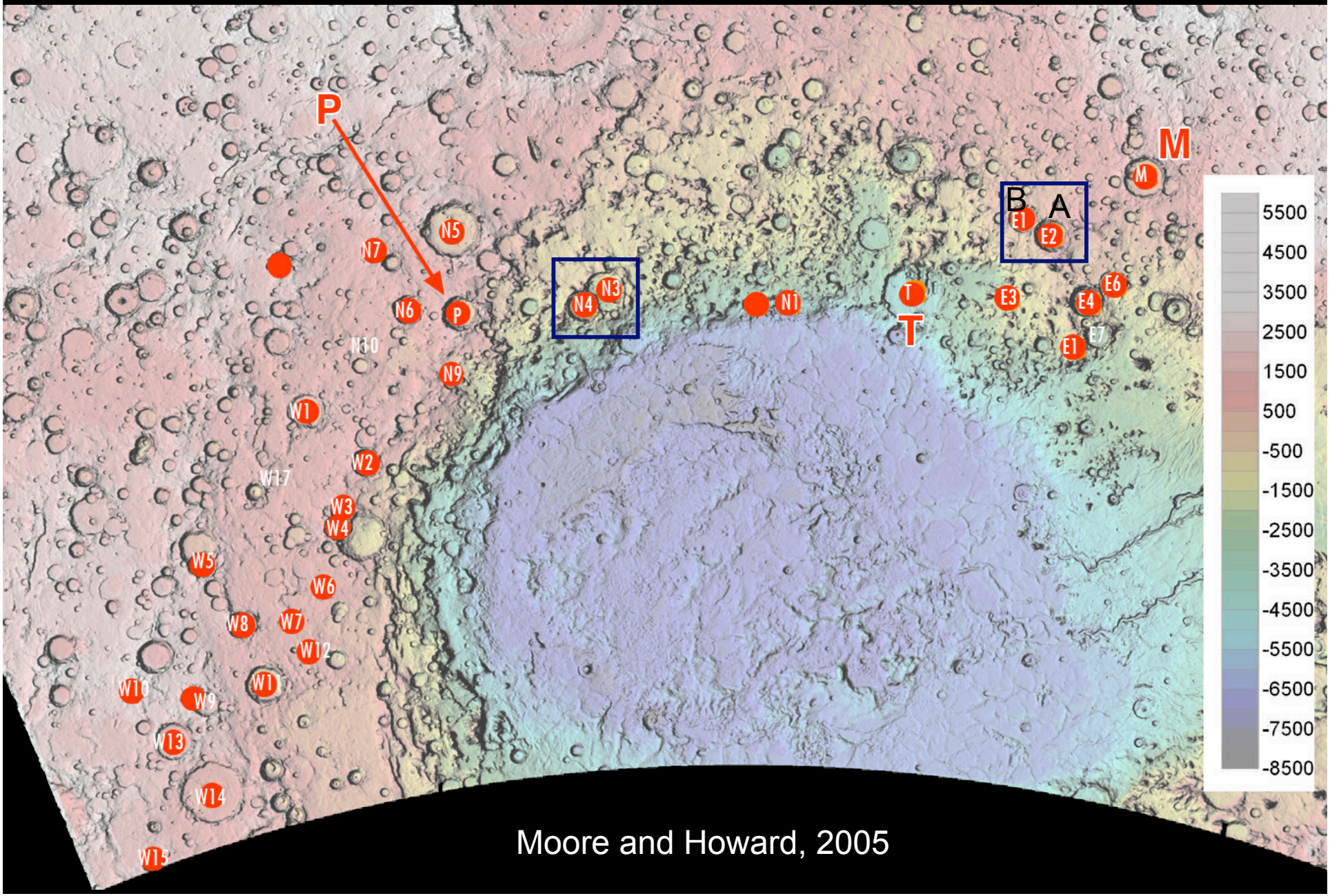
Is Terby One-Of-A-Kind?

- No! Terby is special, but not unique
- Similar morphology in other craters around Hellas
  [comparative study by *Wilson et al., JGR*, 2007]
- Important to discern regional history of deposition and erosion



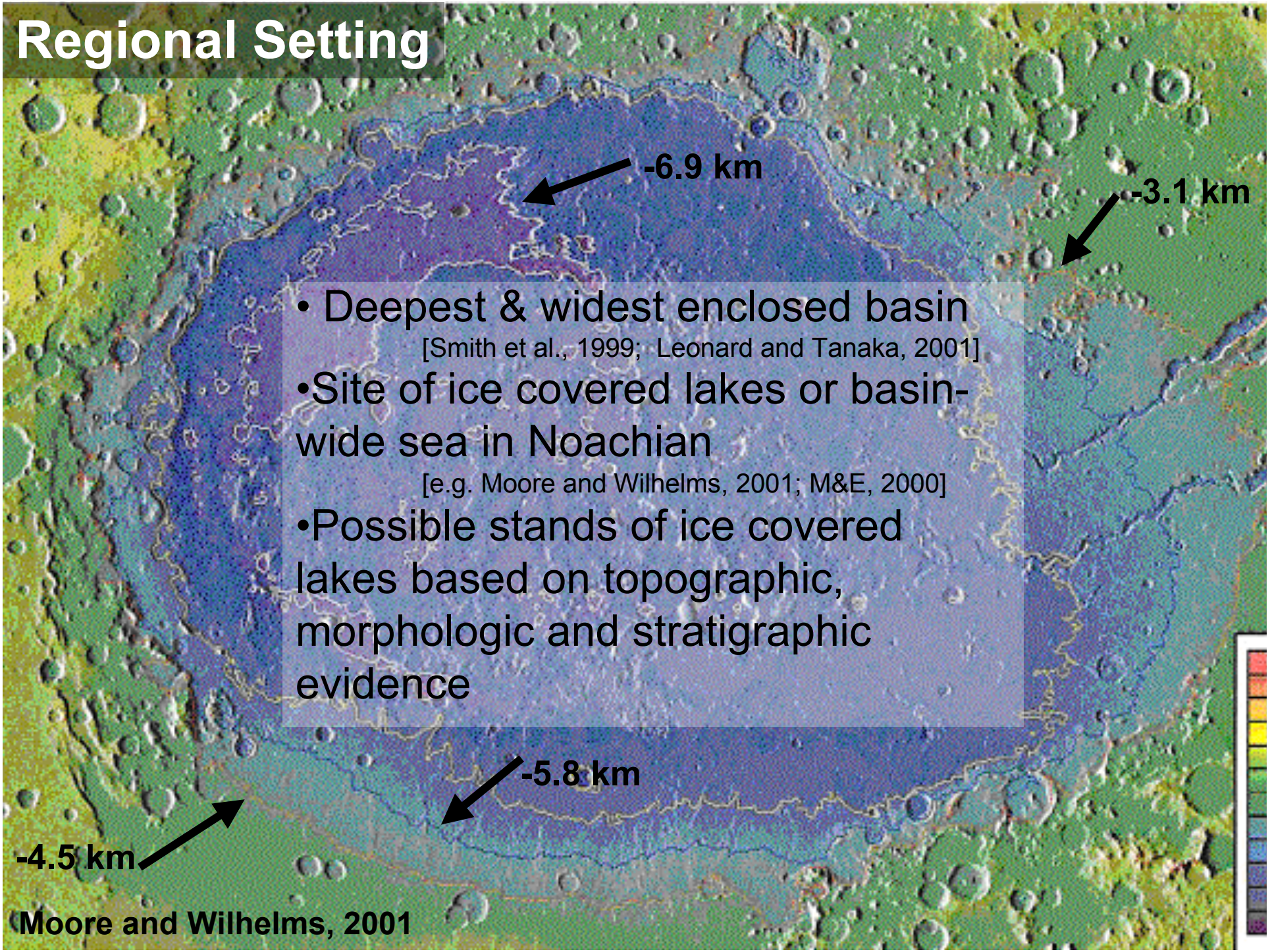


Craters in Circum Hellas with Pits and Layers

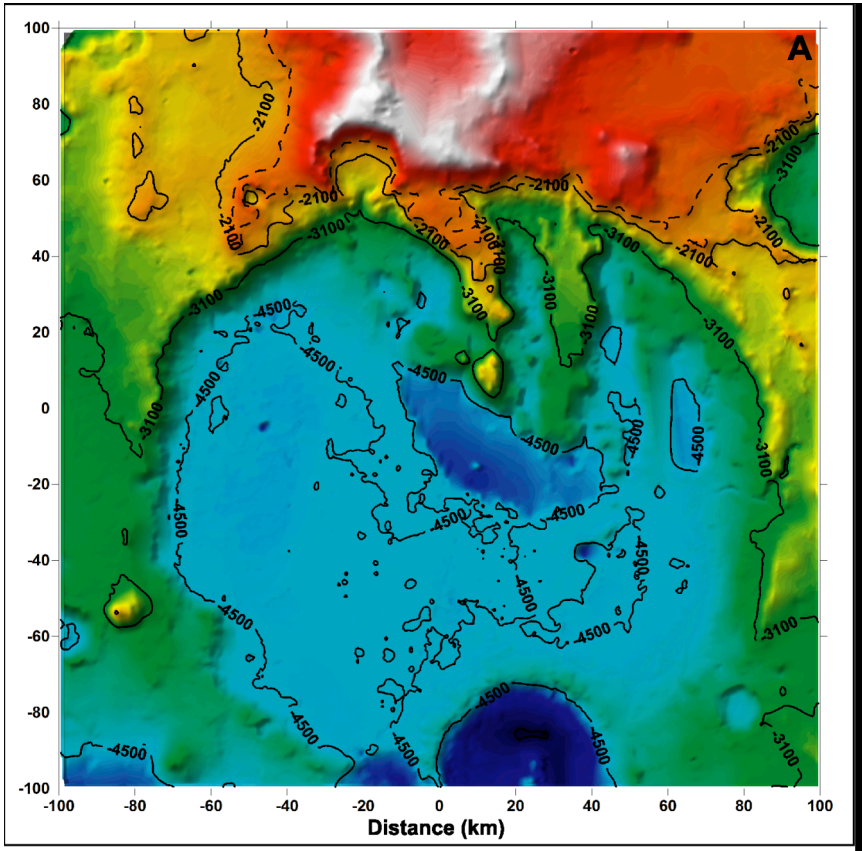


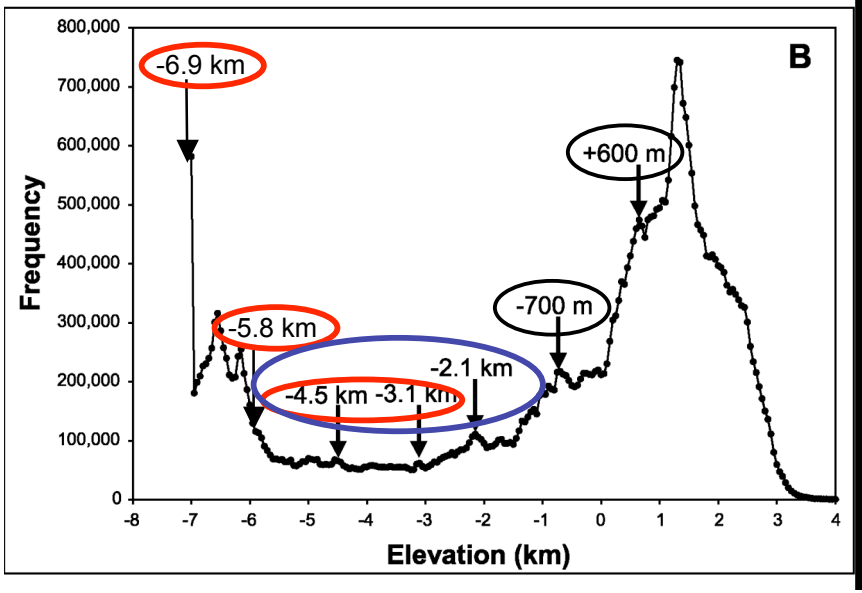
Moore and Howard, 2005

Regional Setting



- Deepest & widest enclosed basin
  [Smith et al., 1999; Leonard and Tanaka, 2001]
- Site of ice covered lakes or basin-wide sea in Noachian
  [e.g. Moore and Wilhelms, 2001; M&E, 2000]
- Possible stands of ice covered lakes based on topographic, morphologic and stratigraphic evidence

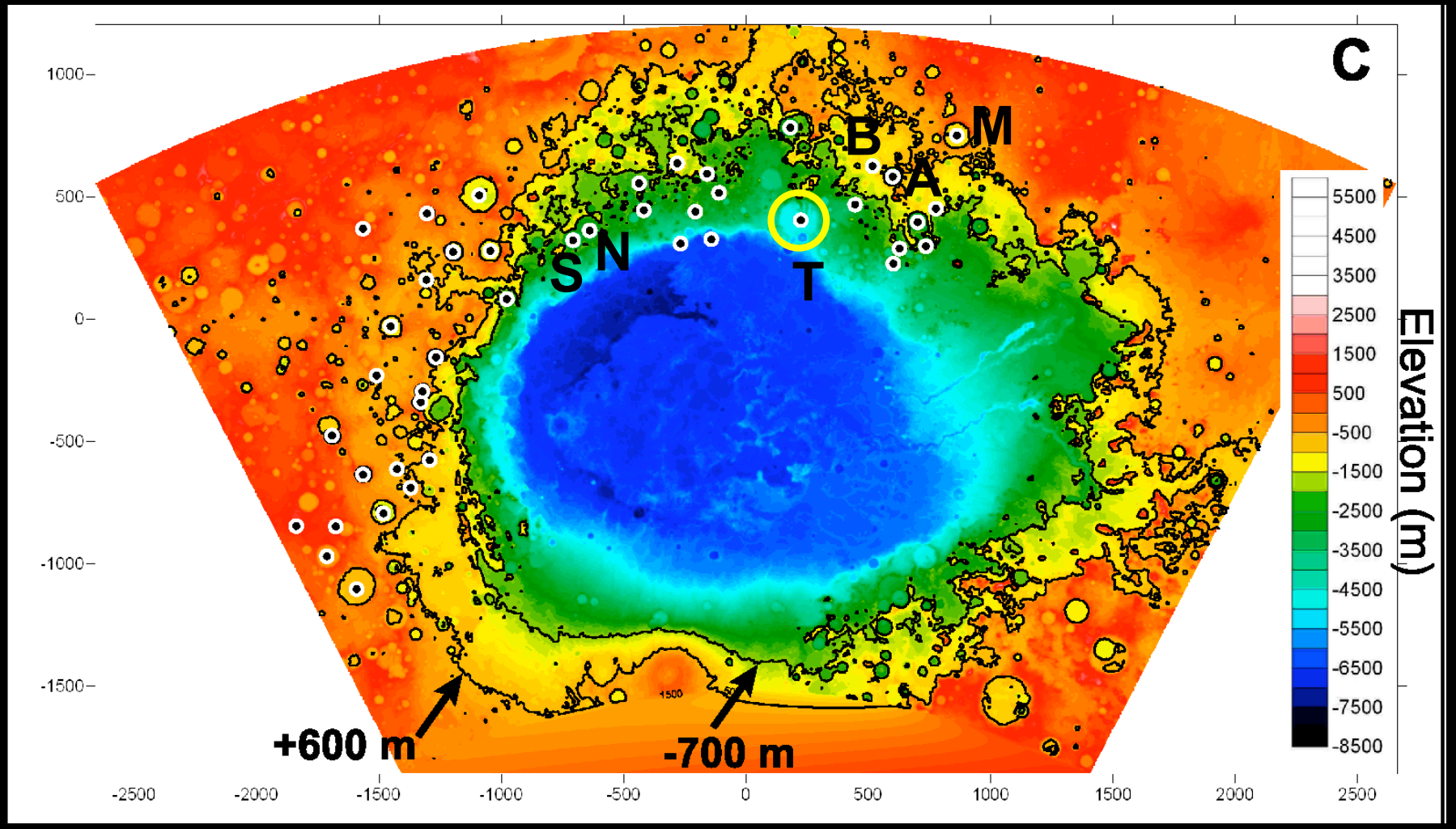




Regional Setting

- Histogram of Elevation in around Hellas
  - Peaks at -6.9 km, -5.8 km, -4.5 km, - 3.1 km, correlate to stratigraphic evidence [Moore and Wilhelms, 2001]
  - Possible water stands in Terby at -2.1 km, -3.1 km, -4.5 km
  - High/low elevation related to deposition/erosion?
  - Also peaks at -700 m and +600 m, correlate to well-developed, inward facing scarps

Regional Setting and Habitability



Wilson et al., JGR, 2007 [*after Moore and Howard, 2005*]

- Circum-Hellas craters with pits/layers ≤ +600 m contour
- Poss. deposition in large, long-lived (?) lake = hospitable!
- Terby submerged; sediment trap; poss. long-shore drift envt

MSL Science Goal Scorecard – A+

Ability to characterize geology/geochemistry

- Geologic history is complex but perhaps more well-constrained than other craters with interior LD
- Stratigraphy, geometry & age of LD similar to circum-Hellas craters
- Well-studied regional context: Hellas

Evidence for Habitable Environment

- Best chance to study large, long-lasting, deep (up to 3.6 km), late-stage water body
- Long-standing periods of water better than ephemeral crater lakes in providing stable, hospitable environment for establishment of life

Preservation of biosignatures

- Thick (2.5km) exposure of sedimentary deposits (varying stratigraphy)
- Nature of LD (fine-grained, laterally continuous, sub meter-scale bedding, mineralogy, etc) ideal & consistent with lacustrine origin
- ***Strong*** Fe/Mg **clay** and hydrated signature may enhance preservation of organics

Ability to assess biological potential with MSL payload

- LD accessible in/outside both ellipses; diversity of landforms/processes

ENGINEERING SCORECARD FOR TERBY CRATER		
ENGINEERING PARAMETER	**REQUIREMENT**	**PASS/FAIL**
Latitude	45°N to 45°S	PASS
Altitude	≤ + 1 km	≤ -4.5 km PASS
Landing ellipse diameter	≤ 25 km	PASS
Slopes	2 to 10 km length scale	PASS
	1 – 2 km length scale	PASS
	200 – 1000 m length scale	TBD
	2 - 5 m length scale	PASS
Load bearing surface	Not dominated by dust	PASS
Rock Height	≤ 0.6 m	TBD
Radar Reflectivity		TBD
Surface winds	<15 m/s (steady); <30 m/s (gusts)	TBD

Summary

- Thickness (> 2 km thick), nature and regional setting of LD indicative of lacustrine origin
- LD in Terby characteristic of Hellas region
- Best chance to study large, long-lasting, late-stage water body
- Fe- or Mg-rich **clay minerals** and hydrated minerals – preservation of organics
- Satisfies MSL Science Goals
- Mid-latitude processes (fan deposit, ice processes)
- Important scientific issues to be resolved:
  - Origin of layers
  - Source of material (aeolian, volcanic, etc?)