Possible Clastic Origin for Olivine-Rich Rocks in the Nili Fossae Region: Implications for NE Syrtis, Midway, and Jezero Landing Site Science

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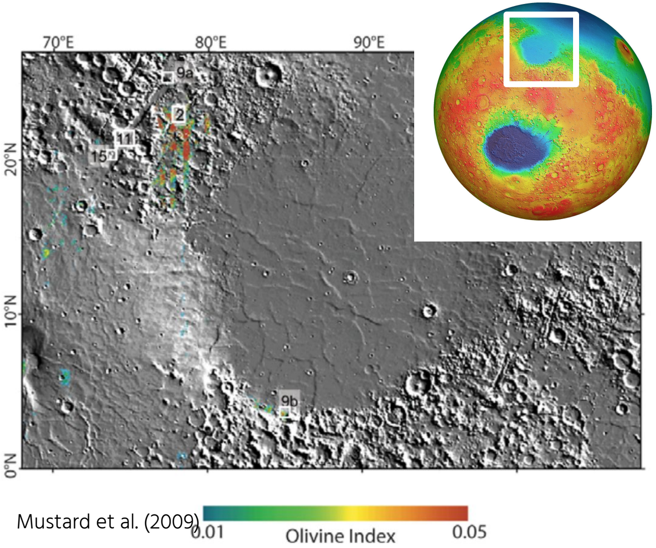
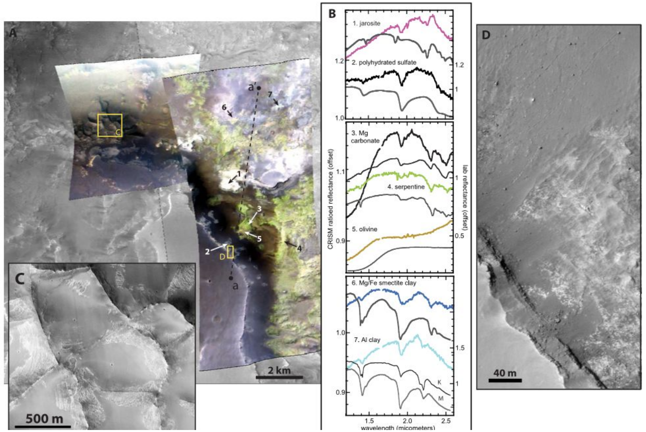
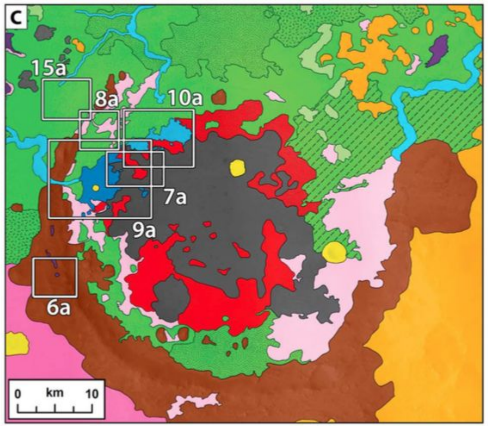
Circum-Isidis Olivine-Rich Unit



Mustard et al. (2009)



Ehlmann and Mustard (2012)



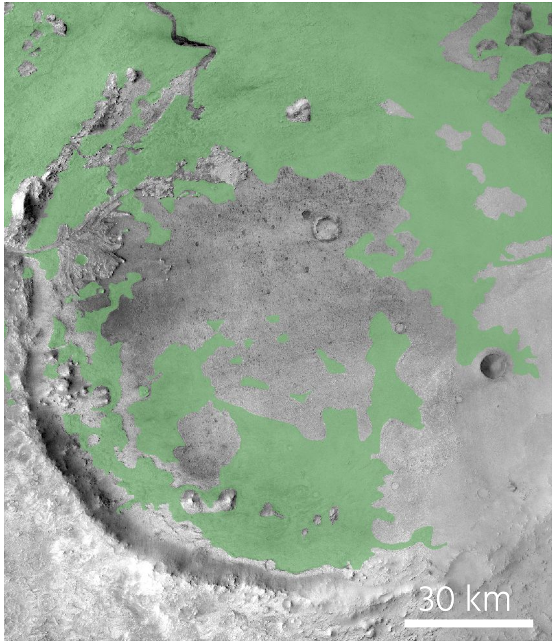
Goudge et al. (2015)

Enriched in $Fo_{68\text{-}91}$ olivine (~10-30%), widely distributed (Hamilton and Christensen, 2005) (70,000 km^2; Kremer et al., *In Review*)

Diversely altered, with exposures of carbonate with local exposures of serpentine and talc/saponite

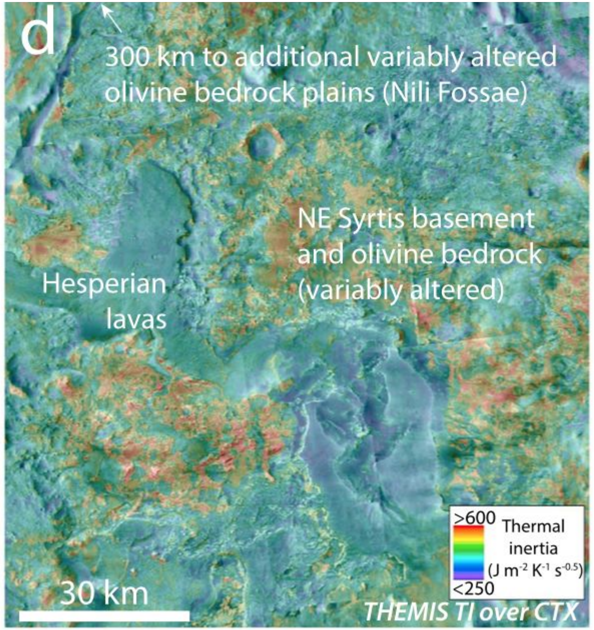
Exposed at **NE Syrtis, Midway, and Jezero** including olivine-rich analog(?) in Columbia Hills

Previous Hypotheses and Observations



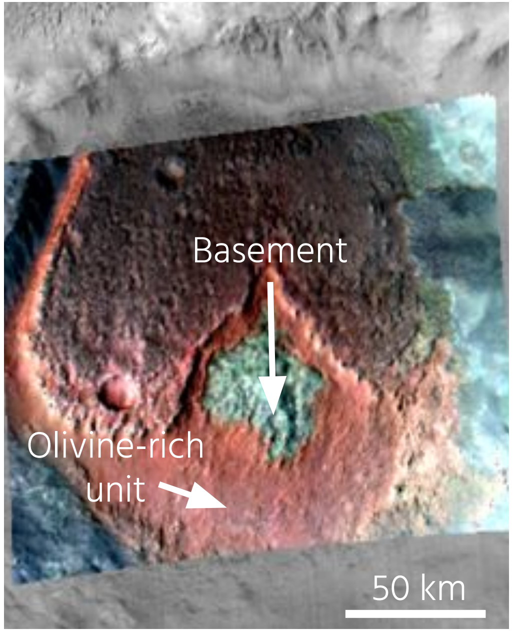
(after Goudge et al., 2015)

Unit superposes crater that is younger than the ~1900 km diameter Isidis impact basin



(Rogers et al., 2018)

Moderate thermal inertia, minimal regolith or craters, yardangs: unit may be friable, potentially inconsistent with most melt rocks



(Mustard et al., 2009)

Intrusive origin ruled out by superposition of basement unit

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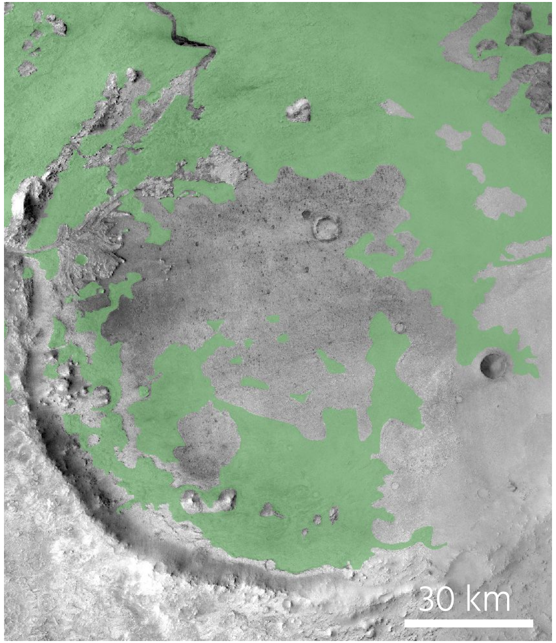

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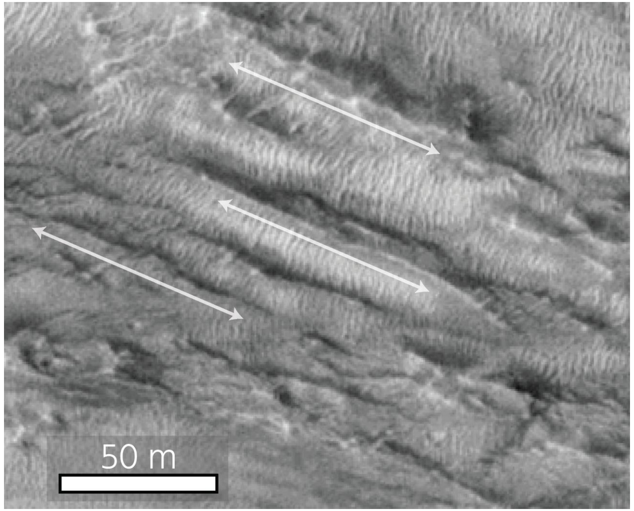

Kremer et al. *In Review*

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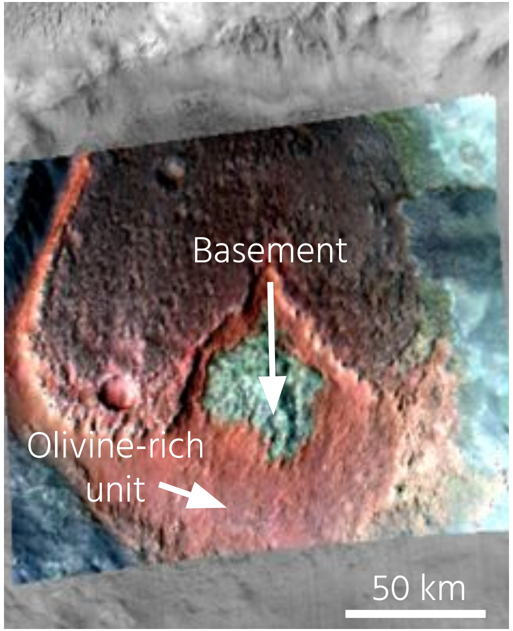

(Mustard et al., 2009)

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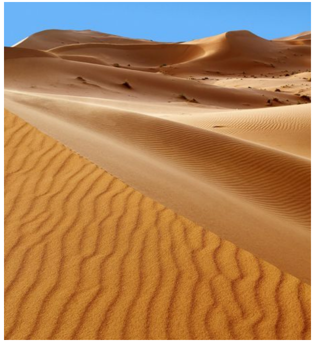
Hypotheses for Origins of Olivine-Rich Unit

Intrusive complex? (Hoefen et al., 2003)

Lava? (Hamilton and Christensen, 2005; Tornabene et al., 2008)

???

Non-Isidis Impact condensate or ejecta?



Sand lag deposit, erg, or other epiclastic (Rogers et al. 2018)?

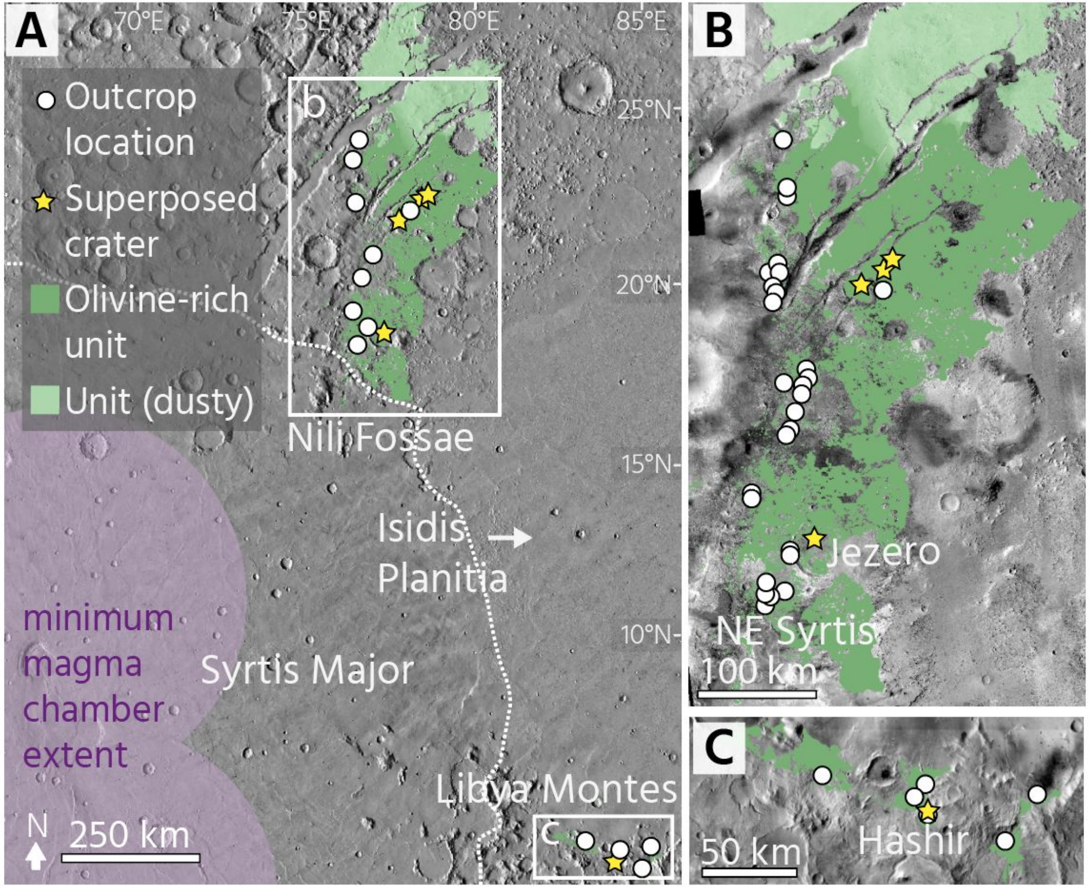
Volcanic ash??

Ash-Fall Characteristics

An ash fall deposit should:

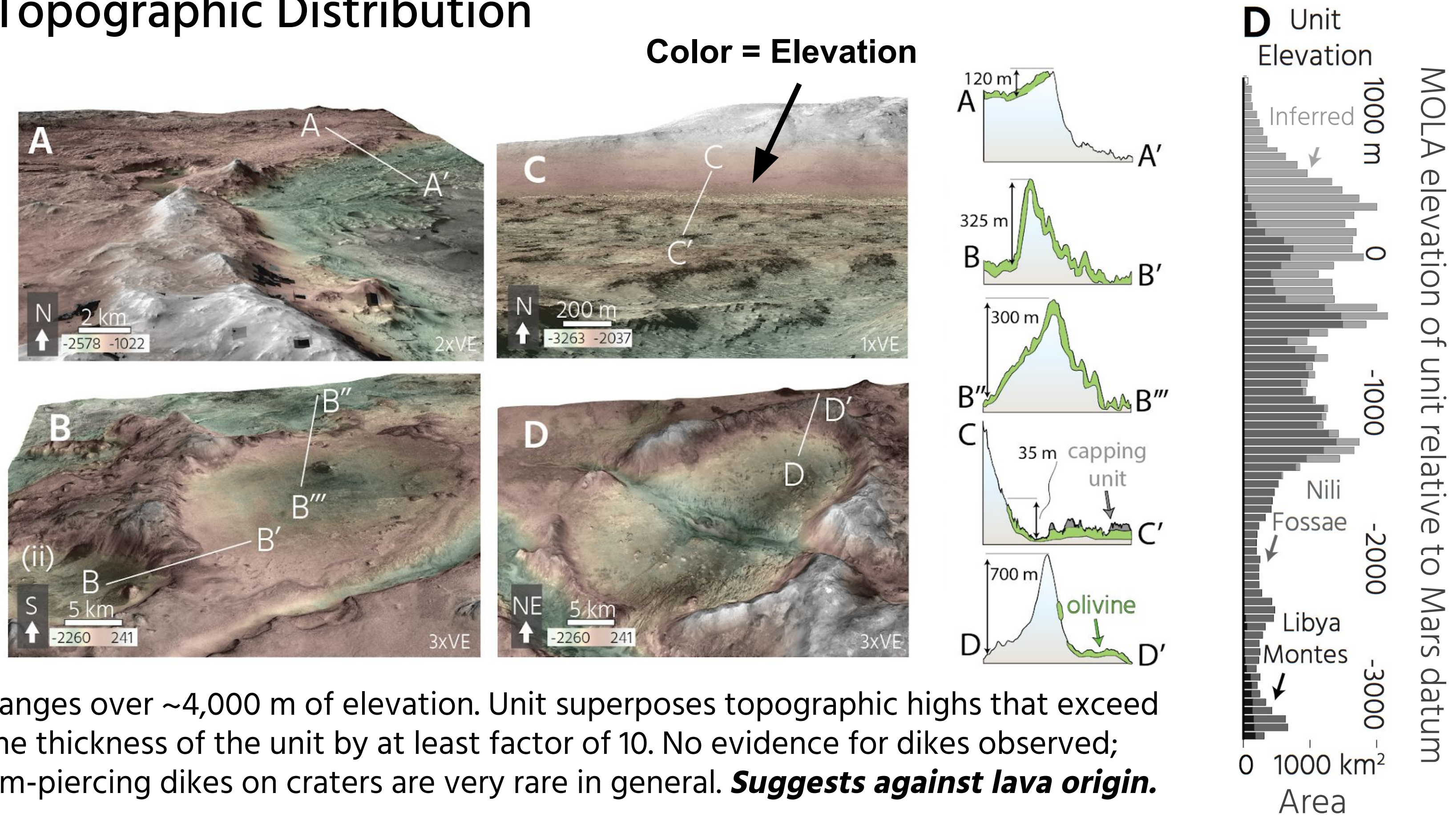
- Drape topography
- Superpose local topo highs
- Exhibit wide regional topographic range
- Consistency with grain size and composition from orbital spectroscopy
- Have thin and parallel internal layering
- Thin away from source

This study: mapping, topo distribution, morphology, and strat, previous spectral modeling. Compared with expected deposit characteristics



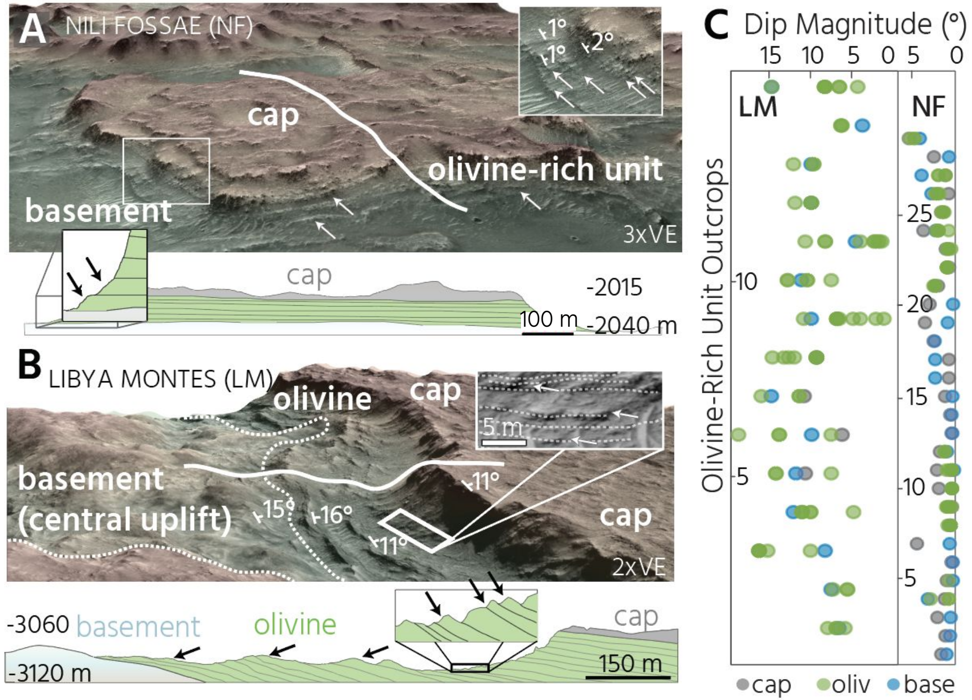
CTX Mosaics from Jay Dickson

Topographic Distribution



Ranges over ~4,000 m of elevation. Unit superposes topographic highs that exceed the thickness of the unit by at least factor of 10. No evidence for dikes observed; rim-piercing dikes on craters are very rare in general. ***Suggests against lava origin.***

Measured Bedding Parallelism and Topographic Draping



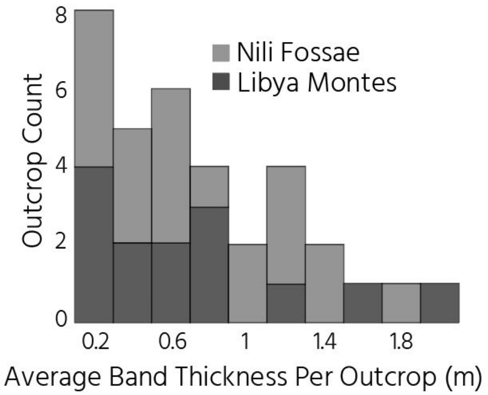
Quantitative and qualitative evidence that "banding" is layering, the unit drapes topography, and conformably overlain by capping unit

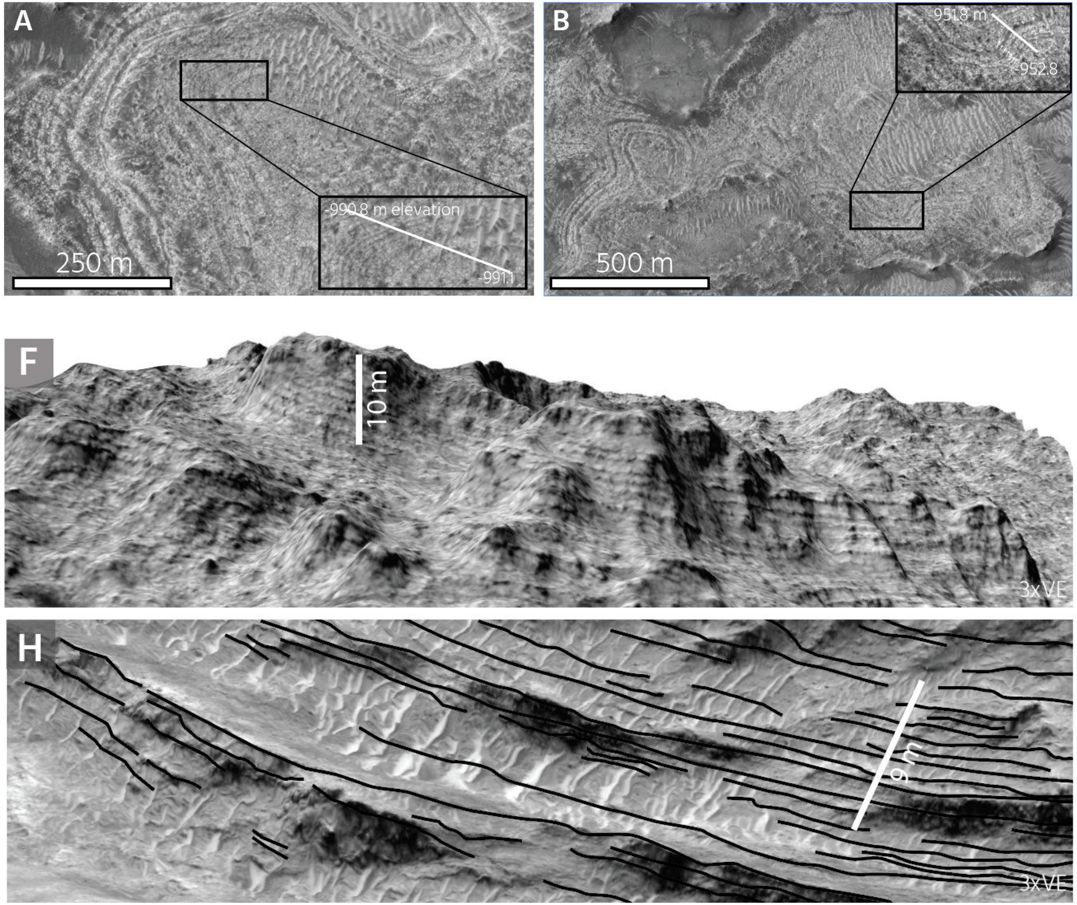
Draping and conformable top contact suggest against aeolian epiclastic deposition.

Can test further criteria using verified bedding

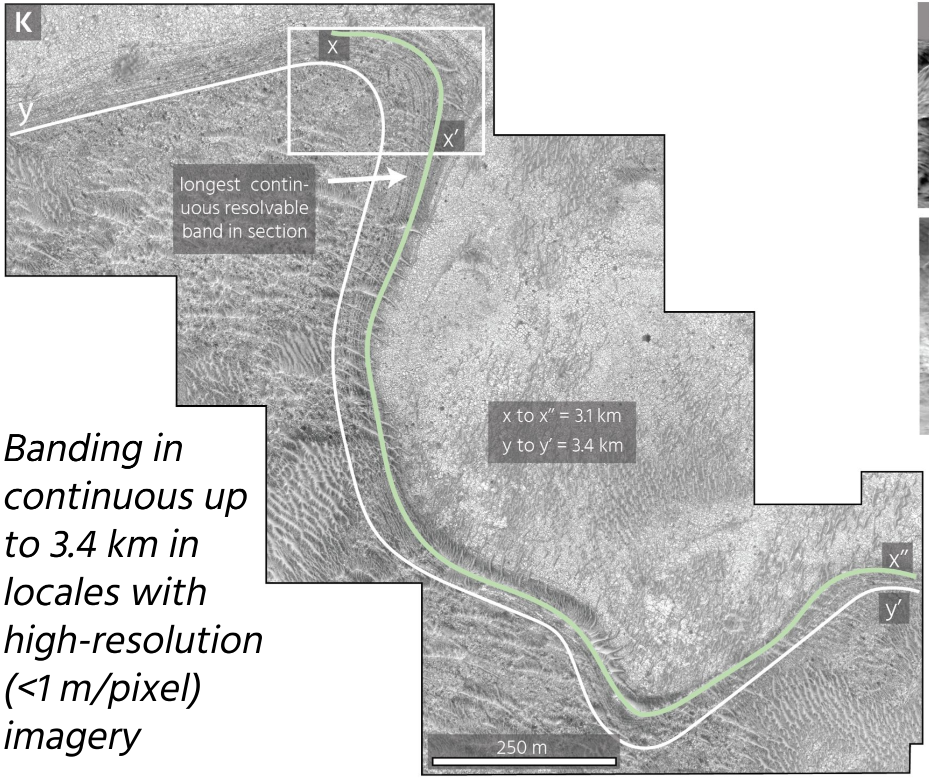
Bedding Thickness

Parallel, meter- to decimeter-scale (and even thinner) bedding with variably alternating tonality pervasive. ***Inconsistent with expected characteristics of flood lavas, global impact spherule deposits, or lag deposits***

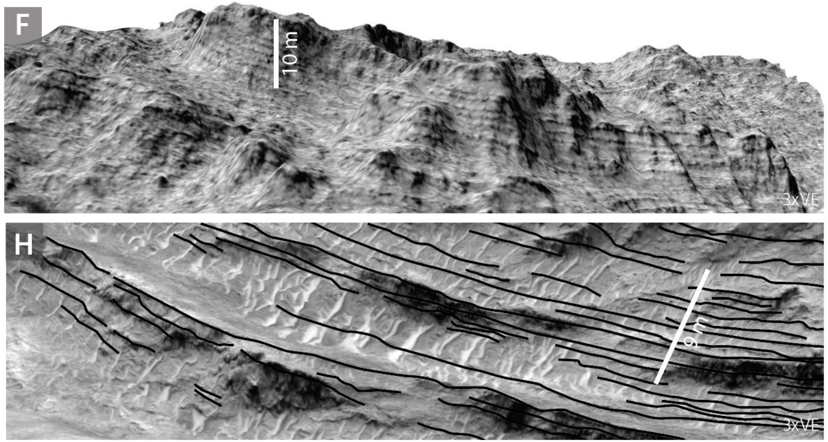




Bedding Continuity: Planar bedding or low-angle cross-stratification?



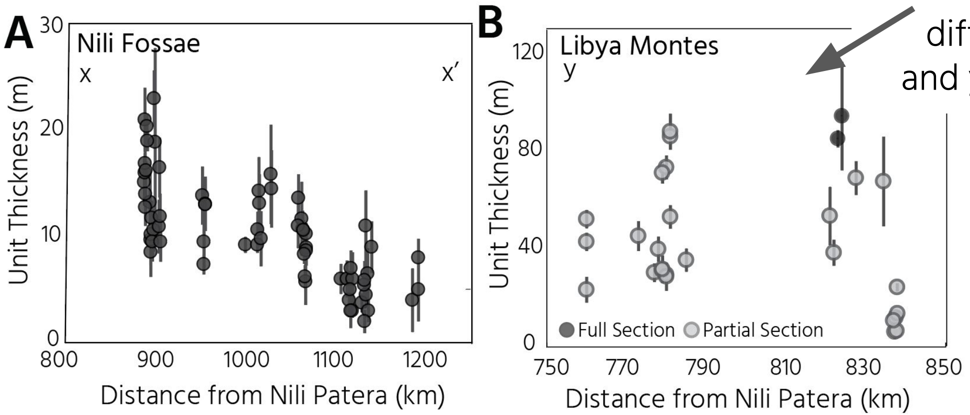
Banding in continuous up to 3.4 km in locales with high-resolution (<1 m/pixel) imagery



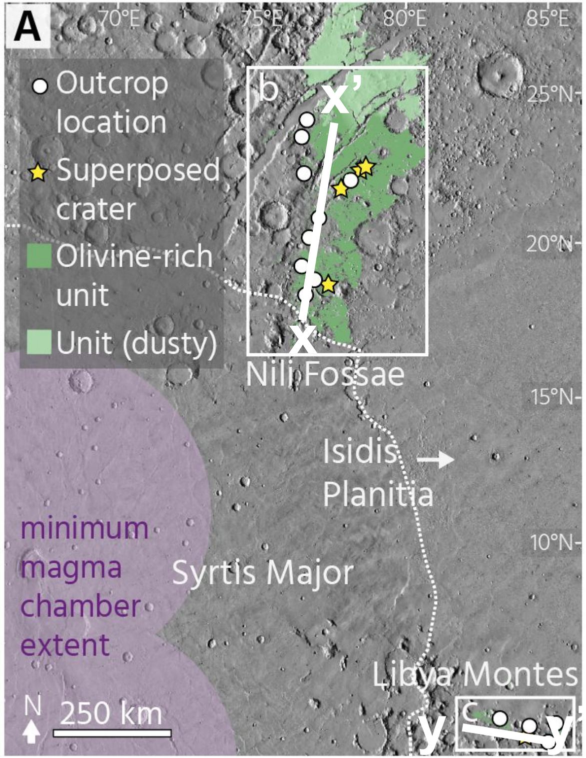
Continuity of m to dm (and cm?) layering in different outcrops over 70,000 km^2 extent consistent with planar bedding

Does not totally rule out low-angle cross-stratification

Thickness Trends in Nili Fossae and Libya Montes



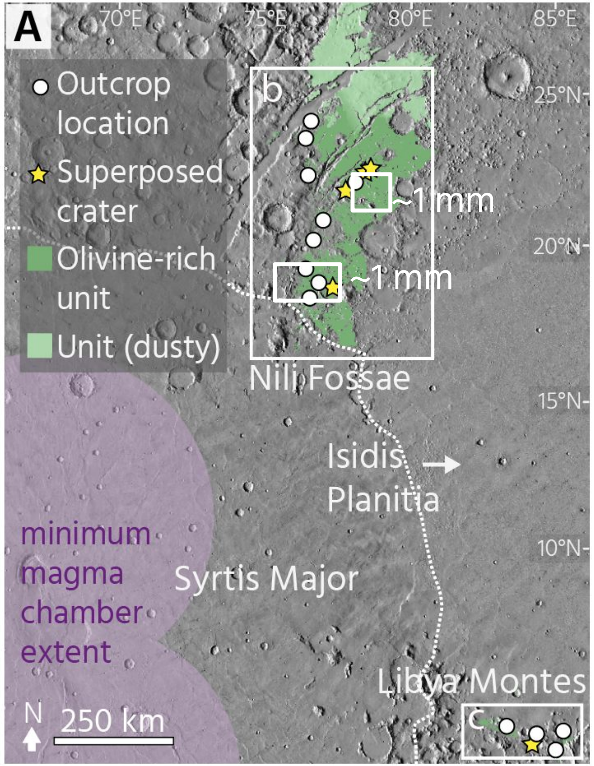
Plots at different x and y scales



Crude outcrop thickness decline in Nili Fossae and no trend observed among thicker, eroded Libya Montes outcrops

Multiple interpretations for clastic deposits

Where would ~1 mm grains have come from?



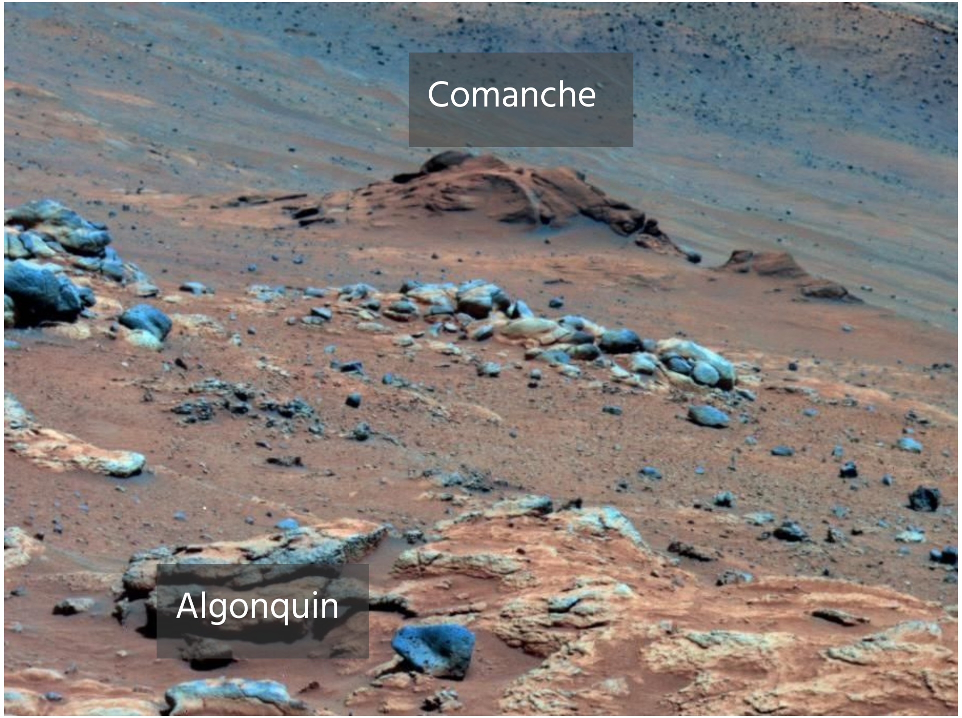
~1 mm modeled grain size (Edwards and Ehlmann, 2015; Salvatore et al., 2018) coarser than average coarse-grained inactive aeolian deposits on Mars or impact condensate crystals

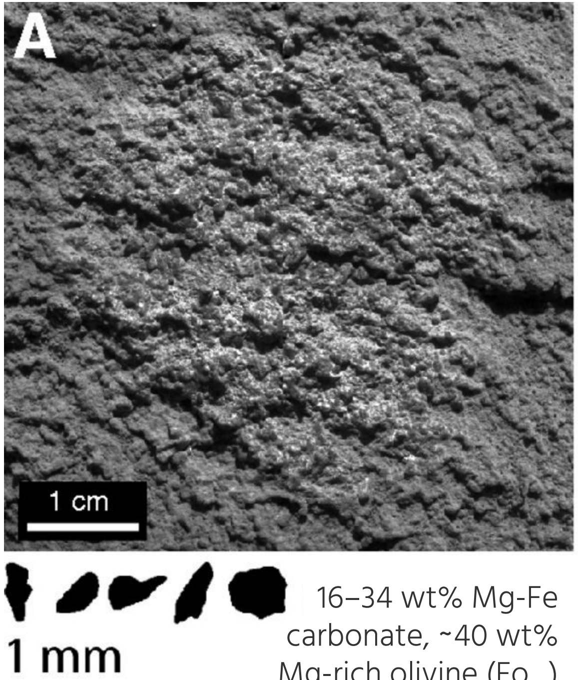
Ancient atmosphere: 1 mm grains travel ~60 km, 0.5 mm travel ~200 km, or further. Several possibilities:

1) Distributed vents have been covered by Syrtis or or Isidis Planitia lavas or eroded over at least ~3.6 Ga

2) Grains traveled from some source closer to Syrtis Major under thicker atmosphere +/- favorable obliquity, seasonality, and dust-loading

Olivine-rich pyroclastic rocks at Columbia Hills





16–34 wt% Mg-Fe carbonate, ~40 wt% Mg-rich olivine (Fo_{72})

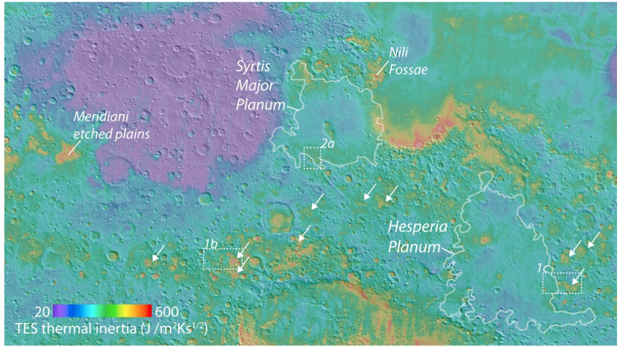
Ruff et al. (2014)

So what is the circum-Isidis olivine-rich unit?

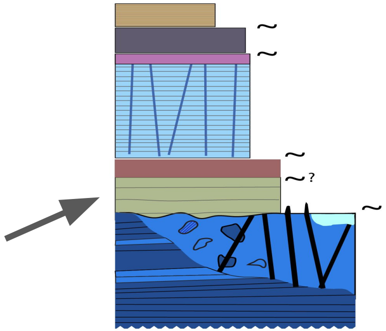
Table DR 6. Hypothesis table for possible emplacement mechanisms of the olivine-rich unit

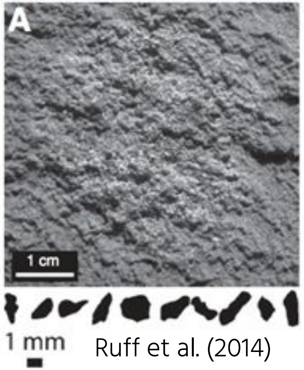
	Syrtis-Isidis Region Ash	Other Ash	Aeolian Erg	Aeolian Lag	Lava Flow	Isidis Melt Sheet	Isidis Condensate	Other Impact Product
Observed/Measured Features								
Drapes Topography	✓	✓	x	?	?	x	?	?
Flow Features Absent	✓	✓	✓	✓	?	?	?	?
Superposes Crater Rims Generally	✓	✓	✓	✓	x	✓	?	?
Superpose Post-Isidis Crater Rims	✓	✓	✓	✓	x	x	x	?
Original Thickness Regionally Variable up to 10^2 m	✓	✓	✓	✓	✓	✓	?	?
Fo_{68-91} Olivine 10-30%	✓	✓	?	x	✓	✓	✓	✓
Readily Deflated/Moderate Thermal Inertia Values	✓	✓	✓	✓	x	x	?	?
Poorly Crater-Retaining	✓	✓	✓	✓	x	x	?	?
Yardangs	✓	✓	✓	✓	x	x	?	?
Olivine Crystals ~1 mm	✓	x	x	✓	✓	✓	x	x
Layered Deposits	✓	✓	✓	?	✓	?	?	?
Layers <1 m	✓	✓	✓	x	x	x	x	x
Many Thin Layers of Alternating Tonality	✓	✓	?	x	x	x	x	x
Cross-Bedding Absent	✓	✓	?	✓	✓	✓	✓	✓
Homogeneous Comp. Across ~10^5 km^2	✓	✓	?	?	✓	✓	✓	✓
No similar deposits observed outside region	✓	✓	✓	✓	✓	✓	x	x

Conclusions and Implications: Olivine-Rich Clastics on Mars



Rogers et al. (2018)





Ruff et al. (2014)

Olivine-rich unit is almost certainly a clastic rock, with a probable origin as a pyroclastic ash-fall deposit. Implies an affinity with clastic olivine-rich lithologies inferred elsewhere on Mars.

Cold clastic emplacement rules out contact metamorphism of basement unit by thin melt rock layer. Higher clastic porosities imply faster reaction rates for alteration?

Possible pyroclastic origin suggests relatively primitive melts compared with later Syrtis lavas.

Mars 2020 can test hypotheses with grain measurements, observe stratigraphic architectures in detail, use bulk chemistry to evaluate magmatic history in the Syrtis-Isidis region, cache samples for potential radiometric age dating