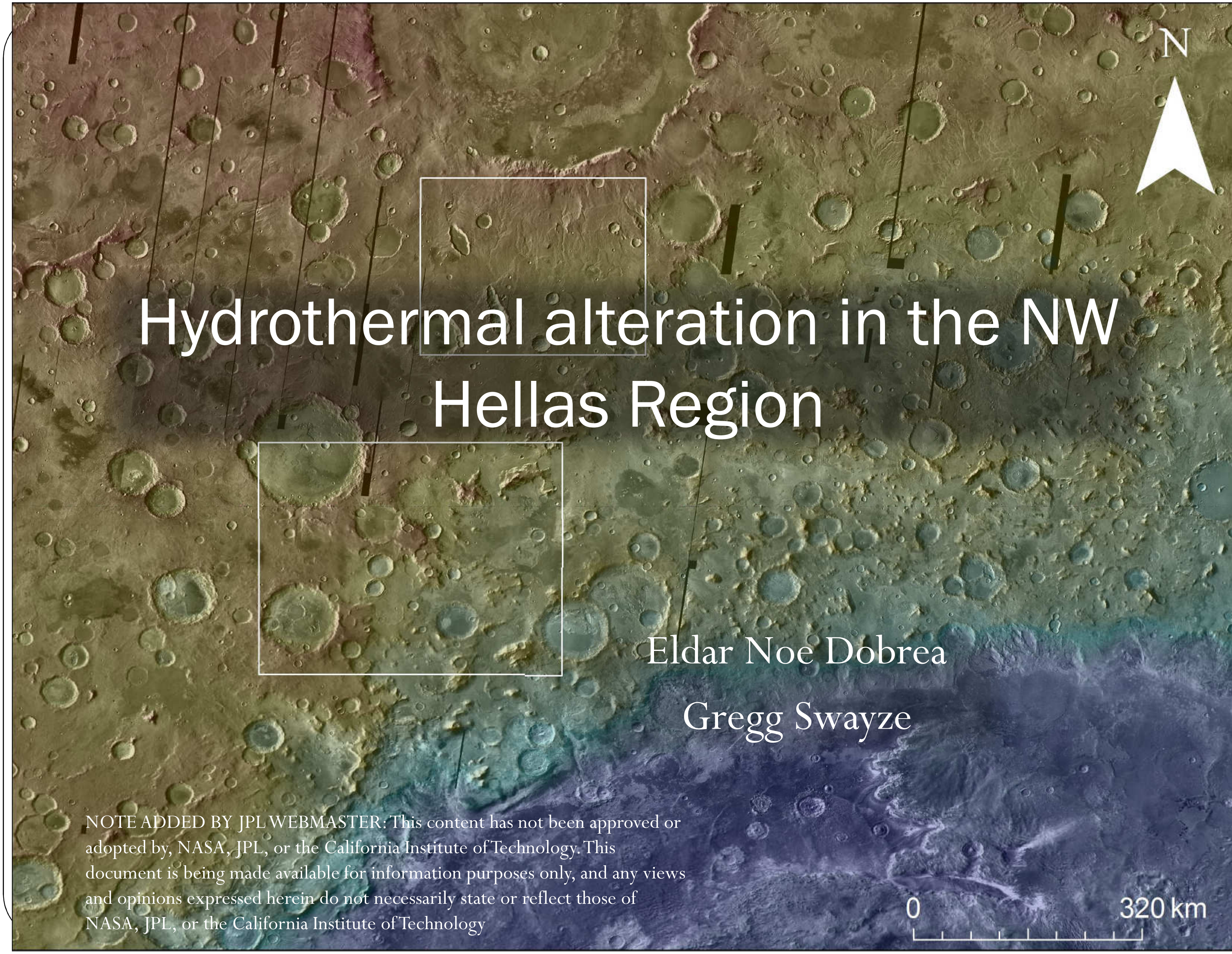
Hydrothermal alteration in the NW Hellas Region



Eldar Noe Dobrea

Gregg Swayze

Hellas

- Formed in Early Noachian by impact of ~250 km object (*e.g.*, Leonard and Tanaka, 2001)
- Subsequent modification by aeolian, fluvial, glacial/periglacial, volcanic processes gave rise to a diversity of geological environments and landforms inside Hellas and in the circum-Hellas region.
- Of particular interest to the question of *habitability* is the possibility that a variety of aqueous systems may have developed in the region after the Hellas impact.
  - Hydrothermal systems (*e.g.*, Newsom, 1980).
  - Marine/lacustrine (*e.g.*, Wilson *et al.*, 2007; Condit *et al.*, 2010 and references therein)
- Energy deposited by impact should have produced elevated temperatures for a prolonged period (how long? how hot?)
- Impact also thought to have triggered vent volcanism (*e.g.*, Williams *et al.*, 2009)
- Evidence for aqueous activity in the region during that time period:
  - Mineralogical: phyllosilicates in Tyrrhena Terra (Pelkey *et al.*, 2007; Loizeau *et al.*, 2009) and around Hellas (*e.g.*, Ansan *et al.*, 2011; Crown *et al.*, LPSC 2011).
  - Morphological: heavy dissection of the region, layered intracrater deposits

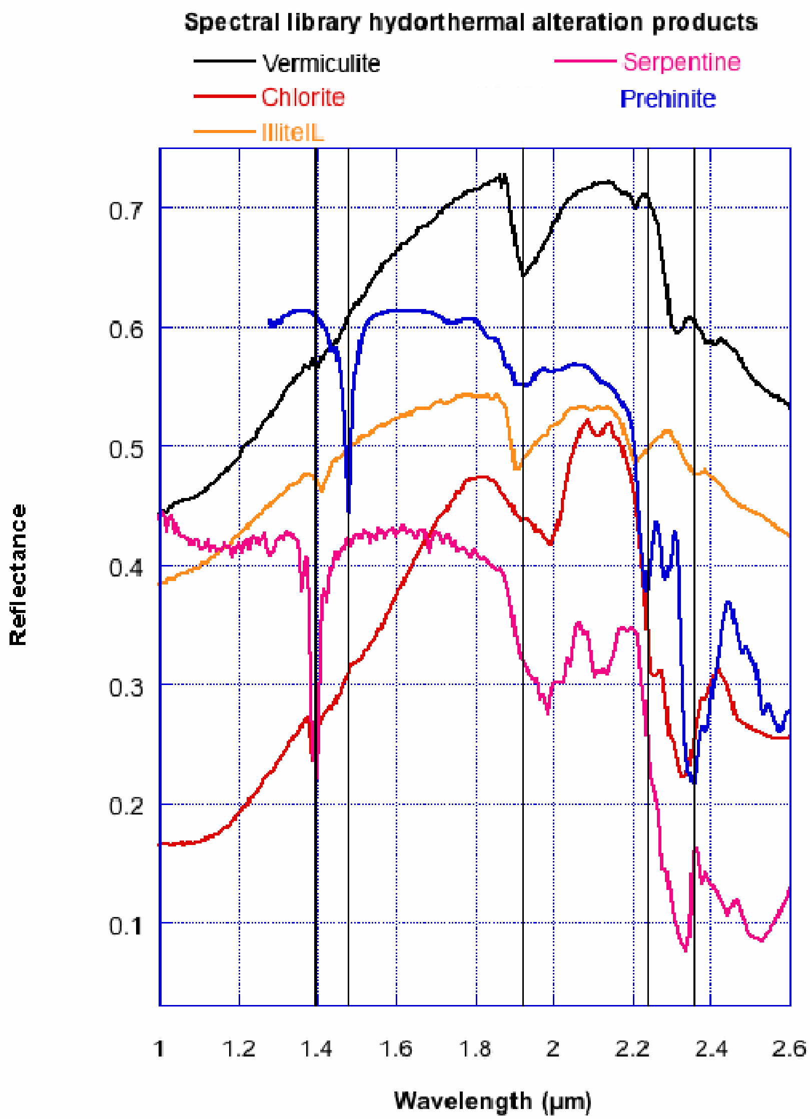
Primary mineral or rock	**Reported alteration minerals**	**Hydrothermal Alteration environment**	**Reference**
Basalt	Kaolinite, smectite, jarosite, alunite	Acidic pH	Morris *et al.*, 2001; Morris *et al.*, 2003
Pyroxene-amphibole andesite	Cristobalite, alunite, pyrite, kaolinite, goethite, hematite	Acidic pH	Isobe and Korenaga, 2010
Basalt	Mg-carbonate, talc	Neutral to basic pH	Brown *et al.*, 2010
Wollastonite	Mg-montmorillonite, talc, mixed layer stevensite/chlorite	Neutral to basic pH groundwater	DeRudder and Beck, 1963; Whitney and Eberl, 1982
Granite, K-feldspar	Kaolinite, muscovite, biotite, halloysite	-	Thomas and Walter, 2004;
Impact melt rock	Fe-chlorite, Fe smectite, silica, K feldspar, zeolite	-	Newsom, 1980; Allen *et al.*, 1982
Olivine	serpentine	-	Normand *et al.*, 2002
Basalt, grabbro	Prehnite, quartz, calcite, epidote	Also in low-grade metamorphism	Freedman *et al.*, 2009

Potential Hydrothermal/low grade metamorphic alteration products on Mars

- Prehnite: Nili Fossae (Ehlman *et al.*, 2009), Argyre rim (Buczkowski *et al.*, 2010), NW Hellas (Crown *et al.*, LPSC 2011)
- Serpentine: Nili Fossae (Ehlman *et al.*, 2009)
- Chlorite: Nili Fossae (*e.g.*, Ehlman *et al.*, 2009; Poulet *et al.*, 2005); NW Hellas (Crown *et al.*, LPSC 2011)
- Hydrated silica: Nili Fossae (Skok *et al.*, this session)

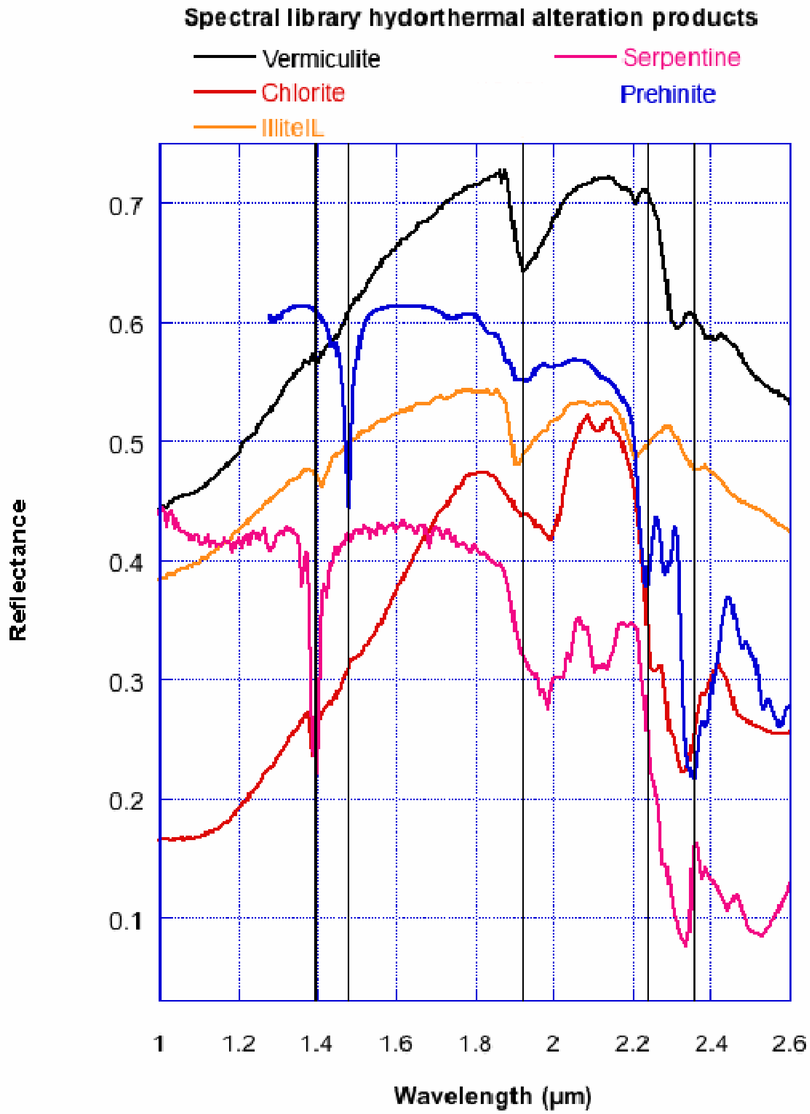
- Of particular interest is Prehnite ($Ca_2 Al_2 Si_3 O_{10}(OH)_2$)
  - Metamorphic grade transitional between zeolite and greenschist facies
  - Forms under specific conditions: 2-7 kbar, 200 – 350°C, and XCO2< 0.004 (Blatt and Tracy, 1995)
  - Typically associated with chlorite and pumpellyite (*e.g.*, Frey and Robinson, 1999).

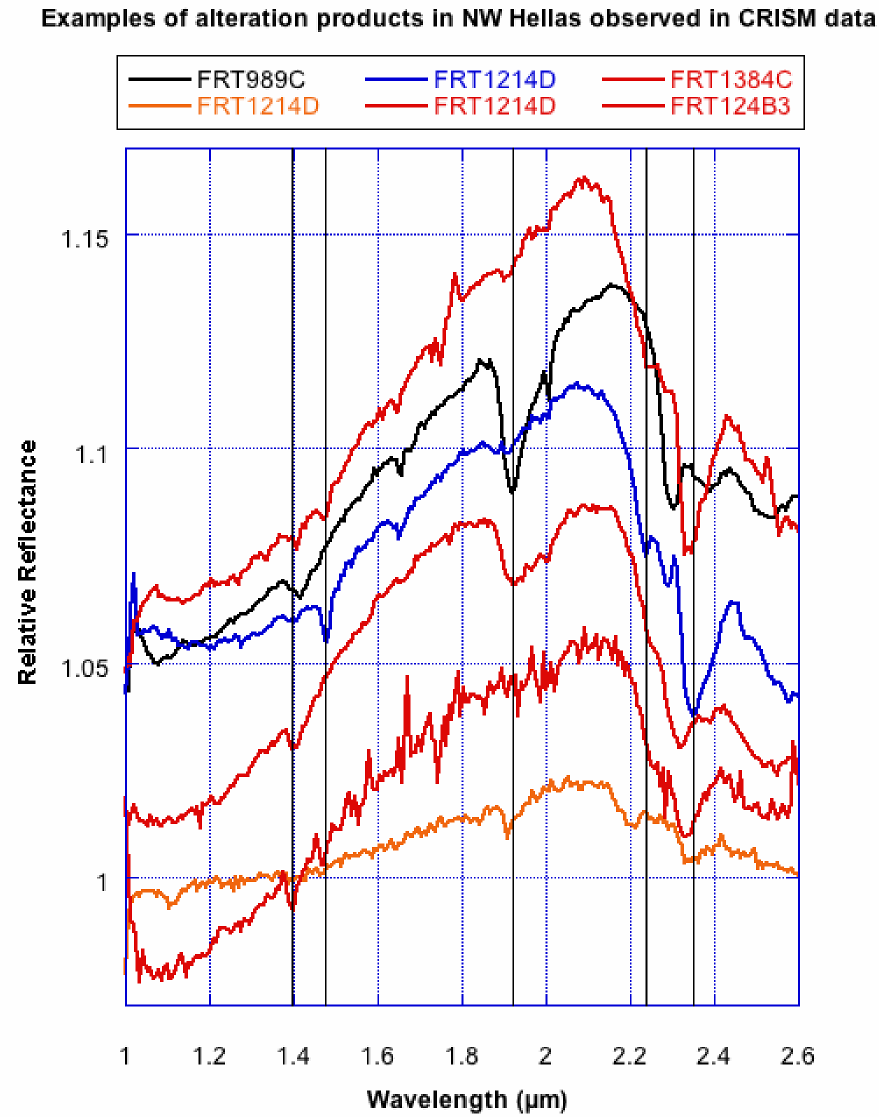
Results



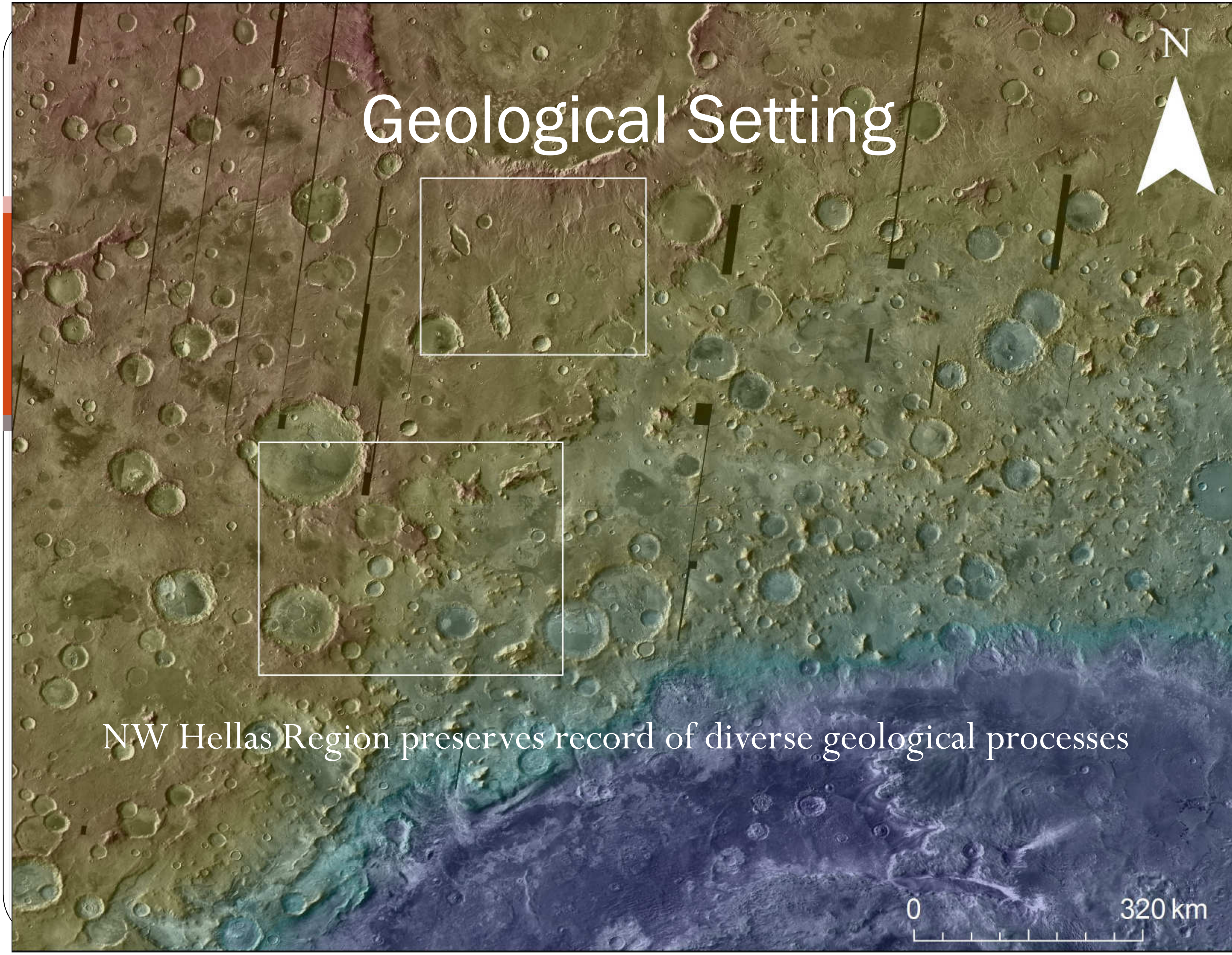
- Prehnite:
  absorptions at 2.35-2.36, 1.48, 2.23, 2.28, 2.57 μm
- Chlorite:
  absorptions at 1.40, shoulder at 2.25-2.26, 2.33-2.35
- Serpentine: absorptions at 1.40, 2.32-2.33, 2.50-2.51
- "Vermiculite" – mixed layer vermiculite/biotite.
  Can also be other mixed layer smectite/chlorite: absorption at 1.92, steep drop-off at 2.30-2.31
- Illite/muscovite -
  absorptions at 2.2, 2.35

Results

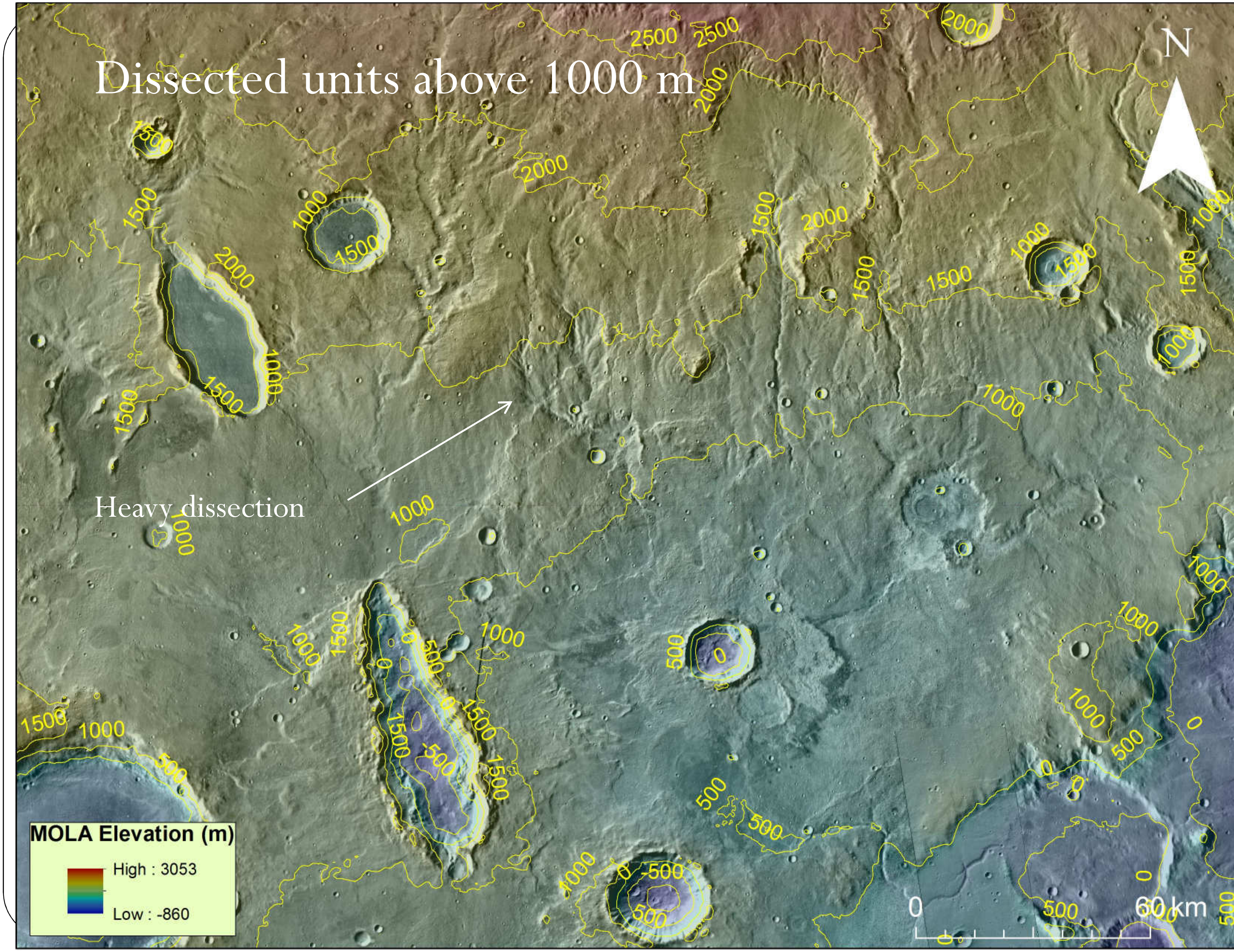

Spectral library hydorthermal alteration products
Vermiculite
Chlorite
IlliteIL
Serpentine
Prehinite
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Reflectance
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
Wavelength (μm)


Examples of alteration products in NW Hellas observed in CRISM data
FRT989C
FRT1214D
FRT1214D
FRT1214D
FRT1384C
FRT124B3
1.15
1.1
1.05
1
Relative Reflectance
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
Wavelength (μm)

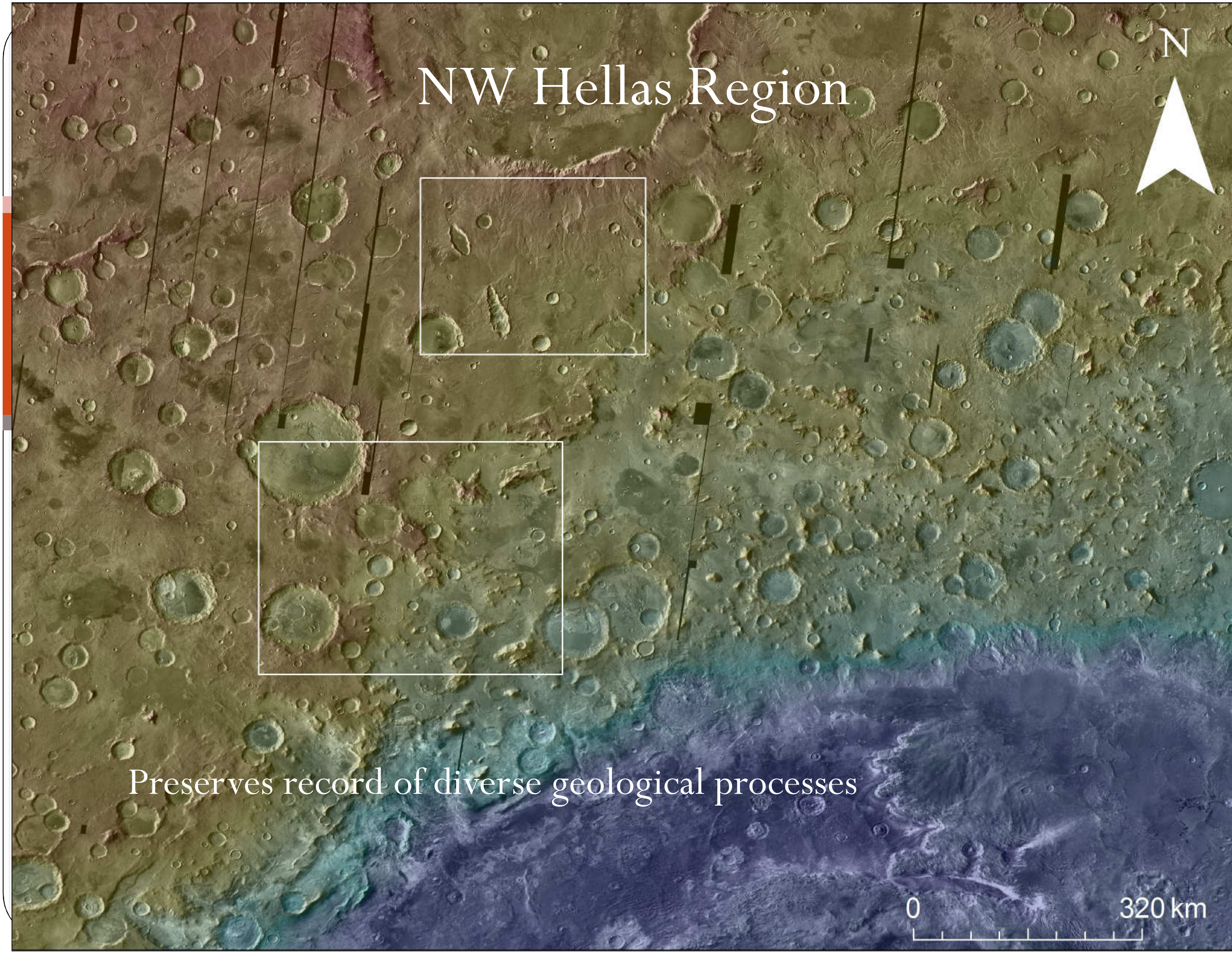
Geological Setting

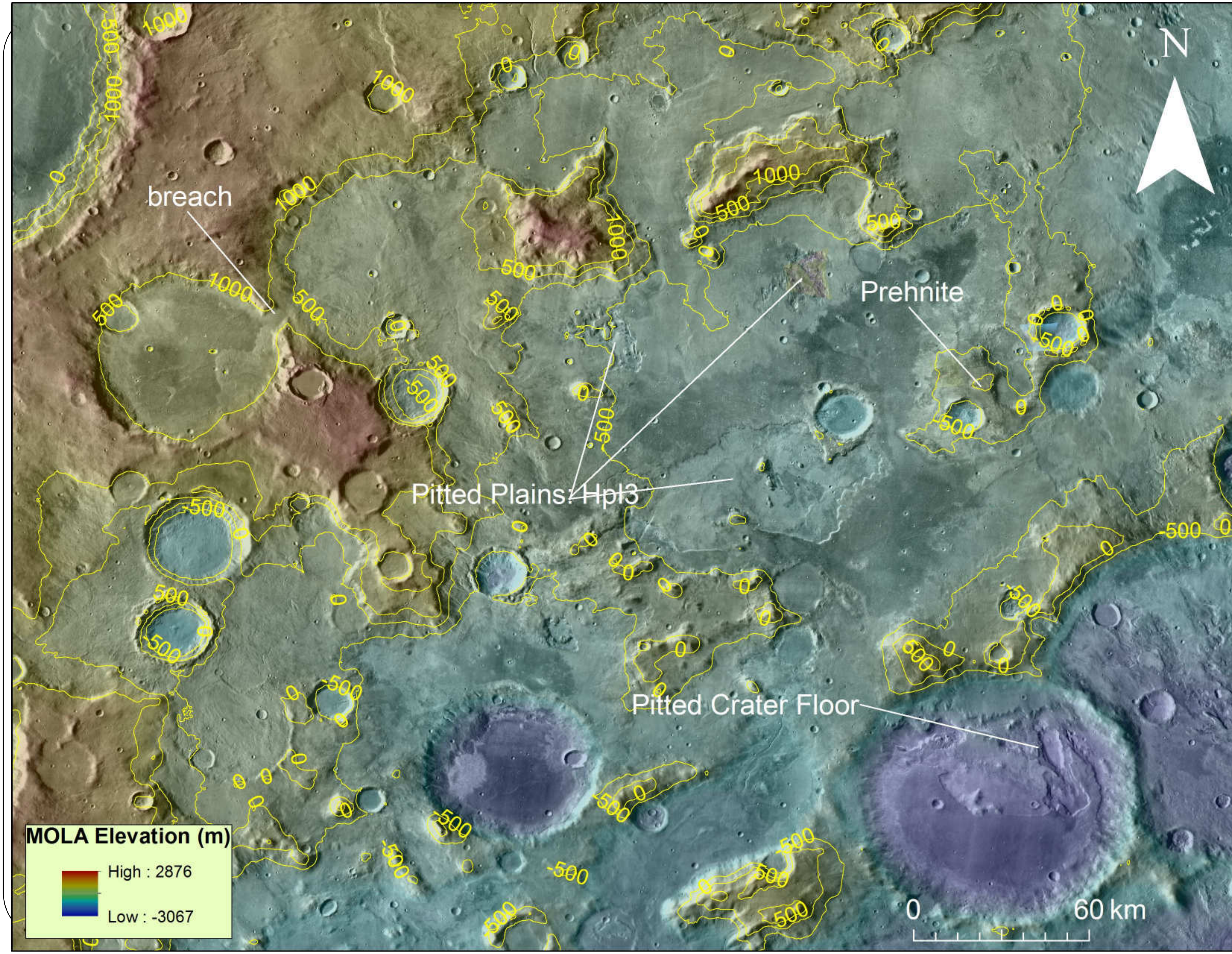


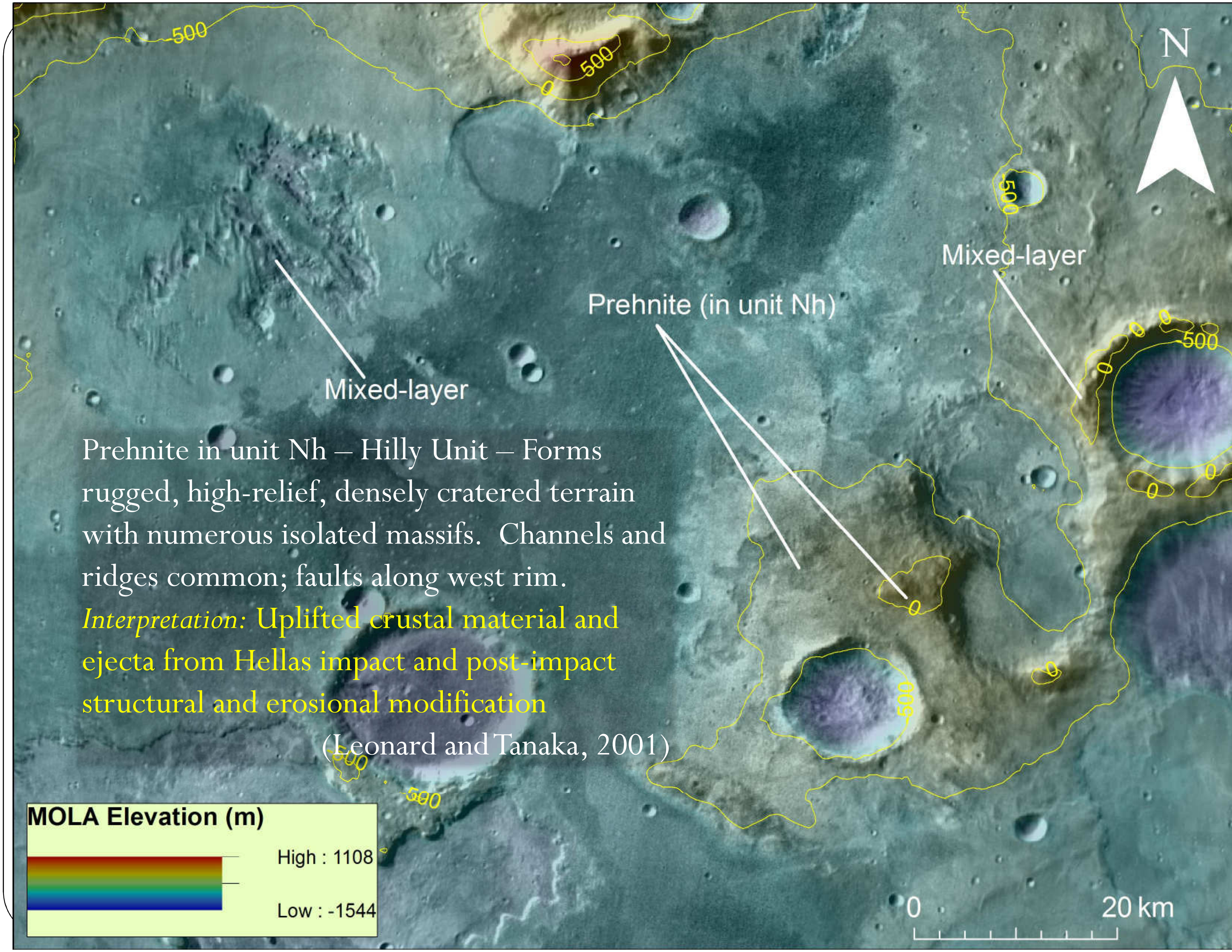
NW Hellas Region preserves record of diverse geological processes



Dissected units above 1000 m
N
Heavy dissection
MOLA Elevation (m)
High : 3053
Low : -860
0
60 km


NW Hellas Region
N
Preserves record of diverse geological processes
0
320 km

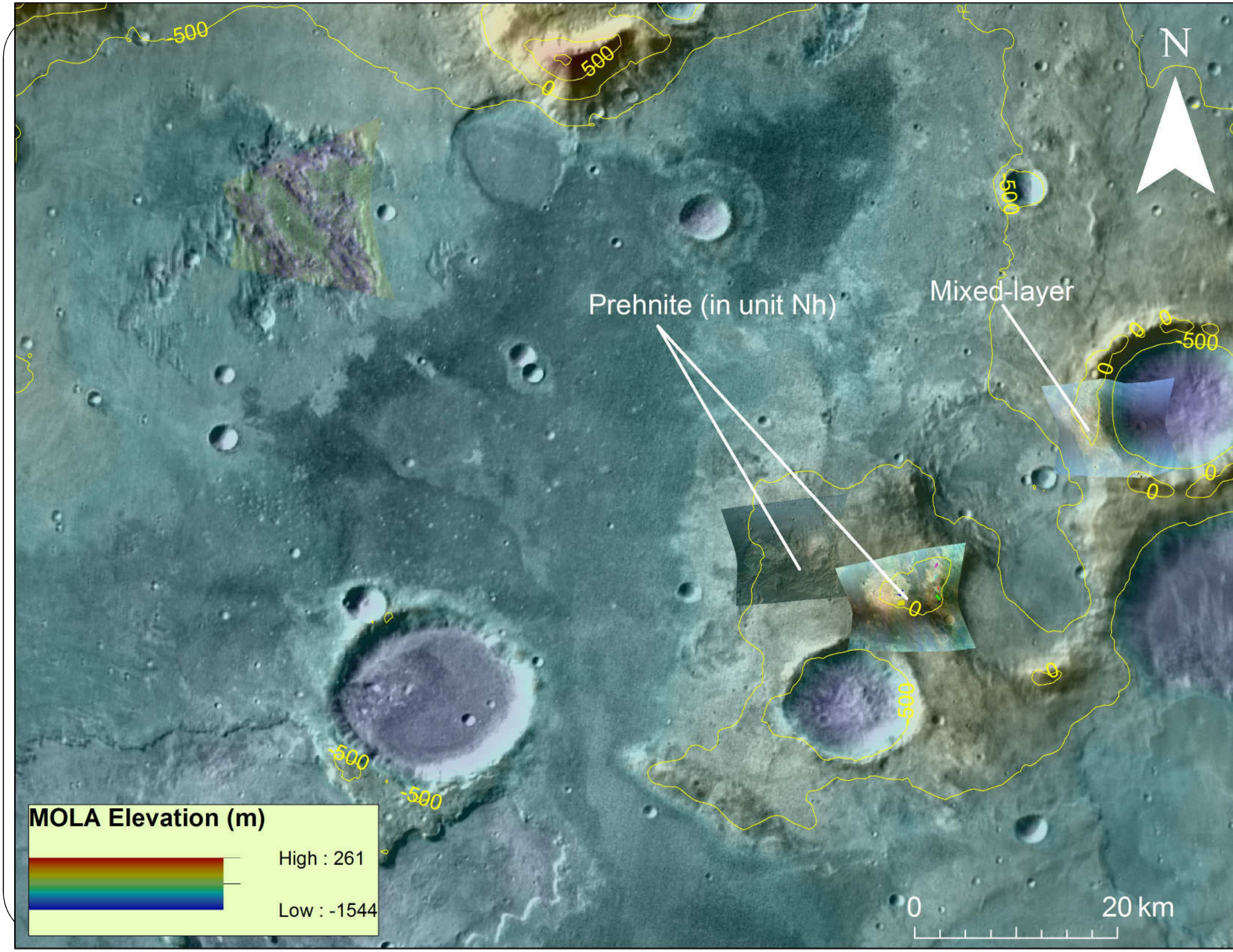

N
breach
Prehnite
Pitted Plains: Hpl3
Pitted Crater Floor
MOLA Elevation (m)
High : 2876
Low : -3067
0
60 km



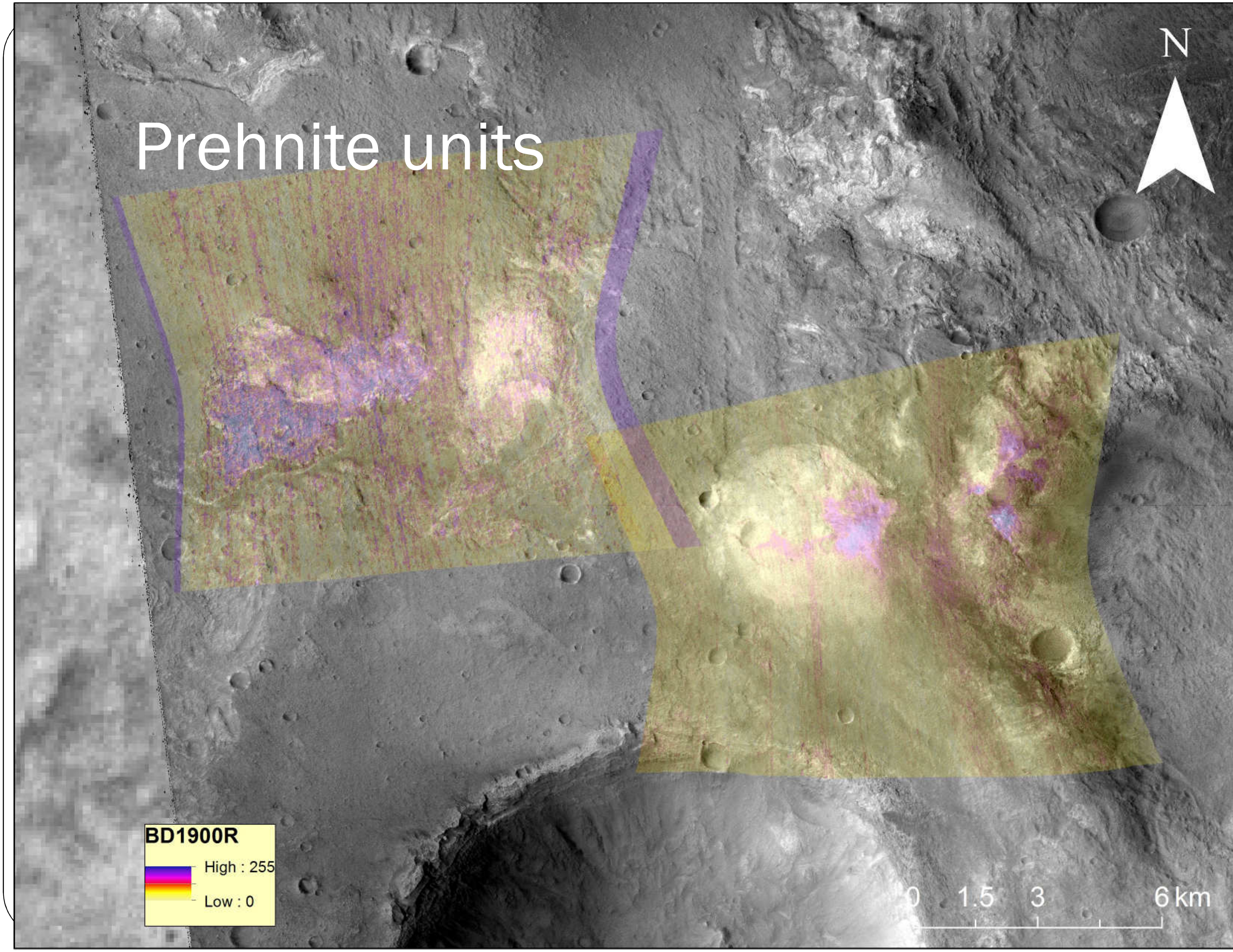
Prehnite in unit Nh – Hilly Unit – Forms rugged, high-relief, densely cratered terrain with numerous isolated massifs. Channels and ridges common; faults along west rim.

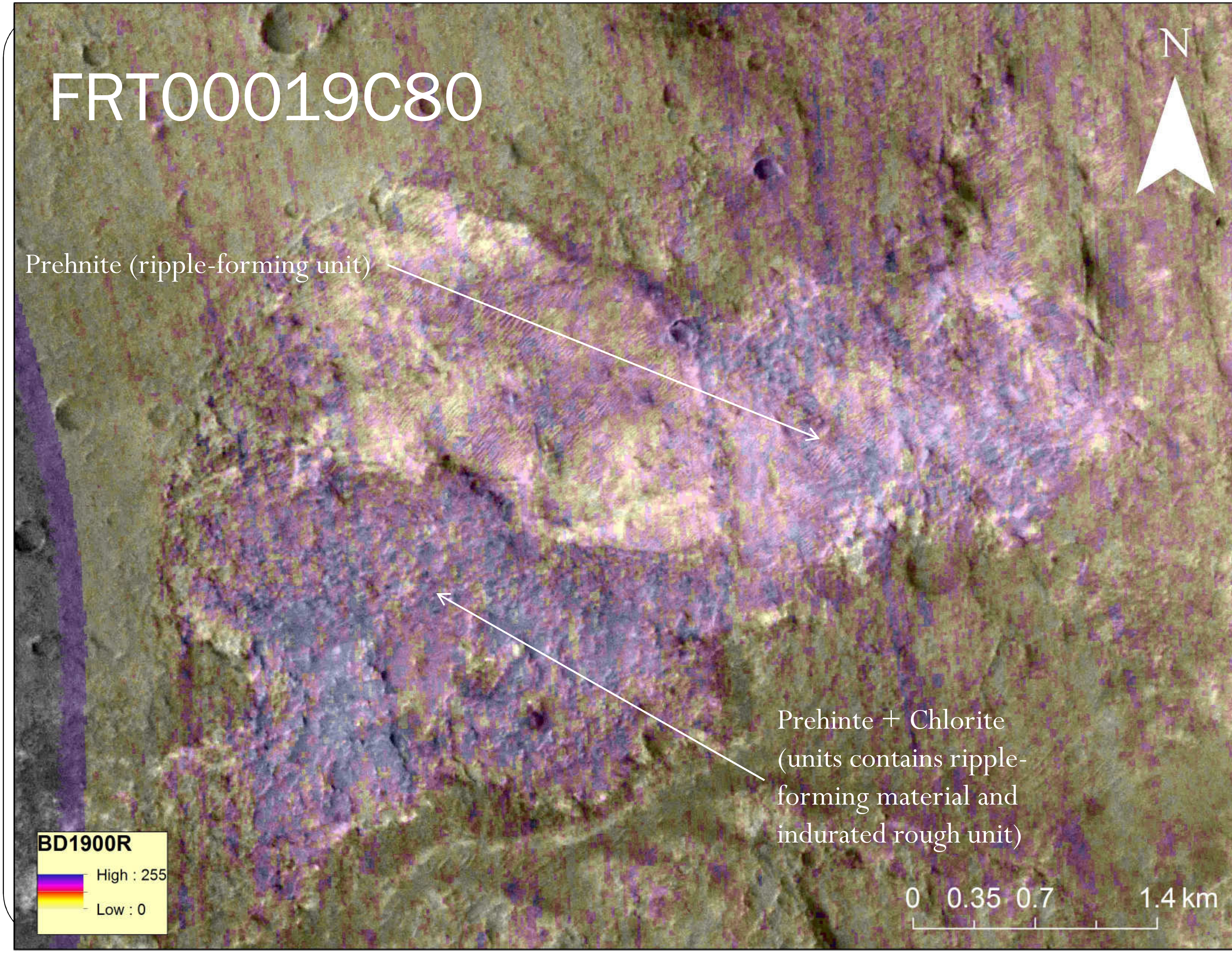
Interpretation: Uplifted crustal material and ejecta from Hellas impact and post-impact structural and erosional modification

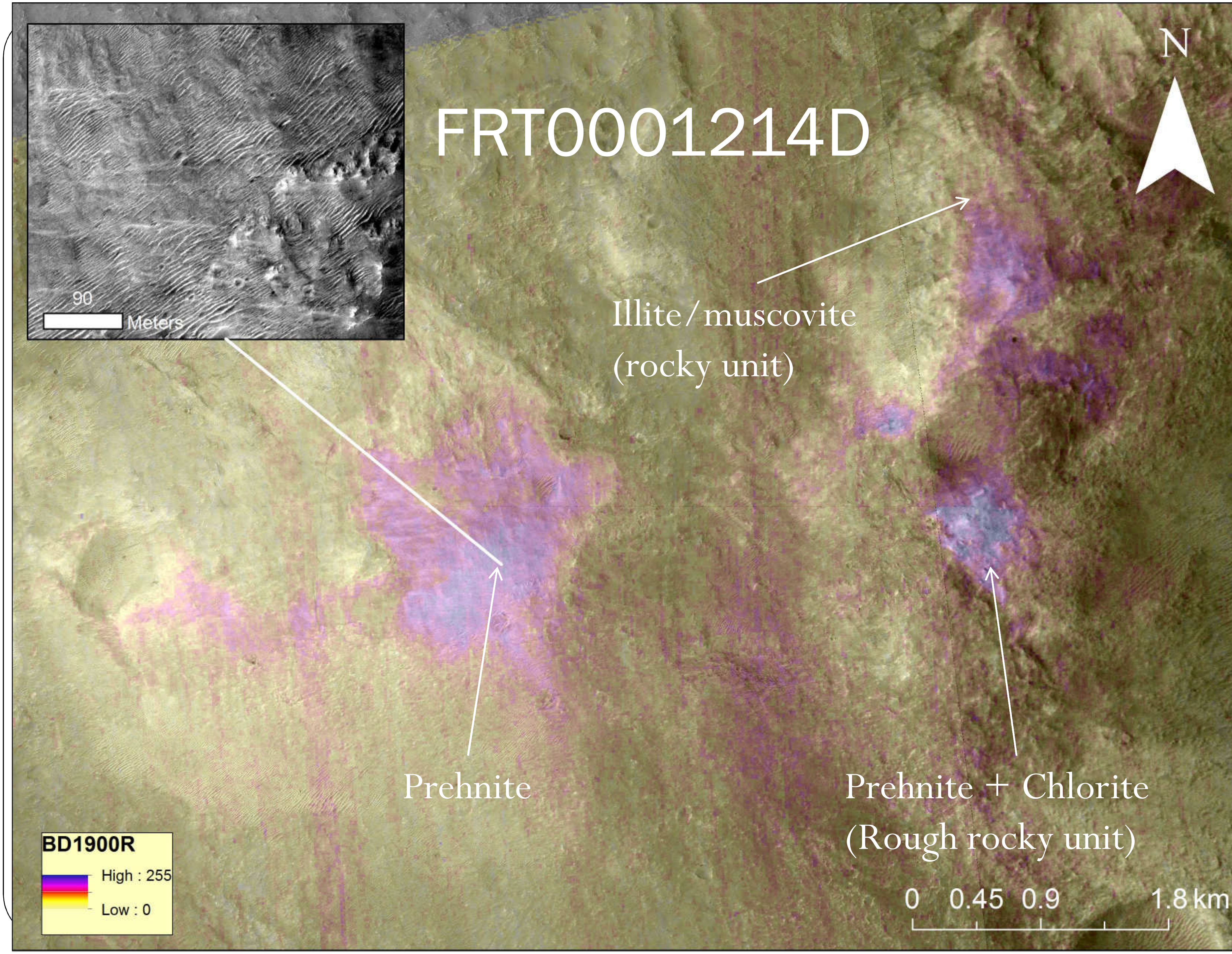
(Leonard and Tanaka, 2001)

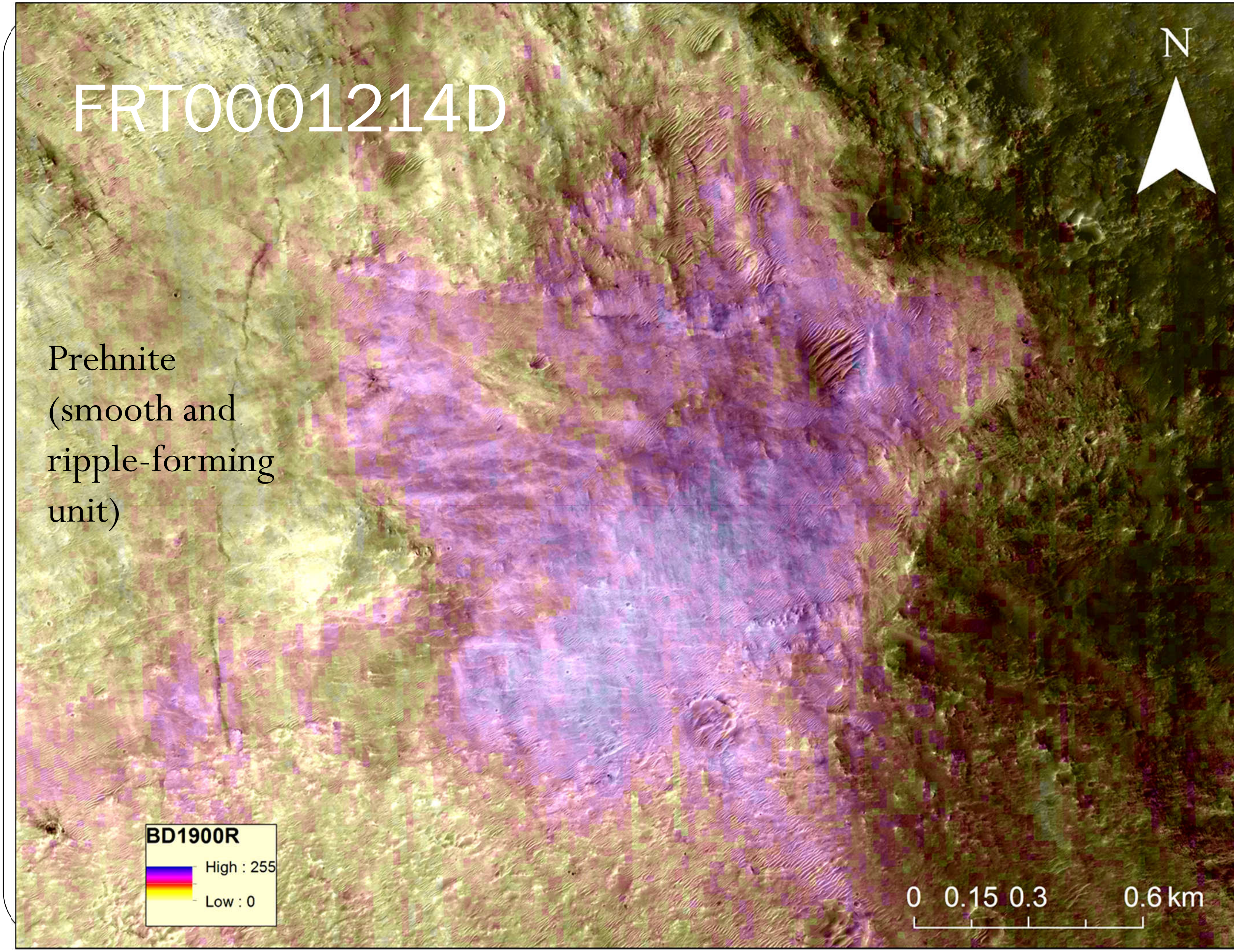


N
Prehnite (in unit Nh)
Mixed-layer
MOLA Elevation (m)
High : 261
Low : -1544
0
20 km
-500
500
0

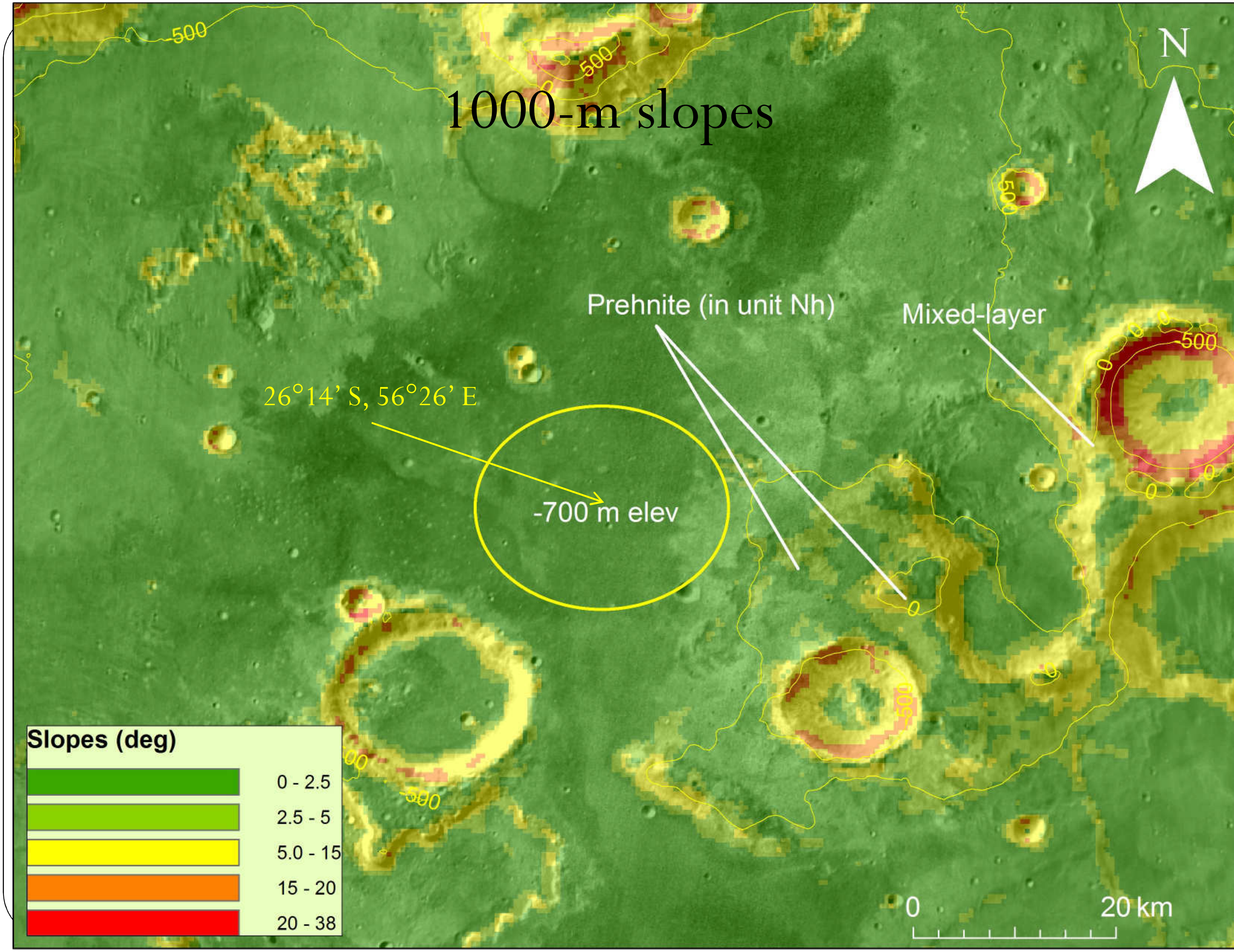

Prehnite units
N
BD1900R
High : 255
Low : 0
0 1.5 3 6 km

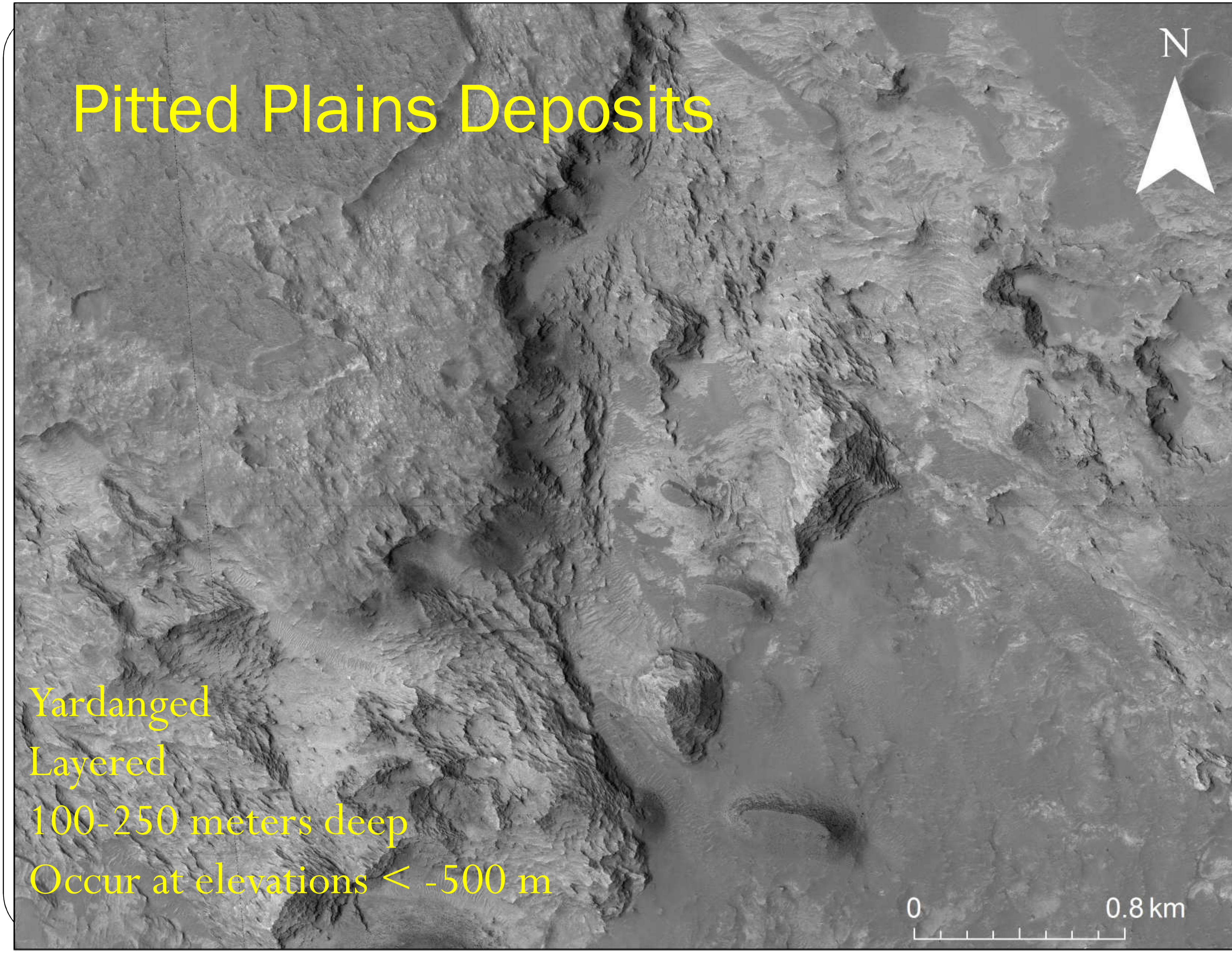

FRT00019C80
N
Prehnite (ripple-forming unit)
Prehinte + Chlorite
(units contains ripple-
forming material and
indurated rough unit)
BD1900R
High : 255
Low : 0
0 0.35 0.7 1.4 km


FRT0001214D
N
90
Meters
Illite/muscovite
(rocky unit)
Prehnite
Prehnite + Chlorite
(Rough rocky unit)
BD1900R
High : 255
Low : 0
0 0.45 0.9 1.8 km

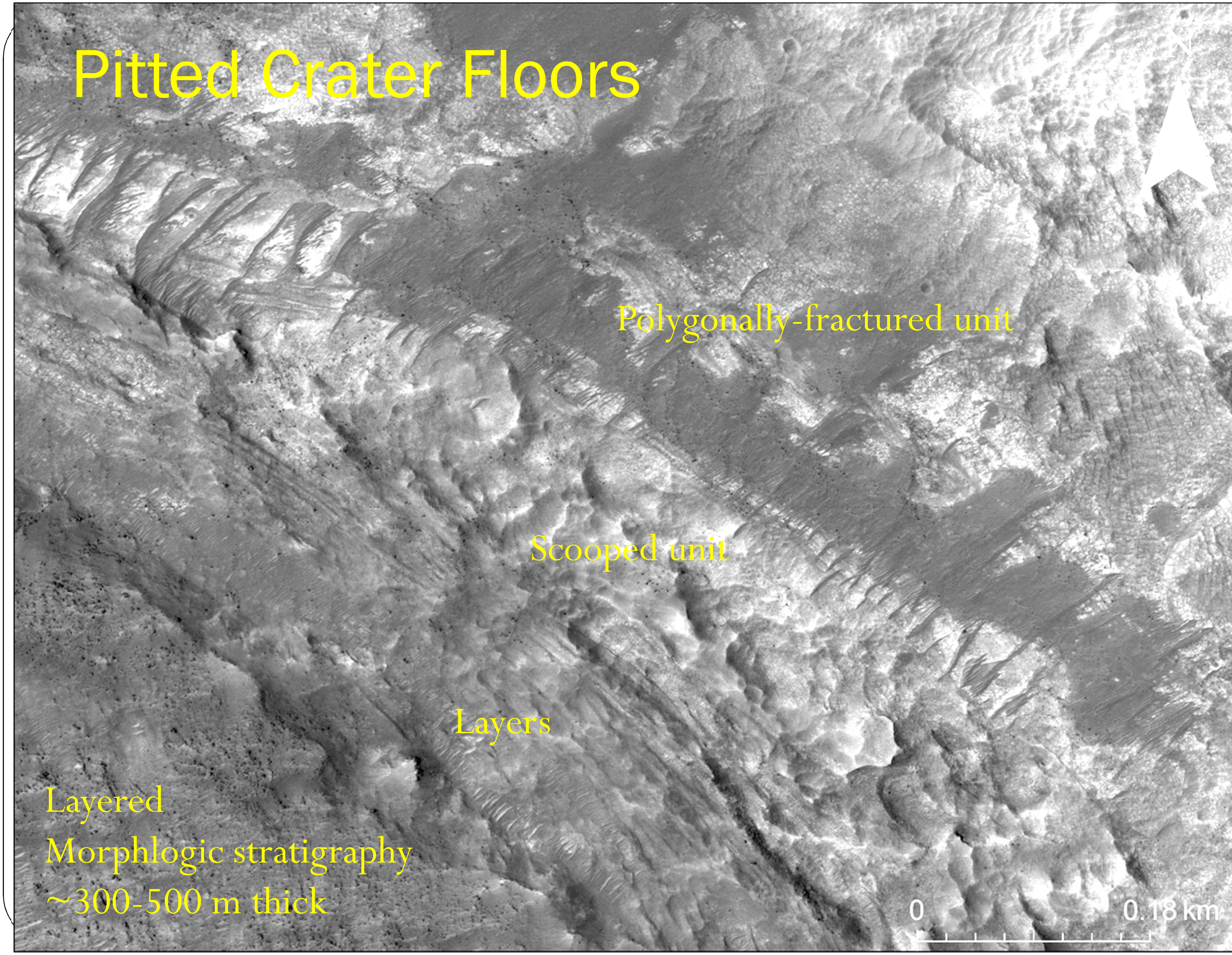


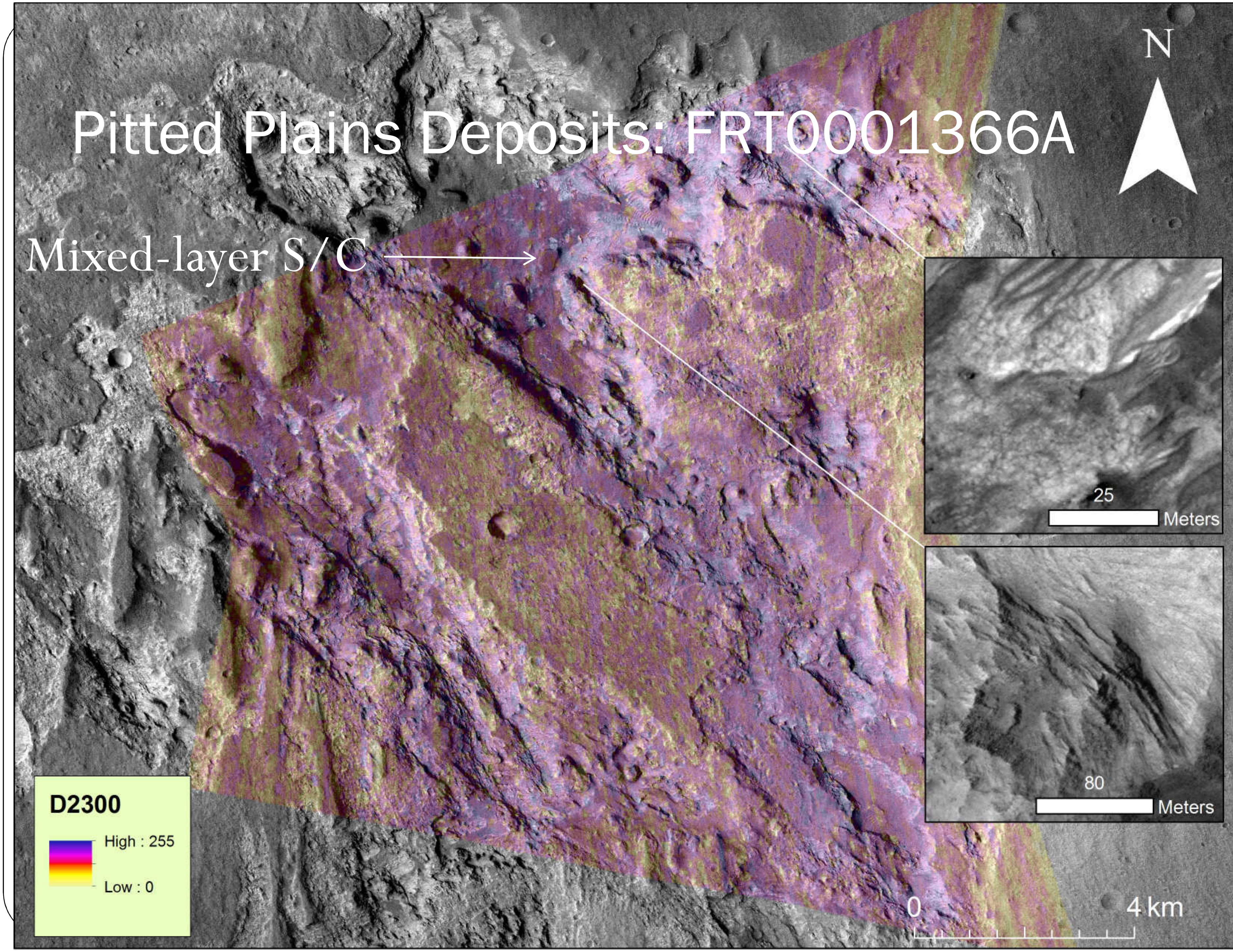
FRT0001214D
N
Prehnite
(smooth and
ripple-forming
unit)
BD1900R
High : 255
Low : 0
0 0.15 0.3 0.6 km


1000-m slopes
N
Prehnite (in unit Nh)
Mixed-layer
26°14' S, 56°26' E
-700 m elev
-500
500
0
Slopes (deg)
0 - 2.5
2.5 - 5
5.0 - 15
15 - 20
20 - 38
0
20 km



Pitted Plains Deposits
N
Yardanged
Layered
100-250 meters deep
Occur at elevations < -500 m
0
0.8 km


Pitted Crater Floors
Polygonally-fractured unit
Scooped unit
Layers
Layered
Morphlogic stratigraphy
~300-500 m thick
0
0.18 km
N


Pitted Plains Deposits: FRT0001366A
Mixed-layer S/C
N
25
Meters
80
Meters
D2300
High : 255
Low : 0
0
4 km

Geological inferences

- We observe a variety of alteration products including prehnite, chlorite, illite/muscovite, mixed-layer S/C or B/V, saponite.
- Prehnite+chlorite+illite in close spatial association on plains unit strongly suggestive of hydrothermal activity.
  - observed in Hilly Unit, which has been interpreted to be uplifted crustal material and ejecta from Hellas impact and post-impact structural and erosional modifications.
- Subsequent erosion of Noachian plains material resulted in dissection and redeposition to form smooth embaying plains and intracrater units 200-400 m in thickness.
- Low-grade metamorphic materials (mixed-layer S/C) identified within pit walls in plains units.
- Plains units have very gentle ($<2.5°$) slopes throughout, and are easily accessible to landing system. Scarcity of boulders in this unit would make traversability very straightforward.

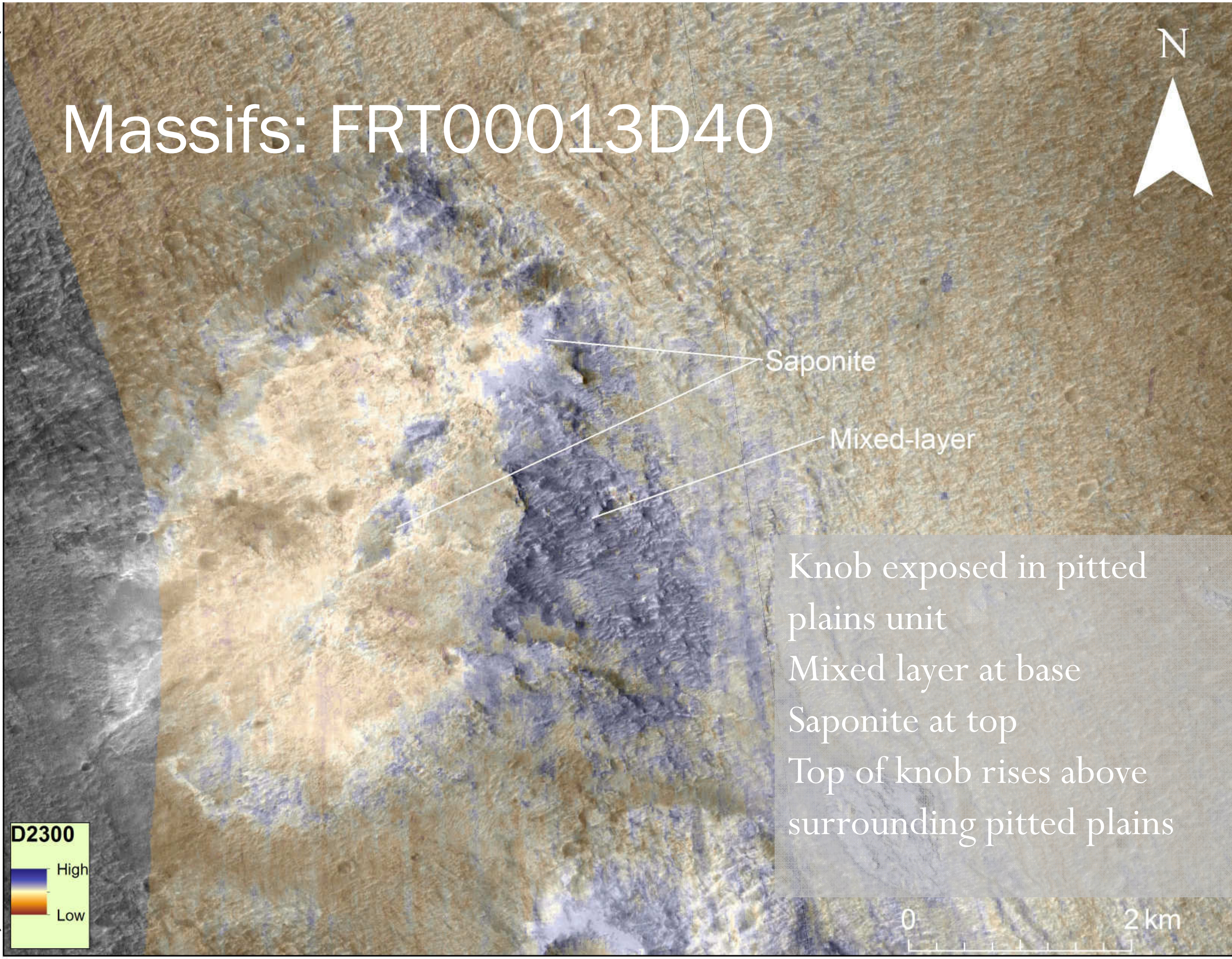
- Unit above 500 m – Npl2 – Subdued cratered unit – Forms widespread moderate to heavily cratered, relatively smooth plains marked by subdued crater rims, small channels, ridges, and uneven terrain. Crater floors partly to completely infilled with smooth material; ejecta blankets rare. Some heavily eroded craters dissected by small channels. Faults rare. Material gradational with most adjacent units. *Interpretation* – Ancient veneer of aeolian, fluvial, and perhaps volcanic materials that partly resurface underlying cratered and dissected units (units Npl1 and Npld).

- Prehnite in unit Nh – Hilly Unit – Forms ruggst, high-relief, densely cratered terrain with numerous isolated massifs. Channels and ridges common; faults aong west rim. *Interpretation:* Uplifted crustal material and ejecta from Hellas impact and post-impact structural and erosional modifications.

- Smooth pitted plains in unit Hpl3 – Smooth unit – Forms moderately cratered, smooth, flat to undulating, relatively featureless pains and patches around the rim and within highlands surrounding Hellas basin. Channel common; faults and flow fronts rare. Embays all other materials of plateau sequence and fills man impact craters. *Interpretation:* Thick fluvial, aeolian, and volcanic deposits burying most underlying rocks

- (Leonard and Tanaka, 2001)

Massifs: FRT00013D40



Knob exposed in pitted plains unit

Mixed layer at base

Saponite at top

Top of knob rises above surrounding pitted plains