

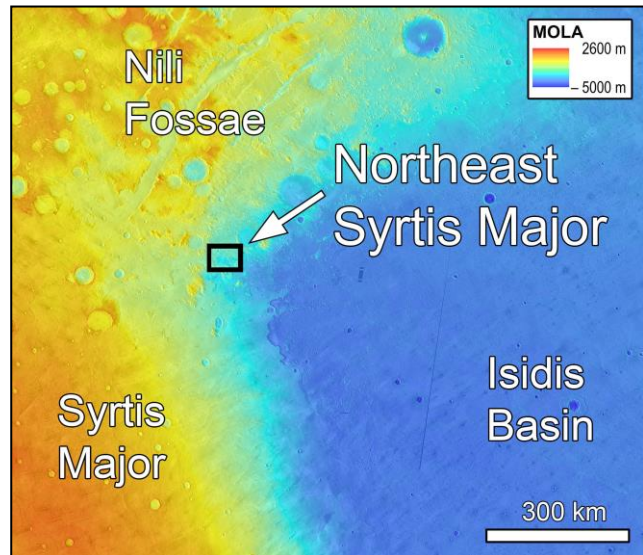
**STRATIGRAPHIC RELATIONSHIPS IN NORTHEAST SYRTIS MAJOR, MARS: APPROXIMATELY 250 MILLION YEARS OF GEOLOGICAL HISTORY SPANNING THE NOACHIAN–HESPERIAN BOUNDARY.** M. S. Bramble<sup>1</sup> and J. F. Mustard<sup>1</sup>, <sup>1</sup>Dept. of Earth, Environmental, and Planetary Sciences, Brown University, Providence, RI, 02912 (Michael\_Bramble@brown.edu).

**Introduction:** Northeast Syrtis Major is the informal name for the region at the nexus of the northeastern extent of the Syrtis Major volcanic province, the southeastern Nili Fossae, and the northwestern border of the Isidis Basin (Figure 1). Orbital-identified aqueous mineral signatures infer the presence of four distinct aqueous environments: ancient crustal Fe/Mg phyllosilicate-bearing terrains, olivine-rich terrains variably altered to carbonate, Al/Mg phyllosilicate-bearing terrains, and sulfate-bearing terrains [1–5]. This diverse aqueous history is bookended by two key dated stratigraphic markers: the formation of the Isidis Basin and the emplacement of the Syrtis Major volcanic province. High-resolution morphological mapping has been performed utilizing the excellent HiRISE coverage, and a paired spectroscopic investigation places the type-locale spectra in stratigraphic context. In this contribution, we present findings from this morphological mapping and discuss their relationship in the stratigraphy of Northeast Syrtis Major.

**Dated surfaces:** The age of the key stratigraphic units in Northeast Syrtis Major are fairly well constrained via the presence of two main stratigraphic markers: the Isidis basin and the Syrtis Major volcanics. Northeast Syrtis Major lies between the 1100 and 1500 km diameter rings of the Isidis Basin [6,7], and the crater size frequency distribution for the Isidis Basin dates the formation to the Mid to Late Noachian at an age of 3.96 Ga [8]. The younger stratigraphic marker is the volcanics from Syrtis Major that cap the sulfate-bearing layered rocks [5]. Crater counting has dated these lavas to the Early Hesperian with ages of ~3.7–3.8 Ga [9] or ~3.5–3.7 Ga [10]. Approximately 250 Myr of geological history is recorded between these two stratigraphic markers, including the Noachian-Hesperian boundary and the evolution of four aqueous environments.

**Methods:** Paired morphological and mineralogical mapping of the study area (~ 17–18 °N and 76–77 °E) was performed using mosaics of HiRISE [11] and CTX [12] images, and visible to near-infrared (VNIR) data from CRISM [13]. HiRISE and CTX Digital Elevation Models were constructed and utilized in the stratigraphic investigation.

**Results:** Despite Northeast Syrtis Major bearing great small-scale morphologic heterogeneity, the geology of the area is unifiable under 5 distinct units of paired morphology and mineralogy (Figures 2 and 3).



**Figure 1:** MOLA colored elevation map depicting the location of Northeast Syrtis Major. The black rectangle denotes the area mapped in this study (Figure 3).

Descending the stratigraphic column (Figure 2) they are: (1) the dated Syrtis Major volcanic unit (SMV) bearing a mineralogy of high-Ca pyroxene, (2) a 100s of m thick slope unit exposing layered sulfates and raised boxwork ridges, (3) a tiered capping mesa unit with an unremarkable VNIR spectrum that preserves craters and sheds boulders, (4) an extensive basal unit to the capping unit that bears an olivine-rich spectrum that is variably altered to carbonate and tapers off into large linear features that descend downsection, (5) a crustal unit that exposes areas of low-Ca pyroxene and Fe/Mg smectite and is observed in a range of morphologies including large crustal mounds, knobby structures, and smooth and knobby plains.

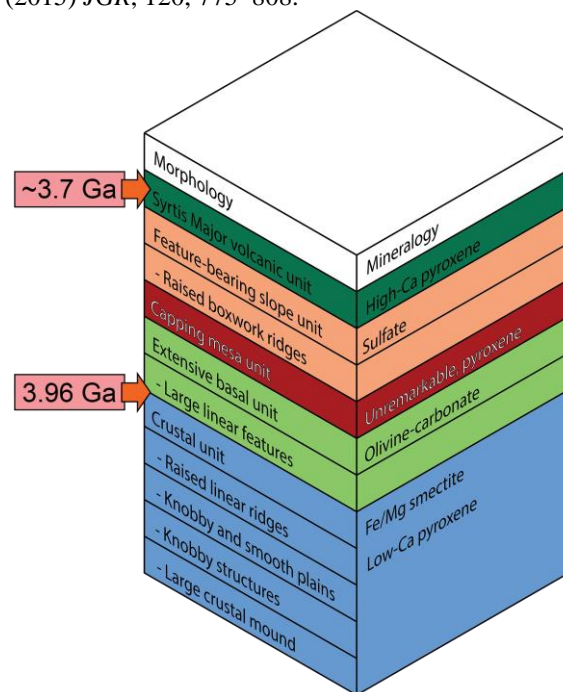
Isolated and distributed outcrops in the crustal unit demonstrate a kaolinite-bearing mineralogy, and while these locations are at the surface of the crustal unit they are not a significant stratigraphic unit as seen elsewhere in Nili Fossae [4]. The crustal unit bears exposures of megabreccia, and the olivine-rich unit drapes topography on both local scales of 10–100s of m and regional scales of 10s of km. These two observations suggest that the formation of the Isidis Basin may have occurred at this boundary and therefore the basin's marker of 3.96 Ga is applicable here (Figure 2).

**Implications and Continuing Work:** Northeast Syrtis Major exhibits a local variation on the regional Nili Fossae group [14] and adds to this lithostratigraphic

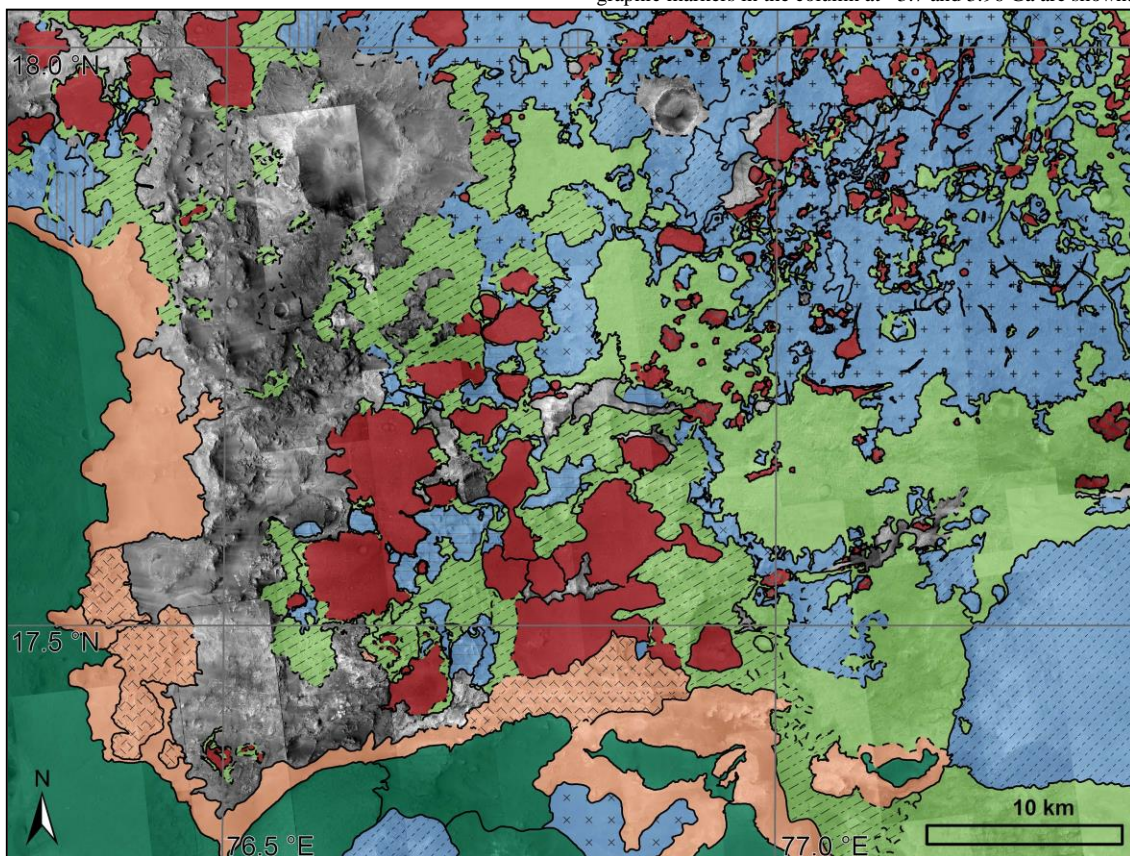
ic sequence by exposing the diverse environmental history of this region through the presence of alteration minerals not exposed or apparent in this fidelity elsewhere in Nili Fossae. Morphological mapping shows that the olivine-carbonate-bearing unit is more extensive than previously reported and extends from the contact with the SMV to the rim of Jezero crater and northward into the crater's watershed [15]. The question remains as to the carbonate's formation mechanism, and processes currently under scrutiny include alteration at high or slightly elevated temperatures or cooler near-surface weathering. Ongoing work focuses on pairing the morphological and VNIR mapping with thermophysical data on the morphological units from THEMIS.

**References:** [1] Mustard J. F. et al. (2007) *JGR*, 112, E08S03. [2] Mustard J. F. et al. (2009) *JGR*, 114, E00D12. [3] Ehlmann B.L. et al. (2008) *Science*, 322, 1828–1832. [4] Ehlmann et al. (2009) *JGR*, 114, E00D08. [5] Ehlmann B. L. and Mustard J. F. (2012) *GRL*, 39, L11202. [6] Schultz R. A. and Frey H. V. (1990) *JGR*, 95, 14175–14189. [7] Frey H. V. et al. (2000) *LPS XXXI*, Abstract #1748. [8] Werner S. C. (2005) *Ph.D. dissertation*. [9] Hiesinger H. and Head J. W. (2004). *JGR*, 109, E01004. [10] Ivanov M. A. et al. (2012) *Icarus*, 218, 24–46. [11] McEwen A. S. et al. (2007) *JGR*, 112, E05S02. [12] Malin M. et al.

(2007) *JGR*, 112, E05S04. [13] Murchie S. et al. (2007) *JGR*, 112, E05S03. [14] Mangold N. et al. (2007) *JGR*, 112, E08S04. [15] Goudge T. A. et al. (2015) *JGR*, 120, 775–808.



**Figure 2:** Simplified stratigraphic column for Northeast Syrtis Major depicting the paired morphology and mineralogy of the mapped units. Colors correspond with Figure 3. The dated stratigraphic markers in the column at ~3.7 and 3.96 Ga are shown.



**Figure 3:** Geomorphic map of Northeast Syrtis Major. Units and colors correspond with simplified column in Figure 2. Select mapped units are not shown for clarity. Background is a CTX mosaic overlain with a mosaic of the available HiRISE images.