INTACT STRATIGRAPHY TRAVERSING THE PHYLLISILICATE TO SULFATE ERAS AT THE SYRTIS-ISIDIS CONTACT, MARS. J. F. Mustard1 and B. L. Ehlmann1, 1Department of Geological Sciences, Box 1846, Brown University, Providence, RI 02912 John_Mustard@brown.edu.

Introduction: The model put forth by [1] for the mineralogic evolution of Mars provides a broad framework for assessing the interaction of water with the crust and surface through time. The transition from early Mars where alteration resulted in a mineralogy dominated by phyllosilicate to middle Mars where hydrous mineralogy is dominated by sulfates may represent a fundamental reorganization of aqueous processes on a planetary scale. Central to understanding this transition are stratigraphic sections that capture geologic processes across this time horizon. Here we analyze one such area on Mars where Hesperian-aged volcanic flows were emplaced atop Noachian-aged rocks on the western floor of the Isidis Basin. A key aspect of this region is aqueous mineral deposits formed in situ on dateable surfaces. These deposits define three distinctive aqueous environments in discrete bedrock units. The aqueous mineralogy is characterized by Fe/Mg phyllosilicate, carbonate, and sulfate minerals.

The key martian geologic processes recorded here are directly related to understanding fundamental processes of impact basin formation, large volcanic provinces and aqueous alteration on ancient Mars, including the most important environmental transition in Mars geologic history.

Site stratigraphy and mineralogy: The Isidis basin is the last and best preserved of Mars’ impact basins (~3.86 Ga, [2]). In this region at the contact between Syrtis Major lavas and the Isidis basin there is a clear stratigraphy of Hesperian lava emplaced on Noachian-aged interior deposits (Figure 1). The steep-sided, sinuous, and branched morphology of the lava flow boundaries has been cited as evidence for emplacement of the lava into a volatile-rich deposit [3]. The likely volatile-rich deposit was the Vastitas Borealis Formation (VBF) [4] that was present at the time of the lava flow emplacement.

The region exhibits a rich and diverse mineralogy (Figure 2) where the specific minerals and mineral assemblages are well correlated with the time stratigraphic units. The CRISM image HRL0000B8C2 (Figure 2) is one example. In this one image are found polyhydrated sulfate, jarosite, Mg-carbonate and serpentine [5] as well as mafic and ultramafic rocks. Fe/Mg smectite clays are not observed in this particular image but are clearly recognized in many of the other observations for this region. This region lies in the watershed of Jezero crater [5, 6] and likely contains the bedrock from which sediments were eroded and transported to the Jezero delta.

Lavas of Syrtis Major are olivine-basalts [8, 9] that were emplaced over an extended period in the Hesperian [10]. The lavas exhibit a steep sided plateau morphology at this contact with the Isidis Basin floor. Topography and morphology here imply volcano-ice interactions [3]. Exposed in the steep walls are hydrated sulfate minerals. We have identified large, tens-of meter scale exposures of polyhydrated sulfate- and jarosite-bearing materials in the exposed volcanic strata (Figure 2). These minerals provide evidence for hydrothermal alteration resulting from the volcano-ice interactions, including precipitation of minerals from acidic waters circulating within the volcanic unit.

Figure 1: West of the Isidis basin is the northern contact between the Hesperian Syrtis Major lava flows (Hs) and the Noachian terrain around Nili Fossae (Nple). Arrows indicate fluvial channels. The phyllosilicates, sulfates, and carbonates of interest are found in all three areas imaged by CRISM in the border region.

The youngest rock units (VBF, volcanic flows) rest on Noachian-aged basement rocks on the interior of the Isidis Basin [5, 11]. These rocks are rich in Fe/Mg smectite clays, a defining characteristic of Mars’ early crust [1]. The Noachian terrains here contain a distinctive ultramafic, olivine-rich late Noachian stratigraphic horizon [11, 13, 14]. In places the ultramafic rocks are altered exhibiting the characteristic signatures of Mg-carbonate [15] and serpentine [5]. Two endmember hypotheses exist for the formation of these units: (1) hydrothermal activity associated with the emplacement of the ultramafic unit and (2) low-temperature, near surface alteration during later Hesperian aqueous activity [5, 15].

The regional geologic context is well defined by recent publications [5, 7, 14, 16]. Immediately following or concurrent with the formation of the Isidis Basin, the ultramafic unit was emplaced. A major period of gradation ensued, concurrent at least in its latest phases with
the creation of fossae concentric to Isidis. Hesperian lavas of Syrtis Major were deposited atop the Noachian units and reached the floor within the Isidis basin and interacted with the VBF [2]. Fluvial activity persisted throughout from the time of the Isidis Basin formation to time of the Hesperian volcanism [11, 16, 17], including fluvial channels that have been carved into the surface of Syrtis Major.

This region thus captures the major era of mineral evolution from phyllosilicate formation recorded in the Noachian basement to the period of sulfate formation. Importantly it appears that the mineral deposits are present in the geologic units in which they formed, and there are clear time stratigraphic markers. What is particularly significant is the sulfate-bearing volcanics. If these indeed represent the result of volcano-ice interactions, they would be definitive evidence for a Martian hydrothermal system and preservation of its associated deposits. The abundance of fluvial features in the region also argues for sourcing from possibly abundant subsurface water. If there had been the development of martian biota, this region has the necessary components that may have led to the entombment of biosignatures in an active hydrothermal system.

**Biological preservation potential:** The aqueous mineral-bearing strata in this region are each distinct in age, primary mineralogy, particular geologic setting, and consequently the biological processes that may be recorded in each unit differ. The units represent bedrock, altered in situ where both reactants and products are in the rock units. This region thus offers the unique opportunity to investigate extensive hydrothermal mineral deposits. These have been identified as of highest importance for organic preservation [18]. Our research shows two hydrothermal episodes are probably represented here. First, the ultramafic rocks of the Noachian olivine-rich unit in some places have the distinctive spectral signature of serpentine, a marker mineral for hydrothermal activity under highly reducing alkaline conditions that are energetically favorable for chemo-synthetic organisms such as methanogens [e.g. 19].

Second, sulfate-silica spring deposits from terrestrial volcanic hydrothermal systems (e.g. Iceland, Yellowstone) entomb rich microbial communities of organisms with diverse metabolisms and may be similar to the sulfate-bearing deposits exposed within the volcanic rock here. In searching for evidence of the earliest Mars life, it is appropriate to note the nature of the earliest Earth life—thermophilic and chemo-synthetic—and guide exploration efforts toward terrestrial planets’ earliest habitats, hydrothermal environments.

**Conclusions:** In this region of Mars the transition from an early, phyllosilicate formation era to a later sulfate formation era is well recorded in distinct geologic units of defined character. We will be analyzing the available MRO, MEx, etc. data to better constrain the geologic relationships, stratigraphy and timing.