ANCIENT CRUST, AQUEOUS ALTERATION, AND IMPACT MELT PRESERVED IN THE ISIDIS BASIN, MARS. J. F. Mustard, F. Poulet, J. W. Head, N. Mangold, P. Bibring, C. Fassett, Y. Langevin, G. Neukum; Dept. of Geological Sciences, Box 1846, Brown University, Providence, RI 02912; John_Mustard@brown.edu, IAS, Orsay Campus, France; IDES, CNRS and Université Paris 11, Orsay, France; Institut fuer Geologische Wissenschaften, Freie Universitaet Berlin, Germany.

Introduction: The Isidis impact basin was formed in ancient cratered uplands and has since experienced tectonic deformation of the impact basin rim (Nili Fossae), volcanic modification of the western basin rim (Syrtis Major Planitia), and filling of the Isidis Basin (Hesperian ridged plains and the Vastitas Borealis Formation). This wide array of post-basin geomorphic units led to the general impression that primary Isidis Basin impact deposits had been highly modified, removed, or buried by eolian, volcanic, and fluvial deposits, and general weathering processes.

Global Thermal Emission Spectrometer (TES) data were interpreted to indicate the presence of both basalt and basaltic andesite in the region [1,2] but also had spectral components consistent with olivine-rich materials. [3] examined the olivine occurrences in detail and concluded that the olivine may be exposures of olivine-rich igneous lithologies exposed by post-basin faulting along ring faults and graben or post-Isidis volcanic flows. [4] re-evaluated these deposits with THEMIS data and assessed a number of possible origins. They found that the majority of the olivine-rich material occurred in the form of in-situ rock, with lineaments interpreted as layering, covering an area significantly larger than previously suspected. They concluded that the evidence best supports olivine-rich basalts extruded subaerially as the source of the anomalies. Based on cross-cutting relationships and the lack of olivine in fractures and graben they suggest the basalts existed at the time of the Isidis impact. Left unexamined are the specific relationships between the impact-forming event, its deposits and the olivine-rich units interpreted by [4] to be of volcanic origin. In the following sections we 1) examine the geology of the Isidis basin, and 2) assess the nature of impact basin geology, settings and formation and evolution processes, in order to assess further the relationship to the olivine-rich unit. We then bring together new Mars Express OMEGA and HRSC data to examine the correlation of the olivine-rich unit to the regional geology of the Isidis basin.

Methodology: Basic reduction of OMEGA data from radiance to reflectance including atmospheric removal is performed as described by [5]. Mafic minerals are recognized and mapped on the basis of crystal field transition absorptions in the 1-2.5 µm region and procedures for this recognition and mapping have been presented previously [5,6]. The determination of mineralogy for hydrated silicates is treated by Poulet et al. [7]. A detailed investigation of phyllosilicate occurrences in this region is presented in a companion abstract [8]. We have generated mineral indicator maps for olivine, low-Ca pyroxene, and phyllosilicates that exhibit a narrow absorption near 2.3 µm. These maps show the locations of regions with absorptions consistent with the presence of the minerals mapped, and the stronger the indicator the stronger the mineral feature that is mapped. We are in the process of developing detection criteria, and the maps robust where the signatures are strong but should be interpreted cautiously where the signatures are weak.

Results: In Figure 1 is shown the mineral indicator maps for the Nili Fossae region. The ancient Noachian crust to the west is enriched in low-Ca pyroxene. A distinct change in mineralogy occurs along a line between 76° and 77°E which also corresponds with a distinct break in slope. To the west of this break in slope crater chains and radial texture can be seen that are due to the Isidis basin forming event. The break in slope may reflect a component of the Isidis ring system [9]. East of the break in slope abundant olivine and clay mineral deposits are observed. The better understand the geologic relationships here, the mineral indicator maps were draped on a mosaic of THEMIS visible images for the regions indicated by the box in Figure 1. This map is shown in Figure 2.

The region shown in Figure 2 offers superb bedrock exposures that allow direct examination of the relationship between morphology and mineralogy. The mineralogic indicators (red for olivine and blue for phyllosili-
cate) have been carefully verified in these data and we are certain that the indicators are mapping exposures of olivine and a clay mineral with a 2.3 µm narrow band absorption. The saturated and distinct colors in this figure also reflect the very strong mineral absorption bands and the almost complete physical separation between olivine-bearing and phyllosilicate-bearing outcrops. Despite OMEGA pixel sizes of approximately 400 meters, there is very little mixing observed. (Note: CRISM spatial resolution will be the same as the THEMIS VIS images in this figure).

As can be seen in Figure 2, the outcrops rich in clay minerals are characteristically lighter toned, exhibit a knobby and dissected morphology, with abundant linear features interpreted to be breccia dikes [10]. The olivine-rich unit rest stratigraphically on top of the clay-bearing outcrops as a meters- to 10’s of meters-thick unit. This unit is regionally extensive and found throughout the olivine-rich zones identified by [3,4] and with OMEGA. The unit traverses a large topographic range (Figure 1) and appears to drape over bedrock on which it rests. Remnant, relatively uneroded patches of this unit are observed as low albedo, rough textured outcrops (indicated by the O symbols in Figure 2). Though the olivine signature appears weak this is due to rock exposures rather than sand or particular textures elsewhere. Sand-sized particles increase the apparent strength of mineral features in the infrared due to multiple scattering while rock exposures have weak apparent features due to little multiple scattering.

The location of the olivine-rich outcrops within the Isidis basin (Figure 1), the preserved basin morphology to the east of the mineral exposures, and the detailed characteristics of the morphology of the unit carrying the olivine signature (Figure 2) lead us to a new conclusion for the origin of this unit. With analogy to the Orientale basin on the Moon, these olivine-rich outcrops occur between the inner and outer rings of the Isidis basin. In Orientale, this location hosts a large concentration of impact melt. Olivine-rich outcrops are also observed near the boundary between Libya Montes and Isidis Planitia and this too lies between inner and outer basin rings.

Elsewhere on Mars, olivine is frequently found on crater floors or isolated outcrops within the boundaries of impact basins [3,5]. Where well exposed, the morphology of the olivine-bearing units are very similar to that observed in the Nili Fossae region, and nighttime temperatures show the units to be rocky. Without obvious volcanic source regions, many of these specific olivine deposits may be impact melts. The morphology of these deposits resembles impact melts observed on Mars and the Moon. As Isidis basin has the thinnest crust on Mars (<10 km) and highest Moho relief [11], the olivine-rich melt may originate from excavation and melting of the mantle. Thus a major conclusion of this analysis is that the olivine-rich material in Nili Fossae is impact melt generated during the formation of the Isidis impact basin.

Conclusions: On the basis of new mineralogic data from OMEGA, detailed mapping of unique mineralogic units and their stratigraphy, and with analogy to the Orientale impact basin on the Moon, we argue that impact melt from the Isidis impact basin is preserved in Nili Fossae. In a broader context, the Nili Fossae region preserves a critical record of early Mars. The Noachian basement, enriched in low-Ca pyroxene is well preserved but has also experienced a deep and pervasive aqueous alteration, characterized by Fe-rich smectite clay [8]. On this basement rests olivine-rich deposits that are interpreted to be impact melt. Thus this sets a critical time-marker for alteration: the crust of Mars in this region experienced pervasive alteration at the time of the Isidis basin-forming event.