NEW INSIGHTS INTO THE NATURE OF MINERALOGIC ALTERATION ON MARS FROM ORBITER, ROVER, AND LABORATORY DATA. S. W. Ruff[1] and V. E. Hamilton[2], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287-6305, steve.ruff@asu.edu; [2]Southwest Research Institute, 1050 Walnut St., Suite. 300, Boulder, CO 80302, hamilton@boulder.swri.edu.

Introduction: Over the past ten years of Mars exploration, a wealth of information has been gathered from various sources that allows us to more fully address questions about the nature of mineralogic alteration of the Martian surface. The role of water now has been clearly identified by the presence of numerous aqueously-derived mineral phases observed from orbit and the surface. Here we present new observations that further elucidate the nature of this alteration and in some cases create new enigmas about the styles of Martian alteration. Thermal infrared (TIR) spectra from the Mars Global Surveyor Thermal Emission Spectrometer (TES) and Mars Exploration Rover Miniature Thermal Emission Spectrometer (Mini-TES) are emphasized herein and supported by laboratory spectra.

Orbital Observations: Visible/near-infrared spectra from the Mars Express OMEGA and Mars Reconnaissance Orbiter CRISM instruments have provided definitive evidence for phyllosilicate alteration phases including clay minerals [e.g., 1, 2]. Such phases had been suggested based on TES data [e.g., 3], but their identification was ambiguous. We now recognize in TES spectra from Mawrth Vallis and other phyllosilicate-bearing locations identified by OMEGA/CRISM, features that are strikingly similar to those of phyllosilicate-altered terrestrial basalts (Fig 1).

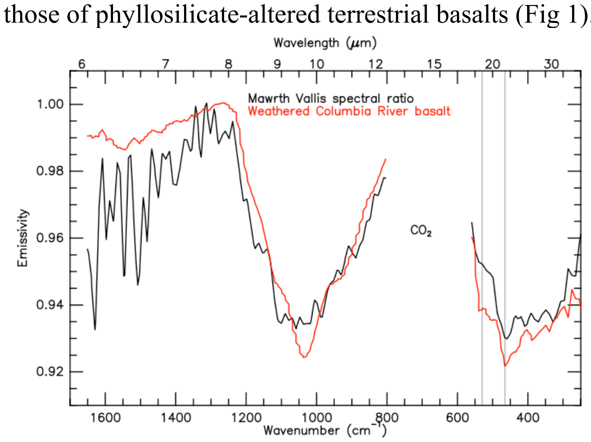

Figure 1. Comparison of a TES spectral average from light-toned outcrops adjacent to Mawrth Vallis vs. a weathered Columbia River basalt from [4]. Six TES spectra with the strongest absorption at ~465 cm^{-1} from OCK p3789 were averaged and ratioed to an average from an adjacent dust-covered terrain observed in OCK p3776. Features near 465 and 530 cm^{-1} are diagnostic of dioctahedral smectites and evident in both the weathered basalt and the TES spectrum.

We have not yet established the abundance of the apparent clay mineral phase(s), but the presence of a shoulder near 530 cm^{-1} rather than a clear minimum in this position suggests that a dioctahedral smectite phase is present near the detection limit (10-20%) established by [5]. Note that abundance refers to areal exposure in a TES pixel, which is ~3x6 km. Although the TES spectrum from Mawrth Vallis is consistent with that of weathered Columbia River basalt, this does not imply that the same lithology is present. Instead, it suggests a comparable mineralogy.

Weathered Columbia River basalt has been presented as a spectral analog to TES surface Type 2 material [6]. But the absence of both a “530 feature” [5] and OMEGA/CRISM phyllosilicate detections in Type 2 locations [7], significantly weaken the case for such alteration of Type 2 material.

Surface Observations: The rocks along *Spirit's* traverse in Gusev crater show a range of alteration from minor sulfate enrichment of minimally altered picrobasalt [8] to major silica enrichment by acid leaching of or aqueous precipitation on an unidentified host rock [9]. In between are several classes of rocks that show indications of significant alteration based upon elemental data from the Alpha Particle X-ray Spectrometer (APXS) and/or Fe mineralogy and oxidation state data from the Mössbauer spectrometer (MB). One rock shows definitive evidence of a coating (Mazatzal) [e.g., 10]. Enigmatically, none of these “in between” examples shows definitive evidence of phyllosilicate, sulfate, or silica alteration despite the sensitivity of thermal infrared spectroscopy to even thin coatings and modest alteration as shown by laboratory measurements [e.g., 11, 12].

Mazatzal coating. The coating on Mazatzal, a rock located on the rim of Bonneville crater, was observed by Mini-TES to completely obscure the spectral character of the underlying Adirondack-class basalt (Fig. 2). Yet its TIR spectrum does not resemble that of any recognized terrestrial rock coating, which typically would be dominated by phyllosilicate, sulfate, carbonate, or silica phases. Instead, it most closely resembles a combination of amorphous silicate phases [8].

Clovis class. Spanning *Spirit's* traverse of the West Spur of Husband Hill are rocks grouped into the Clovis class [e.g., 13, 14]. These layered clastic rocks appear substantially altered based upon both elevated S, Cl, and Br relative to the Adirondack-class basalts and the

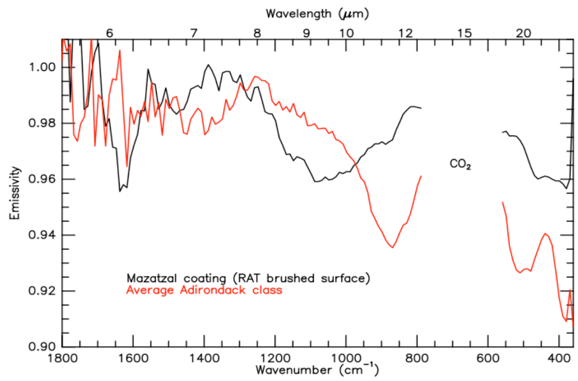

Figure 2. Comparison of a Mini-TES spectra of the coating on Mazatzal rock to the average of Adirondack-class basalt. The Mazatzal spectrum is an average of three observations of the brushed surface of the rock. It has been corrected for contributions from dust, slope, and sky [8] and filtered.

presence of goethite and highly oxidized Fe content [e.g., 14]. Mini-TES spectra show none of the defining features of common terrestrial alteration [12] (Fig. 3). Instead, they appear dominated by an amorphous phase of basaltic composition [13].

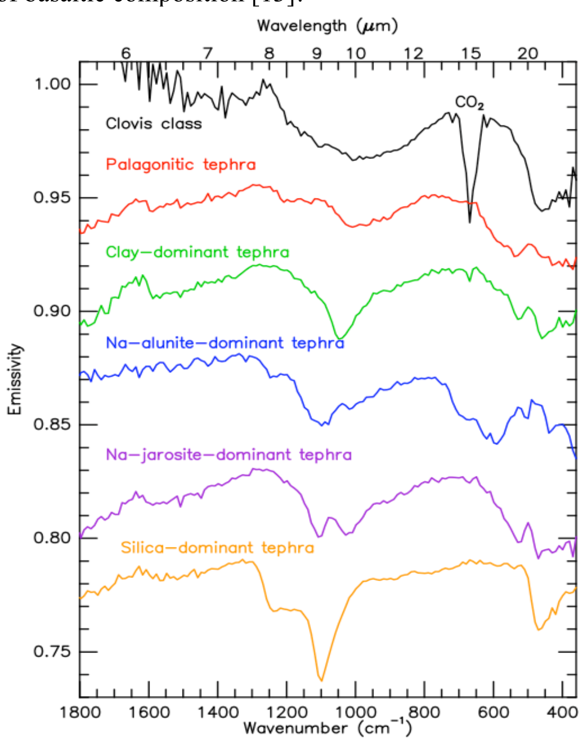

Figure 3. Comparison of a Mini-TES spectrum of Clovis-class rock to altered tephras from Hawaii. Tephra spectra are from [12] except for the silica-dominant tephra from SWR.

Assemblee sub-class. Assemblee is part of a heavily eroded outcrop near the top of Husband Hill. Its APXS-derived chemistry is consistent with a major montmorillonite component (up to 80%) [15]. However, Mini-TES and MB results do not support this. Instead, we have found that its Mini-TES spectrum is remarkably similar to an unaltered tephra from Hawaii (Fig. 4). The addition of a few percent of a sulfate spectral component to the tephra spectrum provides an improved fit to Assemblee, consistent with minor sulfate alteration.

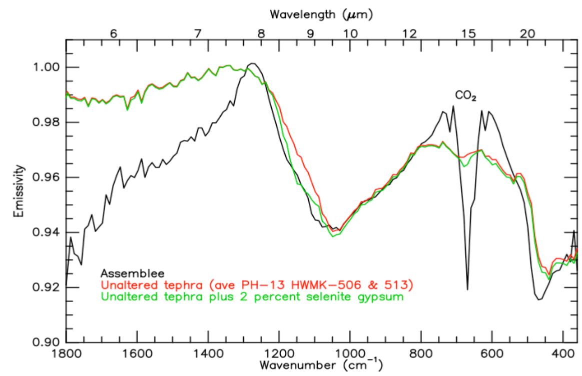

Figure 4. Comparison of a Mini-TES spectrum of the rock Assemblee to unaltered Hawaiian tephra from [12].

Conclusions: TES spectra now appear to support the identifications in some places of phyllosilicates observed by OMEGA/CRISM. This serves to demonstrate the detectability of such phases with TIR spectra. Enigmatically, TIR spectra from Mini-TES in Gusev crater show no such phases on rocks that clearly appear altered based on other data sets. Other typical candidate alteration phases are not evident. This suggests that the products of some styles of Martian alteration are inconsistent with those common in terrestrial alteration. Amorphous phases are candidates that need further investigation.

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