THE ROCKS OF GUSEV CRATER AS VIEWED BY MINI-TES. S.W. Ruff[1], P. R. Christensen[1], D. L. Blaney[2] and the Athena Science Team, [1]Arizona State University, Department of Geological Sciences, Mars Space Flight Facility, Tempe, AZ, 85287-6305, steve.ruff@asu.edu, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109

Introduction: The Miniature Thermal Emission Spectrometer (Mini-TES) on board the Mars Exploration Rover Spirit has been used successfully to acquire thermal infrared spectra of the rocks present at the Gusev Crater landing site and its environs. While initial efforts to interpret these spectra were hampered by spectral contributions from the atmosphere, the combination of a clearing atmosphere and a better understanding of the role of downwelling radiance has yielded improved results. A method to separate the atmospheric contributions from rock spectra is under development. Along the rover's traverse from the lander into the Columbia Hills, at least three distinct rock types have been recognized: an olivine-rich basalt, a volcaniclastic rock dominated by an amorphous component, and a second volcaniclastic rock dominated by plagioclase of intermediate composition.

Cold Rocks, Warm Sky: Spirit arrived on the Gusev plains at a time during which suspended dust in the atmosphere was at a maximum concentration, leading to a strong component of downwelling radiance. The spectral features due to dust and CO_2 can impact the spectrum of rocks (Fig. 1). Because

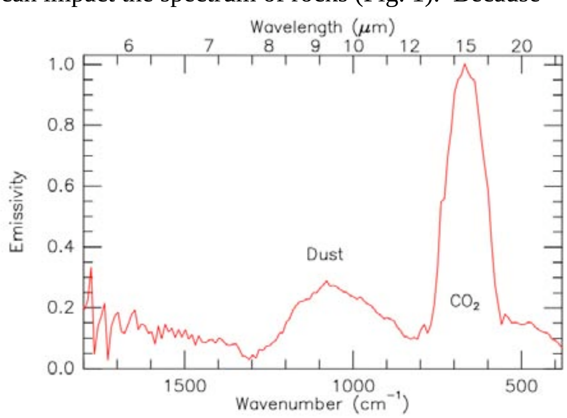

Fig. 1. Thermal infrared spectral features of the Martian atmosphere.

of the high thermal inertia of the cobbles and boulders observed by Mini-TES, it was common to find that the rocks were radiating with a temperature equal to or even less than that of the atmosphere. This situation can be recognized from the appearance of the atmospheric CO_2 feature in any Mini-TES spectrum. When the atmosphere is warm relative to the temperature of a rock, the CO_2 feature appears in emission rather than absorption, i.e., it has a maximum emissivity ≥ 1 (Fig. 2). Under these conditions, the spectral contribution of dust in the atmosphere can be quite significant, leading to a distortion of the rock spectrum impacting most strongly the spectral region between ~1300–800 cm^{-1}. This situation tends to be worse during early afternoon hours. As the months progressed the atmospheric opacity dropped, diminishing its impact on rock spectra. In addition, it was recognized that spectra of rocks measured late in the afternoon were much less effected, due to the drop in temperature of the atmosphere relative to the rocks.

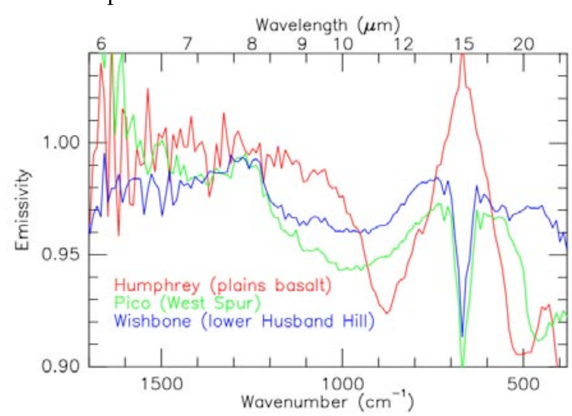

Fig. 2. Three spectral classes of rocks observed in Gusev Crater. Note that the 15 μm CO_2 feature appears in emission in the Humphrey spectrum, indicating that the rock is cooler than the atmosphere and that its spectrum is impacted significantly by downwelling radiance, mostly between ~1300–800 cm^{-1}.

Plains Basalt: With one exception, the rocks measured by Mini-TES prior to arriving at the Columbia Hills generally have the same spectral character. The one exception is the rock named Mazatzal at the rim of Bonneville crater. Its spectral character likely is due to the presence of a rock coating [1] and will not be described further in this work. The plains rocks all share a spectral feature at long wavelengths that is attributed to the presence of an abundant olivine component with a composition in the range of Fo_{35}–Fo_{60} [1]. The spectra of these rocks include a significant atmospheric component that most strongly impacts the middle wavelengths, obscuring the spectral details of the other mineral components. Plains rocks measured later in the mission as the atmospheric opacity dropped show a change that likely represents a more accurate spectrum of these rocks (Fig. 3). However, until a full atmospheric separation method is developed, the spectra of the plains basalts will not be fully interpreted.

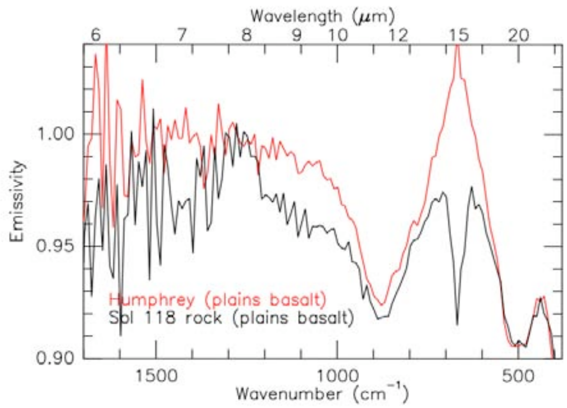

Fig. 3. A rock from sol 118 demonstrates the change in the ~1300–800 cm^{-1} region when the temperature of the rock is greater than the atmosphere. Note that the CO_2 feature appears in absorption and the longest wavelengths are unaffected.

West Spur of the Columbia Hills: By the time Spirit had reached the first rise of the Columbia Hills, dubbed West Spur, the atmospheric opacity had reached a minimum. This condition contributed to improved rock spectra that in some cases appear minimally effected by downwelling radiance. An example is the rock named Pico, which best displays the spectral character of the dozens of rocks measured by Mini-TES on the West Spur (Fig. 2). It is immediately apparent that these rocks are very different from the Plains. The Pico spectrum has been deconvolved successfully, yielding a result that shows that basaltic glass is the dominant component (Mauna Kea glass sample used in the deconvolution was provided by R. V. Morris). Olivine, pyroxene, and plagioclase have not been isolated in the Pico spectrum although they may occur as crystallites in the glass end member. While other amorphous components could mimic the spectrum of basaltic glass, the spectral variations with SiO_2 composition that are known to occur preclude silica-rich glasses as candidates. Impact-shocked minerals like plagioclase remain as viable components. Textural details observed in Microscopic Imager (MI) images and the relative softness of the West Spur rocks as implied from the low Rock Abrasion Tool (RAT) grind energies suggest that they are of volcaniclastic origin.

Lower Husband Hill: Spirit traversed from west to east across the West Spur, crossing an eastern contact of a plains embayment at which point rocks with the spectrum of plains basalt were encountered. Another rock with a spectrum not previously observed was also encountered at this contact. By the time Spirit had reached the lower elevations of Husband Hill, the new spectral type was confirmed by the presence of dozens of rocks with similar spectral features. An especially dark and apparently dust-free rock named Wishbone has provided the best example of this spectral class (Fig. 2). Deconvolution of the Wishbone spectrum shows that plagioclase feldspar of intermediate composition is the dominant component with lesser pyroxene and olivine components. The basaltic glass that so dominates the West Spur rocks is not observed in the rocks of lower Husband Hill. However, the textures observed in MI images look more like those of the West Spur rocks than those of the plains rocks. Combined with the relatively low RAT grind energies, it appears that these rocks also are volcaniclastic albeit with a different geologic history.

Conclusions: We are developing the means to separate atmospheric spectral features from rock spectra. Measurements made in the late afternoon when the temperature difference between the rocks and sky is the greatest provide spectra that are least impacted by downwelling radiance. Additionally, the long wavelength range of Mini-TES spectra contain spectral features that are least effected by contributions from the atmosphere due to its relative transparency in this range. Mini-TES spectra have thus been used to reveal the geological diversity in Gusev crater and will continue to be a rich source of mineralogical information as Spirit continues its traverse.

References: [1] Christensen et al. (2004), *Science*, 305, 837-842.