MULTISPECTRAL REFLECTANCE OF ROCKS IN THE COLUMBIA HILLS EXAMINED BY THE MARS EXPLORATION ROVER SPIRIT: CUMBERLAND RIDGE TO HOME PLATE. W.H. Farrand[1] J.F. Bell III[2], J.R. Johnson[3], D.L. Blaney[4]. [1]Space Science Institute, 4750 Walnut St. #205, Boulder, CO 80301, farrand@spacescience.org, [2]Department of Astronomy, Cornell University, Ithaca, NY, [3]U.S. Geological Survey, Flagstaff, AZ, [4]Jet Propulsion Lab, Pasadena, CA.

Introduction: Since its time at the Cumberland Ridge portion of Husband Hill, the Mars Exploration Rover Spirit has observed several rock types different from those observed previously. In [1], the visible and near infrared (VNIR) reflectance properties of rocks observed through sol 419 of Spirit's mission were discussed. These observations were made using the eleven wavelengths collected by the Spirit rover's Pancam. This paper reports on observations after sol 419 through Spirit's exploration of Home Plate and the nearby "Winter Haven" location (up to sol 1050).

The Pancam Instrument and Data: Pancam consists of two digital cameras mounted on a mast over the deck of the rover. The two cameras enable stereo imaging. Each Pancam "eye" utilizes a 1024x1024 active imaging area frame transfer CCD detector array and has an 8-position filter wheel allowing multispectral imaging in the 400 to 1000 nm VNIR spectral range. Operational multispectral observations typically consisted of observations in 13 "geology" filters with spectral overlap between the eyes near 435 and 750 nm. Further details on the Pancam instrument are provided in [2, 3].

Processing of Multispectral Data: Pancam data are calibrated to absolute radiance using pre-flight radiance coefficients derived from integrating sphere observations and corrected for detector and electronic temperature variations. The data are calibrated to radiance factor (I/F) by reference to measurements made of a calibration target mounted on the deck of the rover. An empirical correction for dust accumulation on the calibration target has been applied to the data [3]. By dividing by the solar incidence angle at the time of data acquisition, the data are converted to relative reflectance (R*).

Spectral variability of Columbia Hills rocks: As was noted in [1], there is substantial VNIR spectral diversity among rocks observed by Spirit in the Columbia Hills. This spectral diversity largely mimicked chemical diversity discussed in [4] and thermal infrared diversity discussed by [5]. An example of this is provided in **Fig. 1** which shows a scene at the summit of Husband Hill with two distinct spectral classes of rocks. The predominant summit rocks characterized by the outcrop rocks Hillary and Tenzing and what appear to be float rocks with a deeper 900 nm band characterized by the rocks Bowline and Prussick.

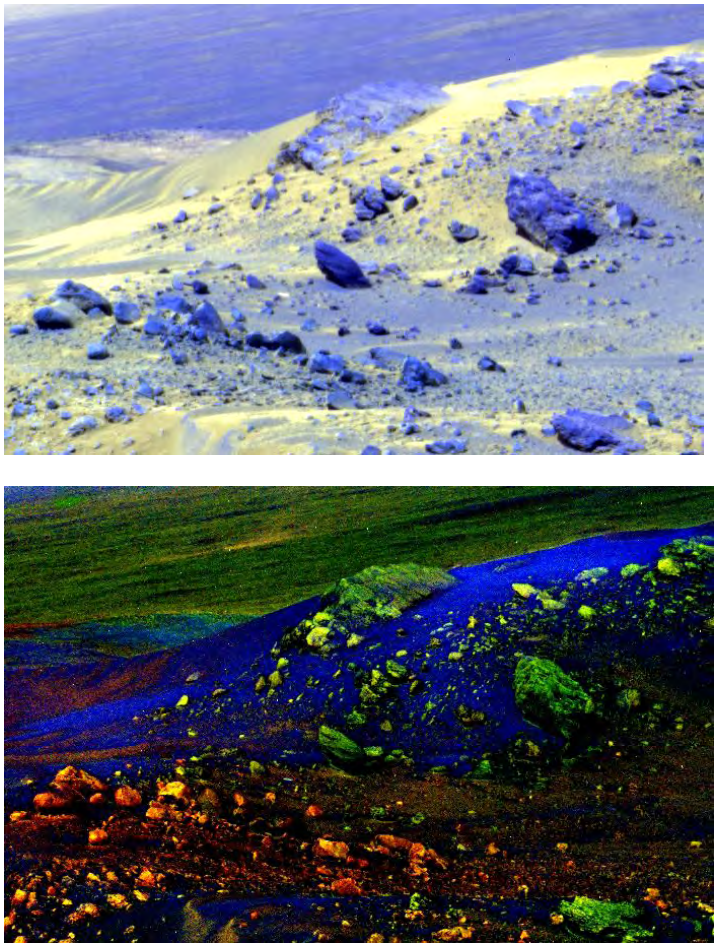

Figure 1. a. (top) Sol 608 P2582 R521 (904, 754, 436 nm) composite of rocks near the summit of Husband Hill. **b.** (bottom) Composite of CEM [6] fraction images of rocks with strong 900 nm band (red), shallow 900 nm band (green) and bright drift (blue).

Post Sol 419 Rock Spectral Classes: Here we describe six primary spectral classes observed by Spirit subsequent to sol 419. Archetypical spectra of these six classes are shown in **Fig. 2**. These clases were determined on the basis of distinguishing spectral characteristics described below and on whether there were multiple examples of rocks displaying these characteristics. Rocks might be grouped within a class, but have reflectance spectra differing somewhat from that of the archetypes shown in **Fig. 2**. The spectra in **Fig. 2** and descriptions of spectral characteristics be-

low are based on spectra from rock surfaces that were either brushed by Spirit's RAT or appear to have been swept clean by wind.

The Watchtower spectral class was described in [1], but since it was seen elsewhere on Cumberland Ridge subsequent to sol 419, it is included here. It is an altered rock with abundant hematite and is characterized primarily by its positive 754 to 1009 nm slope. The Jibsheet spectral class was observed at Cumberland Ridge. Some of the Husband Hill summit rocks, such as those assigned the green color in **Fig. 1b**, could also be characterized as being in that class. It is characterized by a shallow NIR absorption band with a 934 nm band minimum. The Methuselah spectral class is essentially the same as the lower West Spur class described in [1] with a significant NIR absorption centered alternatively in the 900 to 934 nm bands. The class represented in **Fig. 2** by the rock Bowline has a similar NIR absorption as the previous class, but it has a shorter wavelength relative reflectance maximum in the 671 to 754 nm bands. It also has a shallower blue to red slope indicating a lower degree of oxidation. The spectral class represented here by a spectrum from the rock Commanche is distinct from any observed previously. It is distinguished by a band minimum at (or longwards of) 1009 nm and a short relative reflectance maximum in the 671 to 754 nm band. Natural rock surfaces observed at Home Plate and at the Posey RAT brush spot have spectra similar to that shown in **Fig. 2** with a rounded relative reflectance maximum generally centered at 754 nm and a shallow NIR absorption with a low 754 to 864 nm slope, a 934 nm band minimum and a moderate upturn in reflectance in the 1009 nm band.

Discussion: Of the classes described here, several are spectrally similar to several from the first part of Spirit's mission [1] while others are distinct. The Watchtower class is carried over from [1]. Also, in addition to the classes discussed here, there are variations on the Adirondack (Gusev plains basalt) class from [1] amongst the numerous basaltic float rocks observed in the Columbia Hills. As noted above, the Methuselah class has the same spectral characteristics as the lower West Spur class from [1]. The Bowline class is similar to the Methuselah class, but has some spectral differences as described above. It could simply be a less oxidized version of the Methuslah rocks. The spectral class represented here by a spectrum from Commanche represents a new spectral class. Spirit's Mössbauer spectrometer observed that rocks such as Commanche and Seminole have more olivine than any Columbia Hills rocks examined previously [7] and the VNIR spectral characteristics described above are consistent with abundant olivine. The Home Plate class is very similar to the Clovis class described in [1]. Home Plate is a deposit of layered rocks and other layered rocks examined near Spirit's "Winter Haven" site have similar spectra. Layered deposits were also observed among Clovis class rocks on the West Spur. Home Plate and West Spur rocks have been tentatively discussed as potentially being volcaniclastic in nature [2, 8].

Conclusions: More work remains to be done to consider how spectral class mapping of these rocks will help in constraining geologic maps and structural models of the Columbia Hills. The ability to map out these classes, as demonstrated in **Fig. 1**, also holds promise for what could be achieved with a very high spatial resolution orbital instrument with multispectral capabilities in the 400 to 1100 nm spectral range.

References: [1] Farrand W.H. et al. (2006) *JGR, 111*, 2005JE002495. [2] Bell J.F. et al. (2003) *JGR,108*, 2003JE002070. [3] Bell J.F. et al. (2006) *JGR,111*, 2005JE002444. [4] Squyres S.W. et al. (2006) *JGR., 111*, 2005JE002516. [5] Ruff S.W. et al. (2006) *JGR, 111*, 2006JE002747. [6] Farrand W.H. and J.C. Harsanyi (1997) *Rem. Sens. Env., 59*, 64-76. [7] Klingelhoefer G.H. et al. (2006) AGU Fall Mtg, abs. #P43A-02. [8] Squyres S.W. et al. (2007) *Science*, submitted.

Acknowledgements: The Mars Exploration Rover project is administered through JPL. We acknowledge JPL and NASA for their on-going support of the mission.

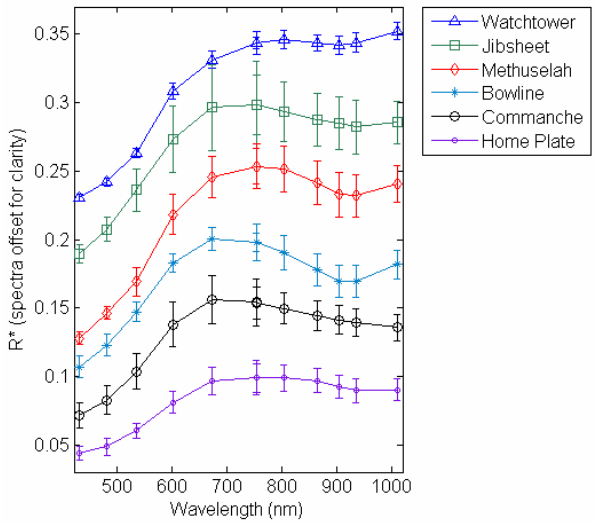

Figure 2. VNIR spectral classes of rocks observed by Spirit after sol 419 and up to its exploration of the Home Plate region.