VISIBLE AND NEAR INFRARED SPECTRAL CLASSES OF ROCKS OBSERVED AT CAPE YORK, ENDEAVOUR CRATER, MARS. W. H. Farrand[1], J. R. Johnson[2], J.F. Bell III[3], M.S. Rice[4], [1]Space Science Institute, 4750 Walnut St., #205, Boulder, CO 80301, farrand@spacescience.org, [2]Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, [3]School of Earth and Space Exploration, Arizona State University, Tempe, AZ. [4]Department of Astronomy, Cornell University, Ithaca, NY.

Introduction: On sol 2681 of its mission, the Mars Exploration Rover Opportunity crossed a geologic boundary to arrive at Cape York, a portion of the rim of the ~22 km diameter Endeavour crater in southern Meridiani Planum. Since that time, the rover has been examining rocks of presumed Noachian age. These rock outcrops and scattered displaced rocks have been imaged by the rover's multispectral Pancam instrument and some have been subjected to *in situ* examination by instruments on the rover's Instrument Deployment Device (IDD). The visible and near infrared (VNIR) multispectral character of these rocks are distinct from those examined to-date on the Meridiani plains [1] and, in some instances are more similar to rocks observed by the Spirit rover at Gusev crater [2, 3].

Pancam multispectral imaging of rocks on Cape York: Pancam collects 11 spectrally unique channels in the 430 to 1010 nm wavelength range. There are 2 overlapping channels for red or blue stereo for a total of 13 filters ("13f") devoted to geologic analyses. These data are converted to radiance factor and then to relative reflectance (R*) by dividing radiance factor by the cosine of the solar incidence angle. More details on the Pancam instrument and its calibration are provided in [4, 5].

Since its arrival at Cape York, Opportunity has collected a large number of 13f observations of rock surfaces as well as 6 band mosaics of various rock targets. These multispectral observations have been analyzed using a number of approaches including decorrelation stretching, spectral parameterization, and spectral mixture analysis. A library of averages of pixels from spectrally distinct surfaces has been assembled and subjected to further study using clustering and endmember determination approaches, many similar to those employed in [3].

Geologic setting: The Cape York outcrop has been named the Shoemaker formation [6] and has been interpreted as an impact suevite consisting of a matrix and embedded clasts [6]. This outcrop has been examined at the Chester Lake, Transvaal, and Greeley Haven outcrops. In addition, a number of ejecta blocks surrounding the ~20 m diameter Odyssey crater were examined and represent a potentially deeper unit lying below the Shoemaker formation. These materials were examined at the rock target Tisdale_2.

Additionally, a presumed vein, Homestake, was imaged and subjected to IDD investigations.

Rock spectral classes: Hierarchical cluster analysis [7] and principal components analysis based endmember determinations of a set of 64 13f spectra (assembled from nearly all 13f scenes acquired to-date at Cape York) indicated at least five spectral classes.

Examination of decorrelation stretch composites of 673, 535, and 432 nm bands such as **Fig. 1B** indicated blue and purple surfaces on many Cape York rocks. The spectral difference between these two color classes is indicated primarily in a red/blue ratio such as 753/482 nm where the purple surfaces have a higher red/blue ratio. Some purple surfaces (such as the *Tisdale 2 purple* spectrum in **Fig. 2**) also display a broad absorption feature with a minimum in the 904 nm band. In the 673, 535, 432 nm composites, most blue rock surfaces on Cape York display a spectrum similar to the *Transvaal rock* spectrum in **Fig. 2** with a reflectance maximum in either the 673 or 754 nm band and decreasing reflectance to 1009 nm; sometimes with a mild upturn in reflectance from the 934 to 1009 nm band. These spectra are similar to those of many basaltic rocks examined by Spirit in Gusev crater [2, 3] (*Spirit basalt* spectrum included for comparison in **Fig. 2**).

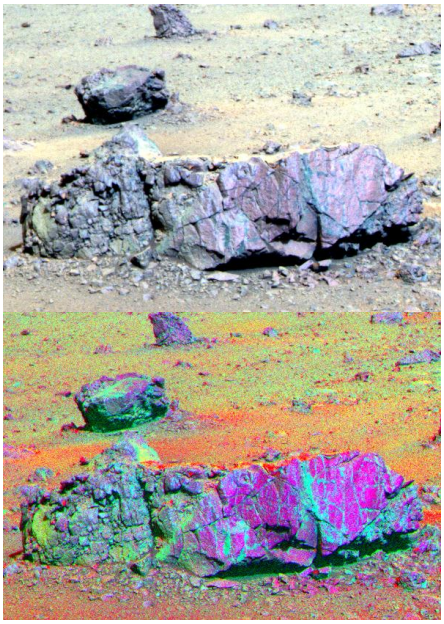

Fig. 1. A. 673, 535, 432 nm color composite of Tisdale_1. **B**. Decorrelation stretch of the same bands that highlights blue and purple surfaces.

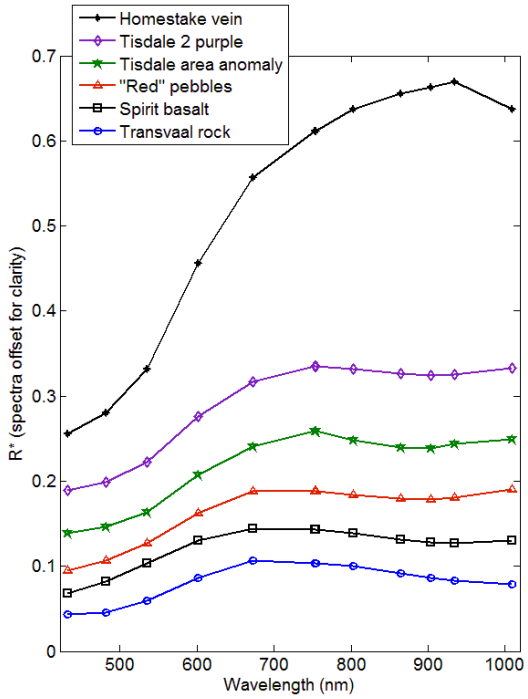

Fig. 2 Pancam spectra of rock spectral classes observed on Cape York plus basalt observed by Spirit, included for comparison with the *Transvaal rock*.

Spectral mixture analysis of right eye (primarily near infrared) data of several blocks in the vicinity of the Tisdale rocks consistently showed three spectral endmembers of shade, bright drift, and bare rock. The RMS error images covering the blocks in question showed high RMS error over several smaller features (**Fig. 3**). These spectrally anomalous patches (such as *Tisdale area anomaly* in **Fig. 2**) display a sharp reflectance maximum at 754 nm and a broad band with a minimum between the 864 and 904 nm bands and an increase in reflectance to 1009 nm with a decrease in slope from 934 to 1009 nm. These patches also display a higher 535 nm band depth. This is likely caused by a Fe^{3+} - bearing mineral, possibly even a hydrated iron sulfate [e.g., amarantite; $Fe^{3+}(SO_4)(OH)\bullet 3(H_2O)$].

The spectral classes also include the *Homestake vein* (**Fig. 2**) which is characterized by a marked turndown in reflectance from the 934 to 1009 nm band which is attributed to the ~1000 nm $2\nu_1 + \nu_3$ H_2O combination absorption band and/or the $3\nu_{OH}$ overtone absorption band in a hydrated mineral [8], likely gypsum based on APXS data of this target [6].

Also of note are a class of "red" pebbles which were first observed scattered about the area of the Chester Lake outcrop. These pebbles appear red in 1009, 934, 754 nm color composites and have a broad ferrous iron absorption band with a minimum in the 904 nm band. Spectral band fitting indicates a best match for the orthopyroxene hypersthene.

Other spectral classes: A six color mosaic collected near Odyssey crater also showed another potentially new spectral class on several blocks, most prominently on the block Skead. In 754, 535, 432 nm composites these surfaces have a blue-green color and a negative 535 nm band depth. These surfaces likely represent a coating of some sort, potentially one similar to terrestrial desert varnishes, although additional 13f observations acquired under better lighting conditions are needed.

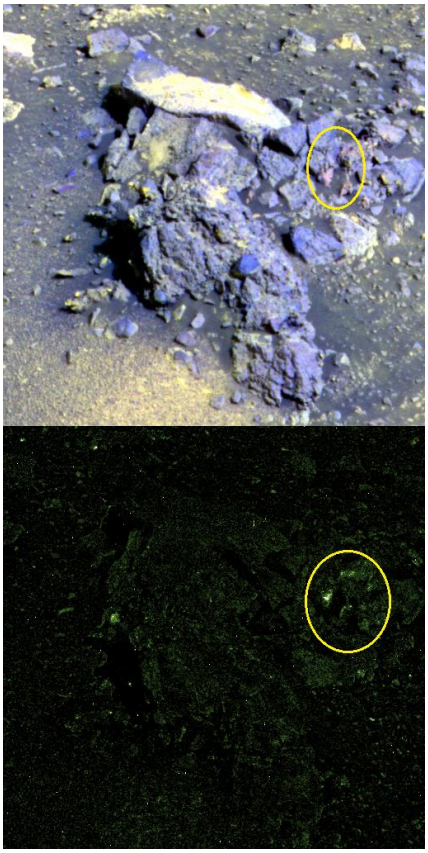

Fig. 3 (Top) 1009, 803, 436 nm composite of rock Tisdale_5. (Bottom) RMS error image of right eye data with high RMS error patch circled.

References: [1] Farrand, W.H. et al. (2007) *JGR*, *112*, 2006JE002773 [2] Farrand, W.H. et al. (2006) *JGR*, *111*, 2005JE002495. [3] Farrand, W.H. et al. (2008) *JGR*, *113*, 2008JE003237. [4] Bell III, J.F., et al. (2003) *JGR,108*, 2003JE002070. [5] Bell III, J.F. et al. (2006) *JGR,111*, 2005JE002444. [6] Squyres, S.W. et al. (in preparation for) *Science*. [7] Davis, J.C. (1986) *Statistics and Data Analysis in Geology*, 646 pp. [8] Rice, M. et al. (2010) *Icarus, 205,* 375-395.