STRATIGRAPHIC RELATIONSHIPS ON HUSBAND HILL, MARS. S. B. Cole, W. A. Watters, and S. W. Squyres, Department of Astronomy, Cornell University, 425 Space Sciences Building, Ithaca, NY 14853, shoshe@astro.cornell.edu.

Introduction: The Mars Exploration Rover Spirit has been exploring the Columbia Hills since mid-2004 (see Fig. 1). The formation of the Hills is uncertain; they are hypothesized to be the overlapping rims of multiple craters, or the remains of a central peak or ring. It is not known whether the units visible along Spirit's traverse are part of the original Columbia Hills edifice, or were deposited after the hills were uplifted. In the former case, outcrop bedding attitudes should conform to the local topography, while with the latter, their dips may be significantly steeper.

Between sols 462 and 503, Spirit investigated three prominent outcrops, separated by ~5-15m, on Cumberland Ridge, to the northwest of Tennessee Valley and the Husband Hill summit (see Fig. 2). The Methuselah, Jibsheet, and Larry's Lookout outcrops were remarkable in their chemical similarity and mineralogical variation [1-4]. Outcrop exposures are rare in the Columbia Hills. As localized bedrock exposures with visible bedding planes, Cumberland Ridge presents a rare example of a potential stratigraphic section along Spirit's traverse.

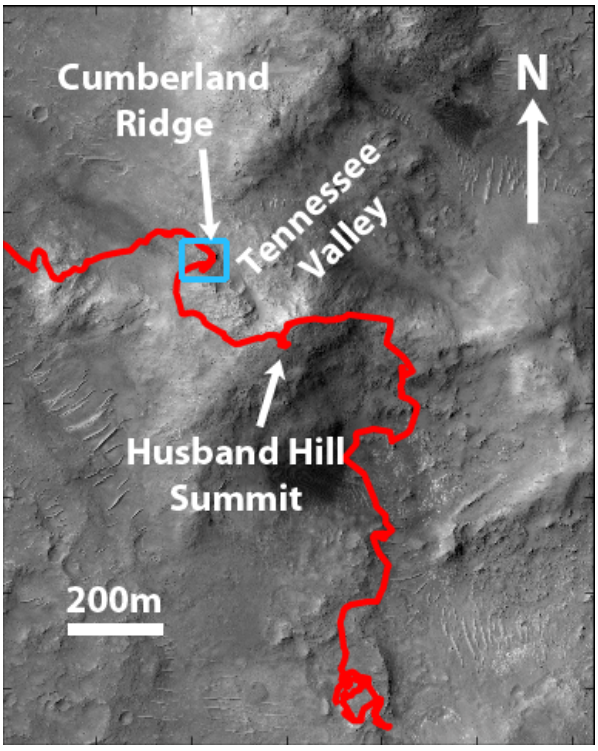

Fig. 1: HiRISE image showing Spirit's traverse through the Columbia Hills. The blue rectangle indicates the location of Fig. 2.

The purpose of this study is to test the hypotheses that 1) the Cumberland Ridge outcrops form a stratigraphic section, and 2) these units drape Husband Hill.

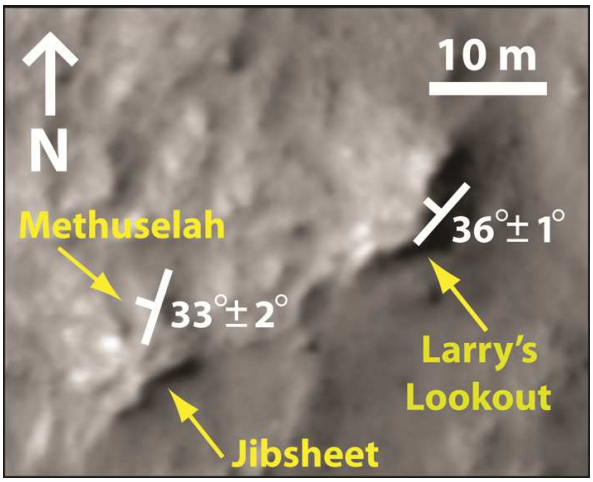

Fig. 2: HiRISE image of Cumberland Ridge. Strikes and dips, with error estimates, are indicated for the Methuselah (left) and Larry's Lookout (right) outcrops.

Dataset and Method: We measure the attitudes of bedding planes using stereo image pairs of nearby (< 2m from the rover) targets. We use Pancam images when possible, and Navcam stereo observations where Pancam stereo coverage was not acquired. The Pancam cameras have a resolution of 0.27mrad/pixel and a 16° x 16° field of view, and are separated by a 30cm baseline, providing good stereo ranging accuracy for distances < 10m [5]. The Navcam cameras have a 20cm baseline, 0.82mrad/pixel resolution, and 45° x 45° field of view [6].

Previous workers [7] have estimated the orientations of several Husband Hill outcrops, including Larry's Lookout, by fitting planes to three-dimensional computer visualization models of the outcrops. Rather than fit planes to large-scale features, we trace the finest-scale (often < 1cm) layering visible in high-resolution stereo images of the outcrops. Fig. 3 shows a subframe of a Pancam image of the Methuselah target Keystone, with bedding planes highlighted. We use the Video Image Communication And Retrieval (VICAR) image processing software system [8] to estimate layer strike and dip and associated uncertainty as well as coplanarity, using the method of Watters *et al.* (2010) [9]. The trace must exhibit significant relief in order for the orientation of the plane to be determined. We use a bootstrap analysis [10] to rigorously estimate the

uncertainty in our measurements. The error analysis includes 1000 bootstrap samples, which were sampled with replacement.

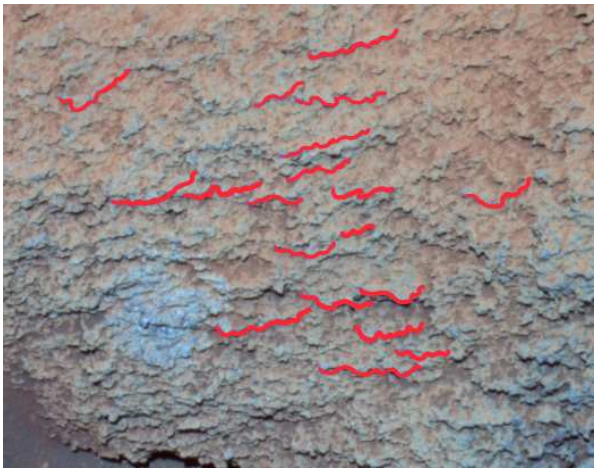

Fig. 3: Examples of bedding planes on the Methuselah target Keystone. The light-toned region towards the bottom left was brushed by the rover's Rock Abrasion Tool (RAT), and is approximately 45mm in diameter.

Results: On the basis of over 60 measurements from several locations on the outcrops, we estimate the bedding planes of the Methuselah and Larry's Lookout outcrops to dip 33°±2° and 36°±1°, respectively, approximately toward the northwest (see Fig. 2). These measurements are consistent with the hypothesis that the Cumberland Ridge outcrops form a stratigraphic section, with Larry's Lookout stratigraphically lower than Methuselah if the stratigraphy is not inverted. We note that our measurements are ~10° steeper than those of McCoy et al. (2008) [7]. Additionally, the measured dips are distinctly steeper than the local topography, consistent with the hypothesis that the material composing the outcrops formed after the Columbia Hills were uplifted, and drapes the edifice.

References: [1] Squyres, S. W. et al. (2006) *JGR, 111*, E02S11, doi:10.1029/2005JE002562. [2] Gellert, R. et al. (2006) *JGR 111*, E02S05, doi:10.1029/2005JE002555. [3] Ming, D. W. et al. (2006) *JGR 111*, E02S12, doi:10.1029/2005JE002560. [4] Ming, D. W. et al. (2008) *JGR 113*, E12S39, doi:10.1029/2008JE003195. [5] Bell, J. F., III, et al. (2003) *JGR 108*(E12), 8063, doi:10.1029/2003JE002070. [6] Maki, J. N. et al (2003) *JGR 108*(E12), 8071, doi:10.1029/2003JE002077. [7] McCoy, T. J. et al (2008) *JGR 113*, E06S03, doi:10.1029/2007JE003041. [8] Lorre, J. and Deen, B. (1999) VICAR-marscorr, NASA/JPL; http://www-mipl.jpl.nasa.gov/external/vicar.html [9] Watters, W. A. et al. (2010) *Icarus*, in press. [10] Press, W. H. et al. (2007) *Numerical Recipes*, Cambridge U. Press.