COMPARISON OF ORBITAL INFRARED OBSERVATIONS AND SURFACE MEASUREMENTS BY THE MARS EXPLORATION ROVER SPIRIT AT GUSEV CRATER. J.E. Moersch[1], L. Crumpler, R. Arvidson, D. Blaney, P. Christensen, R. Fergason, M. Golombek, A. Knudson, J. Piatek, S. Ruff, S. Squyres, L.L. Tornabene, M. Wyatt, and the Athena Science Team, [1]Dept. Earth and Planetary Sciences, University of Tennessee, Knoxville, TN 37996, jmoersch@utk.edu.

Introduction: The Mars Exploration Rovers are the first robotic vehicles to traverse a distance across the surface of another planet that is greater than the size of a single resolution element in remote sensing data collected from orbit. This mobility affords new opportunities in making comparisons between what is seen from above and what is seen on the ground. Rover measurements can be used to ground-truth *a priori* predictions made from orbital data [1], and to make empirical calibrations of orbital data. Orbital data that have been calibrated in this way can then be used to extrapolate predictions regarding the nature of the terrain yet to be traversed.

Thermal infrared observations have featured prominently in orbital remote sensing of Mars. The Thermal Emission Spectrometer (TES) on Mars Global Surveyor has mapped the composition and thermophysical properties of the surface at moderate (~3km) spatial resolution and high (5-10 cm^{-1}) spectral resolution [2], and the Thermal Emission Imaging System (THEMIS) on Mars Odyssey is mapping the same properties at a much higher spatial resolution (100m) and moderate spectral resolution (~1 μm) [3]. Both instruments played key roles in selection of the landing sites for the Mars Exploration Rovers (e.g., [4-5]). Here we present initial results from our efforts to compare these orbital thermal infrared observations with measurements made by the rover Spirit at Gusev crater.

THEMIS thermal inertias: Past comparisons of TES-measured thermal inertias and surface rock abundances have proven favorable [6]. Spirit's long drive across the plains of Gusev crater (spanning over 30 THEMIS pixels) allows comparison not only of absolute values in surface rock abundance versus orbital thermal inertias, but also of trends along the traverse.

A THEMIS nighttime infrared radiance image of the Spirit landing site (#I01511006) was processed to a thermal inertia image using custom software that reads lookup table values generated by the thermophysical model of [7]. Ancillary inputs to the program include topography from the Mars Orbiter Laser Altimeter [8], albedo from TES [2], and atmospheric dust opacity at the time of the THEMIS observation, also obtained from TES [9]. The resulting thermal inertia image was then spatially registered to a very high resolution (1m) Mars Orbiter Camera image showing Spirit's tracks (MOC Release No. MOC2-960) using a moderate resolution (18m) THEMIS visible wavelength image (#V07909002) as an intermediate basemap. Specific sites of rover measurements were located in the MOC image by comparison to rover localization results [10].

Fig. 1 shows the MOC image of Spirit's tracks colorized using THEMIS thermal inertias. The overall range of thermal inertias in the area is small – only 230-370 J m^{-2} K^{-1} s$^{-½}$. Thermal inertias at Gusev derived using temperature measurements made from the surface by Spirit's Miniature Thermal Emission Spectrometer (Mini-TES) range from 150-430 J m^{-2} K^{-1} s$^{-½}$ [11]. The greater dynamic range of these values as compared to the THEMIS values is explained by the difference in spatial resolution between the two measurements – small exposures of extreme values are "diluted" in the 100m pixel size of THEMIS.

Despite the small range of THEMIS thermal inertias at the landing site, there is an excellent correlation between the THEMIS-derived thermal inertias and geologic features in the MOC image, indicating that the thermal inertia data are not noise-limited. For example, the continuous ejecta apron and rim of "Bonneville" crater are seen as a relatively high thermal inertia area, as contrasted to the relatively low thermal inertia interior of the crater. Visual nspection of Spirit's navigation camera (Navcam) and panoramic camera (Pancam) mosaics along the traverse also reveals a definite correlation between rock abundances and the local thermal inertia values derived from THEMIS. For example, the ejecta and rim area of "Bonneville" is heavily populated with large (>10cm) rocks, whereas much of the interior of the crater is seen to be filled with aeolian fines.

Rock abundance surveys: As a first attempt at quantifying the correlation between THEMIS thermal inertia and rock abundance, we have made a survey of rock populations at 23 positions along Spirit's traverse between "Bonneville" and the Columbia Hills using vertically-projected Navcam image mosaics taken along the traverse. Rock counts in each mosaic were taken from a 2x2-m parcel of ground at a horizontal range of about 3.3m from the camera position on the rover. This range was chosen to minimize obscuration of the surface both by the rover's shadow (in the near-field) and by vertical features (in the far-field). Generally, the parcel was selected to the north of the rover to take advantage of the best lighting contrast, although sometimes other azimuths were used to avoid obvious local anomalies, such as drifts. Rock sizes were measured perpendicular to the camera axis to avoid projection distortions. Following the method of [12], the measured populations were fit to an exponential model of the form $F = F_o e^{\beta W}$, where F is the cumulative fractional area of rocks as a function of rock size, W. F_o is the fraction of the surface area covered by rocks of all sizes, and β is the exponent of the fit. Larger (less negative) β values indicate that the rock population is biased toward larger rocks. This is important because thermal inertias are strongly influenced by rocks that are larger than the diurnal thermal skin depth (~10cm).

Results: A scatter plot of THEMIS thermal inertias versus β values from all 23 locations (not shown) indicates only a weak correlation between these parameters. No correlation is found between thermal inertia and F_o. This is likely due to the large difference in scale between the Navcam survey areas and the 100m pixels of the THEMIS image. Put another way, the scale of rock population heterogeneity is significantly smaller than 100m. To partially mitigate these issues, the rock population parameters were averaged into bins associated with different geologic provinces along the traverse and compared to similarly-averaged THEMIS thermal inertias. Six such provinces were used: Bonneville ejecta (sols 91-100), "Missoula" ejecta (sols 105-107), intercrater plains (sols 110-118), "Lahontan" ejecta (sols 121-122), rough intercrater area with overlapping blocky hollows (sols 124-134), and very rough terrain near the Columbia Hills (sols 142-155).

Figure 2 shows THEMIS thermal inertias versus rock population β values, averaged as described above. With one exception, the averaged values correlate well. The outlier point is from measurements made on the ejecta of "Lahonton" crater. We are investigating the possibility that the anomalously low β values at Lahonton come from the numerous aeolian drifts that were seen at the rover stops there, but which may not cover an appreciable fraction of the 100m THEMIS pixel for the area. Ignoring this outlier, the remaining points may be fit by the linear equation $\beta = 0.021*(T.I.) - 0.799$, with an R^2 value of 0.886.

Future Work: Thermal inertias are only half the story told from orbital thermal infrared observations – compositional evaluations based on thermal emissivity spectra are also useful. While preliminary evaluations of THEMIS daytime multispectral images show only minor spectral variations along Spirit's traverse, we will be examining these variations closely to see how they compare to spectral variations observed by Spirit with Mini-TES. Ultimately, we hope to use our orbit-surface comparisons to predict the nature of terrain yet-unexplored by Spirit, and in doing so, help guide her route in the months ahead.

References: [1] Golombek, M. et al. (2004) submitted to *Nature*. [2] Christensen, P. et al. (2001), *JGR., 106*, 23823-23871. [3] Christensen, P. et al. (2003), *Science, 10.1126/science.1080885*. [4] Christensen, P. et al. (2000), *JGR, 105*, 9623-9642. [5] Milam, K. et al., (2004), *JGR, 10.1029/2003JE002097*. [6] Golombek, M. et al. (1999), *JGR, 104*, 8585-8594. [7] Mellon, M. et al. (2000), *Icarus, 148*, 437-455. [8] Smith, D. et al. (2001), *JGR, 106*, 23689-23722. [9] Smith, M. (2004), *Icarus, 167*, 148-165. [10] Li, R. et al. (2005), *JPE&RS, in press*. [11] Fergason, R., and P. Christensen (2005) LPSC, this volume. [12] Golombek M., and D. Rapp (1997), JGR, 4117-4129.

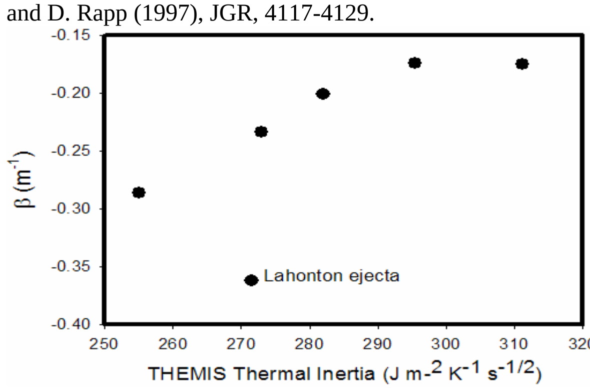

Figure 2: Correlation plot of THEMIS thermal inertias versus rock population β values from the six geologic provinces along Spirit's traverse discussed in the text. The outlier point at low β is from the two "Lahonton" crater ejecta sites.

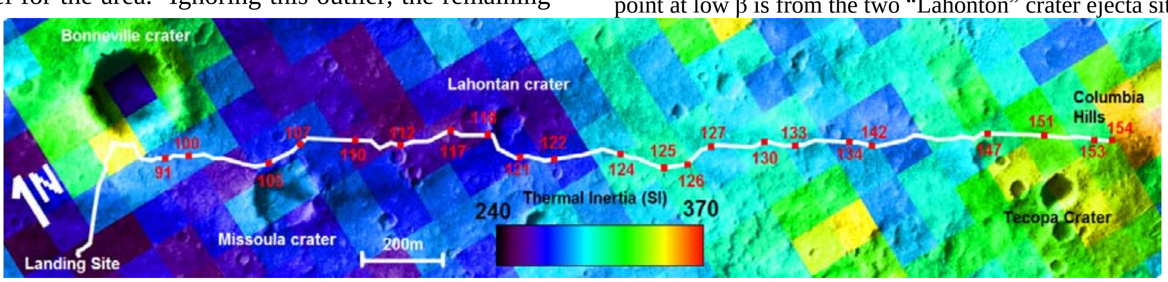

Figure 1: THEMIS thermal inertia values are used to colorize a MOC grayscale image showing Spirit's track (in white) across the plains of Gusev Crater. Red dots indicate locations in which the rock population measurements discussed in the text were made. Adjacent numbers (also in red) indicate mission sol numbers for these locations.