**COMPARISON OF TERRESTRIAL MORPHOLOGY, EJECTA, AND SEDIMENT TRANSPORT OF SMALL CRATERS: VOLCANIC AND IMPACT ANALOGS TO MARS.** V. M. Peet[1], M. S. Ramsey[1], and D. A. Crown[2], [1]Department of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA 15260, vmp10@pitt.edu, ramsey@ivis.eps.pitt.edu, [2]Planetary Science Institute, 1700 E. Ft. Lowell Rd., Suite 106 Tucson, AZ 85719, crown@psi.edu.

**Introduction:** Small craters, of both impact and volcanic origin, may represent some the most recent geologic activity on Mars [1]. Determining formational and erosional processes associated with these craters may have larger implications concerning the climate and surface evolution of Mars. The question of whether analysis of crater morphology, ejecta, and sediment transport can be ascertained through remote sensing data in a terrestrial analog and applied to Mars is the focus of this research.

Research objectives include first field observation/data collection coupled with a multi-wavelength remote sensing analysis. This methodology will be used to quantify formational and erosional processes that operate at smaller scales than previous studies. Ultimately, they will be applied to Mars datasets to determine the surface processes which operated on Mars at these small craters.

**Background:** Multiple remote sensing instruments have been selected for this study to give broad spectral coverage at similar resolutions to those in current operation or expected future operation on Mars. Previous remote sensing work at Meteor Crater has focused on the topographic asymmetry of the ejecta, its distribution, and its subsequent erosion and transport. Several past studies focused on lithologic unit mapping using a linear deconvolution approach of thermal infrared (TIR) data (both high spatial resolution <10m/pixel airborne as well as lower resolution 90m/pixel ASTER) [2-4]. Because of resolution constraints, this approach is ineffective for small scale analysis if lithologies are present in small percentages or if non mineralogic TIR spectra are present. Therefore, what is lacking from these previous studies is a detailed field analysis that describes spatial, spectral, and topographic patterns within the ejecta field. Examination of this problem and the application of similar remote sensing and field analysis techniques to volcanic maar craters (in order to compare and contrast formational and sediment transport processes) is a component of this research. [1].

Detailed field and remote sensing analyses have been undertaken at both an impact and a phreatomagmatically-generated crater. The data span a broad range of the electromagnetic spectrum with higher spatial and spectral resolution than those used in the past. It is hypothesized that interpretation of these datasets in conjunction with the field based data will allow the formational and erosional processes specific to each crater type to be distinguished. Ultimately, this methodology applied to only remote sensing data will provide an analog for small crater processes on Mars.

**Study Areas:** Two craters with different origins (impact and volcanic) of similar size, age, and climate conditions have been selected as field sites. Meteor Crater, located in the desert climate of central Arizona, formed ~50,000 years ago from the impact of a large iron nickel meteorite [5]. El Elegante Crater is a maar crater in the Pinacate Volcanic Field (PVF) in north-central Sonora, Mexico. It formed from a phreatomagmatic explosion ~150,000 years ago [6-7]. The craters have a diameters of 1.2 and 1.6 kilometers, depths of 180 and 250 meters, and rim heights of 30 and 50 meters, for Meteor Crater and El Elegante, respectively [5-7].

**Field Observations:** Data collection and field observations began in June, 2004. Five days of investigation included data and sample collection at Meteor Crater, AZ. Similar work was completed in December, 2004, at El Elegante Crater, Mexico. Cerro Colorado, a tuff cone in the PVF near El Elegante was also studied for comparison to El Elegante, but is not the primary focus of this study.

Equipment used included 1) a real-time differential GPS (d-GPS) with centimeter horizontal accuracy for locating positions, 2) a laser range finder, which when combined with the GPS, generated topographic profiles of the crater rim and near ejecta field with decimeter vertical accuracy, 3) a Forward Looking Infrared (FLIR) camera for thermal analysis of ground deposits including thermal inertia data, and 4) a Visible and Near Infrared (VNIR) field spectrometer for collection of vegetation spectra.

Nearby roads, crater rims, and distinguishing features such as ejecta lobes and sediment units were mapped using the d-GPS. These data are used for precise image georeferencing and unit mapping. A VNIR field spectrometer was used at Meteor Crater for vegetation spectra. These data will be critical for later subtraction from remote sensing data in order to produce uncontaminated mineralogic spectra. The FLIR was positioned to gather discrete images over the course of the day to capture thermal trends of rock and sediment units. Both crater wide and small ground areas (~1m) were examined with the FLIR.

Radial transects 500 to 1000 meters long were established. These projected from the crater rims into near field ejecta and were used for topographic data collection and detailed ground cover sites. These sites were placed at 50 meter intervals along each transect and were gridded into 2 meter by 2 meter areas for site classification and data/sample collection. Surficial fines and small blocks were sampled for later laboratory based spectral collection and comparison to remote sensing image data. Distinguishing features at the sites, such as ejecta lobes and sediment units, were also characterized and samples collected.

**Results**: Site classification methodology included: 1) ascertaining vegetation types and percentage surface cover, and 2) environmental description including location and erosional environment characteristics. Surficial physical characteristics were also quantified at each study site and included a surface roughness classification by comparing the percentages of blocks to fines and quantifying block size/groups within the gridded area. Mineralogic data were recorded including block/fine compositions and percentages where possible and each site was photographed in detail.

From this field based collection, a dataset of crater rim and near ejecta topography, block and fines proportions, block sizes and compositions, vegetation types and percentages, and qualitative environmental observations for both Meteor Crater and El Elegante Crater have been generated (Figure 1). Sediment transport environments data also includes Cerro Colorado.

**Conclusions:** Application of field data and results to integrated remotely sensed datasets provides an opportunity for verification of remotely sensed data that is not available in planetary scenarios. To facilitate the application of developing formational and sediment transport methodologies of small craters to Mars datasets, the removal of vegetation influences in remotely sensed spectra is an important factor. On average, Meteor Crater is 5-10% vegetated and El Elegante Crater is 15-20% vegetated. In addition, the understanding and application of the effects of vegetation on sediment transport processes is also a consideration. Near rim and far field ejecta and crater morphologies differ between the impact and maar crater sites, however, whether this is due to formational or erosive processes/erosional exposure time is still under study.

**Continuing Work:** Remote sensing dataset acquisition and analysis is a continuing part of this project. The HiRISE and CRISM instruments planned for the future Mars Reconnaissance Orbiter (VNIR and VNIR/SWIR, respectively) pair with this study's IKONOS and Hyperion datasets. THEMIS and ASTER act as the Mars/Earth TIR instrument analogs respectively; MOLA (Mars) and ASTER (Earth) function as comparable surface elevation datasets [8-9, 3]. IKONOS and Hyperion datasets for both Meteor Crater and El Elegante Crater will be analyzed and integrated into the broad spectral dataset obtained for this study.

Spectral analysis of samples in the University of Pittsburgh's Image Visualization and Infrared Spectroscopy (IVIS) Laboratory will be used for more precise end member analysis, quantification of the atmospheric effects in the remote sensing data, and determination of the spectral effect of vegetation on the VNIR and TIR data collected from space.

**References:** [1] Ramsey, M.S. and D.A. Crown (2004), *LPS XXXV*, Abstract #2031. [2] Ramsey M. S. (2002) *JGR*, *107*, doi:10.1029/2001JE001827. [3] Wright S. P. and Ramsey M. S. (2002) *LPI #1129*, 91-92. [4] Wright S. P. and Ramsey M. S. (2003) *LPI XXXIV*, Abstract #1495. [5] Shoemaker E. M. (1960) *Princeton Univ. Press*, 55 pp. [6] Gutman, J. T. (1976) *GSA Bull.*, *87*, 1718-1729. [7] Greeley R. et al. (1985) *NASA Con. Rep. 177356*, 44 pp. [8] Christensen P. R. (2003) *Science*, *299*, 1048-1051. [9] Malin M. C. and Edgett K. S. (2000) *Science*, *288*, 2330-2335.

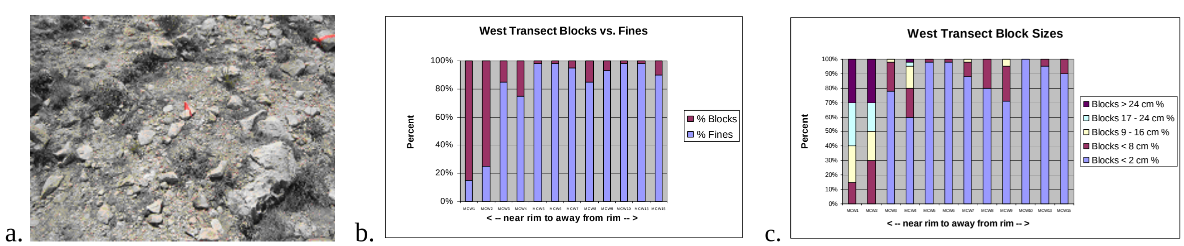


**Figure 1**. *Meteor Crater*: a. A ground based image of a transect classification site. b. A comparison of fines and block percentages from crater rim to near field ejecta. c. A comparison of block sizes from crater rim to near field ejecta.