QUANTITATIVE ANALYSES OF TERRESTRIAL CRATER DEPOSITS: CONSTRAINING FORMATION AND SEDIMENT TRANSPORT PROCESSES ON MARS. M. S. Ramsey[1] and D. A. Crown[2], [1]Department of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA, 15260, ramsey@ivis.eps.pitt.edu, [2]Planetary Science Institute, 1700 E. Ft. Lowell Rd., Tucson, AZ 85719, crown@psi.edu.

Introduction: Data currently being returned from Mars orbit is at spatial and spectral scales never before acquired. High spatial resolution THEMIS and MOC data have provided both morphologic and compositional information for small-scale processes (volcanic, fluvial, eolian, and impact cratering) on the Martian surface [1-2]. Future instruments such as HiRISE and CRISM planned for the Mars Reconnaissance Orbiter (MRO) will further improve spectral and spatial resolution. Those data coupled with the lander-based perspective of the Mars Exploration Rovers (MER) require a quantitative investigation of both formation processes and subsequent erosional modification for common small-scale features on Mars. A number of questions arise that relate not only to the geology of the surface features themselves, but to the larger implications for Mars climate/surface evolution. For example, can the formation process of craters below 1km in diameter be ascertained? Do such small-scale features represent more recent activity on the surface? Does the erosion and/or composition of the ejecta materials provide any clues as to current erosional processes?

Background: Previous workers have focused on using analog sites and remotely acquired data sets from Earth orbit to examine both process and erosion of small-scale features [3-5]. Many of these studies have centered around algorithm validation and compositional mapping of impact crater ejecta. They have also served as a foundation for new and future work as part of the Mars Fundamental Research program. In particular, a quantitative set of field-based studies is planned that will utilize current terrestrial orbital data to examine two different cratering environments. The ultimate goals are to (1) distinguish the formational mechanism from the erosional processes based on the data; (2) compare the analyses across spatial and spectral wavelength scales thereby creating a classification index, which will eventually allow the discrimination of the crater formation process on Mars; and (3) develop methodologies for analysis of erosional processes that operate at these smaller scales.

Examples of small surface units of scientific interest are impact and volcanic craters and their associated deposits. For features that appear to be relatively pristine, their small size may translate into a geologically recent age. Young Martian surface features are important because of the limited potential of mechanical/chemical weathering, a lesser amount of airborne dust accumulation, and a spatial distribution (for young volcanic features) that may be associated with water/ice interaction. The overarching question is how can these high resolution data sets be interpreted in order to best distinguish process and characterize the erosion.

Study Areas: The intent of the current research is to examine small, relatively fresh craters and their ejecta deposits on Earth in order to develop the tools critical for a similar style of investigation at Mars. Craters serve as probes of Martian stratigraphy, and their ejecta can be used to examine recent erosional styles and rates. At present, two craters created by different processes (impact and volcanic) and yet of similar size, age, and erosional histories are being examined with both orbital and field-based research.

Meteor Crater, AZ. Meteor Crater is located in north-central Arizona west of Winslow, AZ. The impact of an iron-rich meteorite approximately 50,000 years BP produced a simple bowl-shaped crater that is 180m deep and 1200m in diameter with a 30-60m high rim [6]. The impact sampled three primary sedimentary units and subsequent erosion by near-field fluvial incision and far-field eolian reworking has been the dominant process acting on the ejecta. Numerous studies of Meteor Crater's ejecta have focused on the amount of erosion and the implication of climatic shifts on the stability of the ejecta to that erosion [3, 6-7].

El Elegante Crater, Mexico. Elegante is a maar crater located in the Pinacate Volcanic Field (PVF) of northern Sonora, Mexico southeast of Yuma, AZ. It is a nearly circular depression with a diameter of 1400m and a depth of 240m (nearly identical in scale to Meteor Crater). The ejecta deposits of the PVF maar craters are commonly weathered and highly mobile, which produces complex mixing and inter-fingering with deposits from adjacent craters, flows, and allochtonous material. The PVF includes a complex basaltic shield with at least 650 lava flows, 500 cinder/agglutinate cones, and 10 maar craters, which formed from magma groundwater interaction [e.g., 8-9]. Previous work in the PVF has concentrated on the physical and petrological volcanology of the craters and flows [10-11]. Other researchers have focused on the eolian overprinting of the volcanic field and the geomorphic similarities to dark streaks around Martian craters [12-13].

Field Observations: The areal distribution patterns of the Coconino sandstone at Meteor Crater imply that a modest erosional rate had occurred in the past, which produced low amounts of sediment transport [3]. Recent work has focused on the new multispectral capability of the spaceborne ASTER instrument using the TIR data as a proxy for THEMIS [4-5]. Field-based topographic measurements have also be made both at the small scale (number and size of blocks, local slope) and large scale (lobate ejecta, windstreak, near rim). The larger scale measurements were be made using a laser profiling/differential GPS package (Figure 1). This provides for rapid cm-scale accuracy measurements to be acquired from one location up to 600m away. These measurements have allowed characterization of the slopes and zones of ejecta, as well as validate the ASTER-derived digital elevation model. Further and more detailed work is planned at both craters in the coming months. These measurements will include TIR field spectra, elevation profiling, and surface unit characterization. This will place bounding estimates on depositional features (i.e., lobate vs. sheet, style of the erosional channels, percentage/size of the blocks, slope/roughness of the ejecta blanket).

Conclusions: A critical challenge to the Mars science community is the integration of datasets of widely variable spectral and spatial resolutions and geographic coverage to optimize the scientific return. For example, there has been no definitive identification of carbonates minerals or quartz from orbit using TES, however with the better spatial scales of THEMIS (and now the mini-TES), it appears these minerals are present [14-15]. It is probable that similar ambiguities and scale-dependant identification will occur in the future with data from CRISM. However, the use of complementary datasets may allow robust characterization of surface units over a wide range of spectral and spatial scales.

The connection of detailed field mapping to the remote sensing data through quantitative modeling of spectral, spatial, and topographic scales provides a critical information bridge for the detectability and interpretation of Mars data. Such a linkage is currently lacking with most analyses based purely on laboratory work or spatial/spectral scales that are not appropriate. The intended work is therefore focused on the spectral and spatial scales of the data using process analogs, detailed field mapping, and quantitative modeling. A primary goal of the study would be for example to distinguish small volcanic craters on Mars from impact craters of similar size/age using this approach. In turn, this could lead to a more complete understanding of the spatial and temporal relationships of small-scale volcanism on the planet and its potential interaction with near surface ground water/ice.

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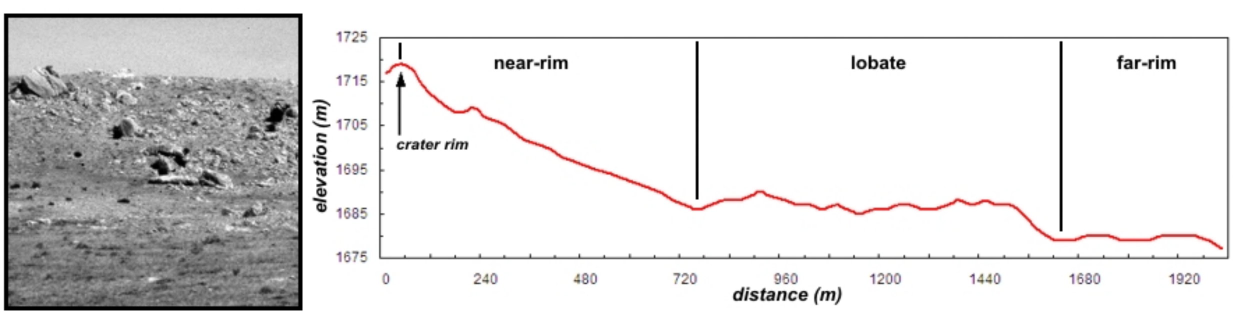

Figure 1. A ground-based image of the Meteor Crater rim and near-field ejecta deposits, which has centimeter-scale resolution similar to PanCam or HiRISE. Also shown is a topographic profile of this location that reveals the primary topographic ejecta units also seen in the digital elevation model (DEM).