CRATER GRADATION IN GUSEV CRATER, MERIDIANI PLANUM, AND ON THE EARTH. J. A. Grant[1], M. P. Golombek[2], A. F. C. Haldemann[2], L. Crumpler[3], R. Li[4], and the Athena Science Team [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, [3]New Mexico Museum of Natural History and Science, Albuquerque, NM 87104, [4]Department of Civil Engineering and Remote Sensing, The Ohio State University, Columbus, OH 43210.

Introduction: The Mars Exploration Rovers Spirit and Opportunity have examined multiple impact craters since landing in Gusev Crater (14.569°S, 175.473°E) and Meridiani Planum (1.946°S, 354.473°E), respectively [1-3]. Craters at both locations are in varying states of preservation [4] and comparison between their evolved gradation signatures and those around simple, unglaciated terrestrial craters provide clues to the processes and amount of Martian crater modification.

Summary of Terrestrial Crater Gradation: With few exceptions and even in arid settings, fluvial gradation dominates at terrestrial craters and enables definition of a first-order gradation sequence [5-7]. Early backwasting via mass-wasting dominates modification of steep walls to form debris chutes and aprons that then are incised by runoff as more competent steep wall-rock is exposed. Continued gradation leads to coalescing fans on the crater floor as wall drainages erode headward and eventually breach the rim and pirate headward reaches of exterior networks. In this sequence, wall slopes decrease from generally above to below the angle of repose and associated drainage densities decrease from ~13 km/km^2 (Meteor Crater), to ~5 km/km^2 as walls are stripped (Lonar Crater, India), then increase to ~7 km/km^2 (Talemzane Crater, Algeria) as the rim is breached and basin area increases. Rim breaching is associated with development of 10's m's relief that persists after significant eolian deposition (Roter Kamm, Namibia).

By contrast, gradation of ejecta is more subtle, as surfaces are first modified to form a lag whose incisement is limited by a higher infiltration capacity and lower slopes than on the walls. As a result, drainage scale and density is lower, with density averaging ~3-5 km/km^2 around most craters examined.

Overall effects of these processes are dependent on crater size and local slopes, but a ~1 km in diameter crater with a fluvially breached rim likely experienced 10's of m's erosion in steep near-rim areas while retaining up to 25% of the more distal continuous ejecta.

Impact Structures in Gusev Crater: Craters and their associated ejecta deposits dominate the surficial landscape on the Gusev Plains [2]. The craters have depth-to-diameter ratios generally <0.10 and many may be secondary craters [8]. Most possess raised rims and obvious ejecta deposits. Walls bounding the 210 m-in-diameter Bonneville crater are debris-mantled and slope an average 11 degrees, but there is little evidence of downslope movement (e.g. debris chutes or talus aprons) and eolian infilling is generally only a few meters based on observations of protruding rocks.

Basaltic ejecta fragments around Bonneville and nearby 150 m diameter Missoula crater possess a size and spatial distribution consistent with that expected for pristine deposits [2]. Eolian deposits are local and generally <50 cm thick, whereas exposed surfaces likely experienced no more than 60 cm deflation [9].

Smaller (<20 m in diameter) and generally more modified impact structures referred to as hollows are distributed across the Gusev plains. These craters are mostly sediment-filled and surrounded by abundant fractured and perched rocks [2]. Trenching with the rover wheels reveals uniform sediments capped by dust, but devoid of any detectable dust interbeds.

Impact Structures in Meridiani Planum: Craters explored at Meridiani are fewer and farther between than at Gusev and all are formed into bedrock. The Meridiani craters have depth-to-diameter ratios >0.10, thereby suggesting they may be modified primary craters, and they preserve walls sloped generally between 10 degrees (Eagle crater, 22 m diameter) and 15-30 degrees (Endurance crater, 140 m in diameter) that locally exceed the repose angle in Endurance. Craters are variably infilled, but an absence of protruding rocks precludes precise constraint of thickness. Profiles across Eagle crater reveal smoothly varying slopes (except over outcrop), whereas profiles across Endurance generally display an inflection halfway up the walls corresponding to the occurrence of large rocks and transition to lower slopes immediately above.

Except for the 7 m diameter Fram crater, little ejecta are definable, though large rock "plates" are seen along the flank and near-rim of Endurance crater. None of the craters show evidence of incisement.

Martian Crater Gradation: Unlike most terrestrial craters, the Martian craters lack evidence for appreciable modification by water, thereby enabling processes that are typically subordinate on Earth to dominate. As on Earth, gradation on Mars is highly slope and scale dependent and may be predictable. For example, craters >100 m in diameter at Gusev likely experienced variable, but limited (meters) of infilling and backwasting of walls by eolian and mass-wasting activity (Fig. 1), whereas ejecta are little modified by mostly eolian processes that account for ~1 m gradation. By contrast, similar amounts of gradation of the hollows produce more modified forms.

Impact excavation of the craters and hollows and emplacement of associated ejecta disrupted a surface in equilibrium with the gradational environment, thereby resulting in deflation of ejecta to expose perched rocks and infilling (nearly complete for many hollows) as sediment is redistributed by the wind. The absence of dust interbeds in the fill suggests that early gradational activity inside and around the craters in Gusev was initially more important as newly exposed surfaces equilibrated with the geologic setting (Fig. 1).

Preserved morphology of craters at Meridiani indicates most experienced relatively greater gradation than at Gusev. Gradation is accomplished as less competent bedrock along crater walls is subject to more eolian stripping (especially along the upper wall) that together with mass-wasting causes backwasting, crater enlargement, and some infilling that proceeds without development of debris chutes characteristic of mass wasting on Earth (Fig. 1). At Endurance, backwasting of the wall is slowed as large rock “plates” along the rim are undercut and slide into the crater, thereby helping to armor the wall in much the same manner that a lag slows erosion of terrestrial crater ejecta. At Eagle crater, more advanced gradation creates a fairly stable profile, with active backwasting largely limited to areas with exposed outcrop. Some of the mobilized sediment along with fines swept in from the surrounding plains contributes to crater infilling. Lower portions of crater walls experience lesser backwasting due to a combination of reduced exposure to winds, protection by remnant talus, and eolian deposition (Fig. 1). If Eagle and Endurance are primary craters, these processes collectively account for ~30-40% infilling/backwasting, or some combination of up to 10 m infilling/25 m backwasting and 1.5 m infilling/3.5 m backwasting at Endurance and more degraded Eagle crater, respectively.

The predicted amounts and processes or crater gradation at Gusev and Meridiani is consistent with inferred erosion rates at both sites since the Hesperian [10]. It is unclear, however, how representative the craters investigated at Meridiani to date are of regional gradation. For example, orbital data reveal craters to the south that may be mantled and/or partially exhumed. Hence, exploration of these craters may lead to modification of the outlined gradational sequence.

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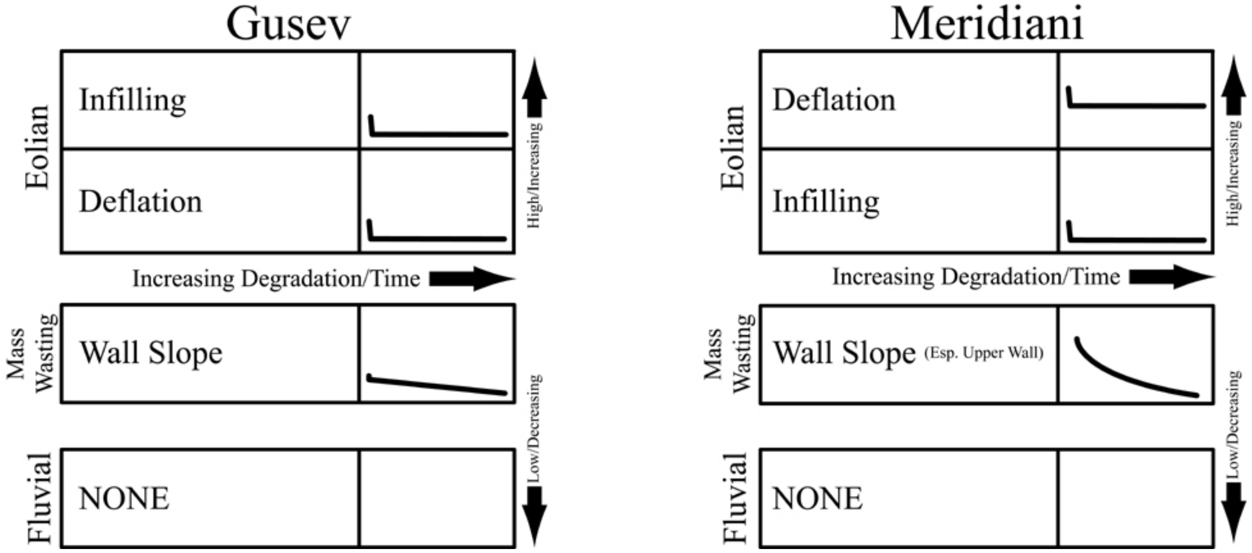

Figure 1. Summary of relative importance of gradational processes in and around craters explored at Gusev crater and Meridiani Planum. At Meridiani, the relative importance of eolian deflation and mass-wasting along crater walls may vary from crater to crater and over time. The scale and slope dependent nature of gradation and resultant signatures necessitates the qualitative summary shown (see text for specific, quantitative examples).