SURVEY OF CRATERS BY SPIRIT IN GUSEV CRATER AND OPPORTUNITY IN MERIDIANI PLANUM. A.F.C. Haldemann[1], M.P. Golombek[1], L. Crumpler[2], J. Grant[3] and the Athena Science Team, [1]Jet Propulsion Laboratory, Caltech, Pasadena, CA 91109, [2]New Mexico Museum of Natural History and Science, Albuquerque, NM 87104, [3]Center for Earth and Planetary Studies, NASM, Washington, DC 20013.

Introduction: The mobility of the Mars Exploration Rovers Spirit and Opportunity have carried them over 3.6 km and 1.6 km respectively since their landings in January of this year [1]. That mobility has allowed the first robotic in-situ survey of crater populations on Mars. This paper will review the field geologist's perspective of a number of impact craters in various states of degradation along Spirit's traverse in Gusev crater and along Opportunity's traverse in Meridiani Planum.

Gusev Crater Observations: Spirit's landing site, dubbed the Columbia Memorial Station, is located a generally low-relief, somewhat rocky plain dominated by shallow circular depressions and low ridges [2]. The Columbia Hills over 2 km to the east are over 100 m high and the rim of Bonneville crater (200 m diameter) forms the horizon 240 m to the northeast. After initial exploration of the vicinity of the lander, Spirit proceeded towards Bonneville crater, and thereafter, across the plains to the Columbia hills, passing many craters, of varying sizes along the way.

Hollows: A number of shallow circular depressions, called hollows, were observed in the first panoramas at the Columbia Memorial Station site. The hollows generally have rocky rims and smooth soil filled centers. Perched, fractured and split rocks are more numerous around hollows than elsewhere, but lighter toned (redder) rocks are often closer to eolian drifts [2]. Spirit continued to find hollows throughout her traverse across the Gusev plains, and indeed, even up into the Columbia Hills. Hollow morphology and size-frequency distribution strongly argue that they are impact craters rapidly filled in by eolian material. Excavation during impact would deposit ejecta with widely varying grain sizes and fractured rocks, which would be in disequilibrium with the eolian regime. This would lead to deflation of ejected fines, exposing fractured rocks, and creating a population of perched coarser fragments. Hollow interiors would be filled as transported fines are trapped within the depressions. Trenching in Laguna hollow near the edge of the Bonneville ejecta exposed unaltered basaltic fines capped by a thin layer of brighter, finer, globally pervasive dust. The dust-free nature of sediment in the hollows coupled with their uniformly filled appearance implies rapid modification to their current more stable form.

Bonneville Crater: Several lines of evidence suggest Bonneville is a relatively fresh crater that was formed by impact into unconsolidated blocky debris [2]. Rock abundance and the largest block size increases by a factor of 2-4 from the discontinuous ejecta, through the continuous ejecta to the rim, suggesting a relatively pristine ejecta blanket. The rim is ~3 m high and although the crater is shallow (~10 m deep), the shallowly-dipping (~11º) rubble walls show no signs of mass wasting. Eolian material deposited inside Bonneville is constrained to 1-2 m thickness by protruding boulders (see Figure 1). No bedrock is exposed in the walls, even where impacted by smaller craters in the wall. The low depth to diameter ratio of Bonneville and other small craters in and on its walls suggest that they formed as secondary craters [3].

Gusev Discussion: Bonneville is the freshest of the large craters visited by Spirit. The rover skirted Missoula crater (180 m diameter, 4 m deep), Lahontan crater (100 m diameter, 4 m deep), and an unnamed crater west of Lahontan (100 m diameter, 1 m deep) on its way from Bonneville to the Columbia Hills. All of these craters are more degraded than Bonneville, with more infilling by fines. It is possible that the hollows represent our first good look at a population of secondary craters.

Meridiani Planum Observations: Opportunity has observed far fewer craters than Spirit due to the relatively young surface age of Meridiani Planum. However, those few craters she has characterized have been studied in depth! All the craters imaged by Opportunity have been modified by eolian activity with sediment in their interiors and with modified rims. Opportunity landed in Eagle crater, departing on sol 58 of her mission, stopping briefly at Fram crater on her way to Endurance crater, where she arrived on sol 95. All three of these craters expose the sedimentary "dirty" evaporites in their walls that are the signature of Meridiani's watery past [4].

Eagle crater appears the most degraded of the three. It is 20 m in diameter, but only 3 m deep, with a sand- and granule-filled interior. Its rim is smoothed, exposing almost no large clasts, thus appearing highly modified. No ejecta on the adjacent plains has been identified. Fram is a 10 m diameter crater that appears to be the freshest of the three named craters, but is only 1 m deep. Fram is the only crater with obvious ejecta blocks on the surface, although even it does not have fresh ejecta rays. En route from Eagle to Endurance, Opportunity imaged many shallow circular sandy depressions (1-10 m in diameter). While their circularity suggests craters, most lack raised rims, making them difficult to distinguish from modified collapse pits that are observed in association with a regional northeast-trending set of fractures.

Endurance: Endurance crater retains steep interior walls (Figure 2), but also appears to have experienced backwasting and in-filling. Endurance is 21 m deep and its rim rises 2-7 m above the surrounding plains. Fresh ejecta appears absent. Endurance's current rim-to-rim diameter is ~160 m, but its original diameter was probably less. There are variable slope breaks around the walls of Endurance. These are generally represented by a steeper bowl-shaped central area surrounded by a reduced-slope annulus ringed by steeper slopes below the rim. The origin of this morphpology remains controversial, although it appears that some amount of backwasting or undercutting has produced the "folded-down" appearance of the 'flagstones' that armor the surface of the rim, most notably at Pan Position 2, in the viewpoint for Figure 2. This suggested erosion may be coupled to the large blocks sitting at the slope break level. Certainly Endurance crater has been subjected to eolian modification as evidenced by the well-developed dune-field at its center. Plains materials litter the rocks inside the crater, and also appear to spill into Endurance around the steep upper wall outcrops.

Meridiani Discussion: We have explored the few craters at Meridiani in some detail. They appear to represent a range of crater ages. The modification of Endurance crater may, in addition to eolian processes, be telling us about cratering target effects. Careful topographic mapping of Endurance in particular could provide some constraints on modeling of the processes that shape Meridiani craters, addressing thereby both the age of the surface and the processes that have affected it since water flowed across evaporitic sands.

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References: [1] Squyres, S. et al. (2004) *Science, 305*, 794-799, 2004. [2] Grant J. et al. (2004) *Science, 305*, 807-810, 2004. [3] Hurst M. et al. (2004) *LPS XXXV,* Abs. #2068. [4] Squyres, S. et al. (2004) submitted.

Figure 1. Preliminary geologic sketch map of 200 m diameter Bonneville crater interior. View to the north-east.

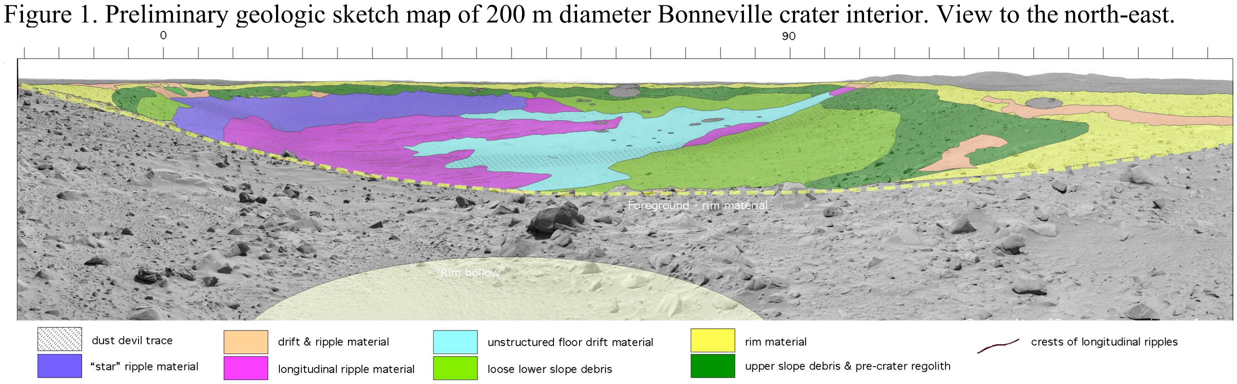

Figure 2. Preliminary geologic sketch map of 160 m diameter Endurance crater interior. View to the north-west.