STRUCTURE AND MORPHOLOGY OF SANTA MARIA CRATER, MERIDIANI PLANUM, MARS

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Terrestrial studies of simple craters have been central to understanding the cratering process [e.g., 1,2,3]. Rover-based studies of craters on other planets are important because of the paucity of well-preserved simple craters on the Earth and the difficulty of scaling results of laboratory experiments in targets with strength, and for understanding the role of complex geologic targets. The few terrestrial studies may not have captured the full range of cratering styles [4], and cannot be used to address the variation of structural class (e.g., Odessa vs. Barringer) on other planets [2].

The Mars Exploration Rovers have shed new light on the formation, shape, structure and modification of simple impact craters on the Martian surface [4,5,6]. A structural analysis of Endurance crater (D ~ 150m) suggests that some polygonal craters form via "stellate" excavation in aligned-fractured targets [4]. Rover-based studies of simple craters on other planets can be used to understand erosional processes [5,6,7,8], as well as determine the stratigraphic position of crater rim materials [4].

We describe the structure and shape of Santa Maria crater, which formed in the sulfate-rich aeolian sandstones of Meridiani Planum, ~13.5 km south of Endurance crater. Santa Maria formed in rocks cut by long, wide fractures (~10 cm wide, 1-10 m long) separated by several meters, often visible as linear troughs where covered with sand (Fig. 3). Based on the preservation of significant rim relief, large ejecta blocks on the surface, and positive relief ejecta rays, Santa Maria is likely the youngest D > 50 m crater visited by Opportunity. Comparison of the morphology of Santa Maria crater with the freshest (and youngest) craters on Meridiani Planum (Concepcion and the Resolution crater cluster [8]) shows it has been substantially modified with thick aeolian bedforms inside, an ejecta blanket visible in the rim that has been eroded and resurfaced similar to that at Victoria crater [e.g., 6], and cuspate interior walls that expose both ejecta and bedrock.

At the time of writing, Opportunity was commanded to acquire Navcam and Pancam stereo imagery of the crater cavity, rim, and flanks, on sol 2467 of its extended mission. These and earlier observations have been used in combination with HiRISE images to measure the crater and ejecta planform, the range to ejecta blocks, the orientations of fracture-aligned troughs and crater-rays in the far-field, stratal attitudes, and rim elevations.

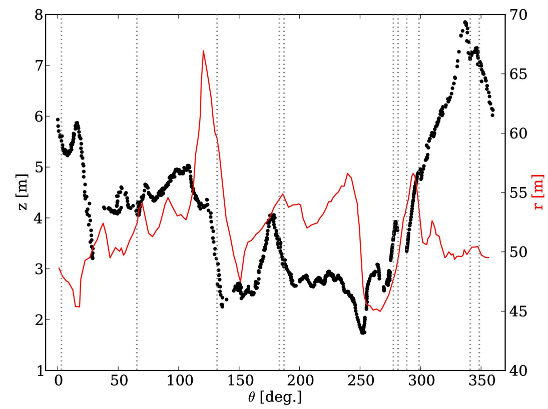

Fig. 1: Rim elevation (black) and radius (red) and location of "roots" of prominent rays on rim (dotted lines) as function of azimuth from crater center.

Rim and cavity shape: Santa Maria has a concave-cuspate rim planform, unusual for impact craters in general but not uncommon at Meridiani. The mean diameter of the crater rim is 104 m +/- 6.5 m (std. dev.). Maximum diameter is ~119 m along the 120 deg. azimuth. The crater depth (crater bottom to top of rim) ranges from 11 m to 17 m so that rim-depth to rim-diameter ratio (d/D) varies from 0.10 to 0.16, suggesting a hypervelocity impact even though clusters of small craters to the northeast (Fig. 3) may indicate the meteoroid partially fragmented in the atmosphere [e.g., see discussion and ref.s in 8]. Pancam stereo-derived rim elevations (black) and HiRISE-derived rim radius (red) are plotted in Fig. 1. Dotted lines mark the azimuthal rim positions from which prominent rays emanate (see Fig. 3). The pattern suggests that rays may tend to emanate from the proximity of local maxima in rim radius or local maxima in rim elevation.

Ejecta and far-field: Fig. 2 shows the azimuthal orientations of features on the crater flanks and far-field. Plotted are (a) a length-weighted probability density function of trough azimuths on surrounding plains (gray bars); (b) the distance of ejecta blocks visible in both HiRISE and Pancam imagery (blue dots) from crater center; (c) the orientations of prominent rays that emanate from the crater rim (dashed lines). The trough distribution is not a simple conjugate set as observed at Endurance crater, and lighting geometry has likely biased the sampling. The distribution at least suggests a relationship between prominent rays and fracture orientations (i.e., the direction of least shear strength). It is noteworthy that rays sometimes occur in pairs, are commonly not crater-radial, and that large blocks (up to ~1 m scale) are ejected as much as 500 m from the crater rim. It should also be noted that rays are not pristine and their shapes may have been significantly modified.

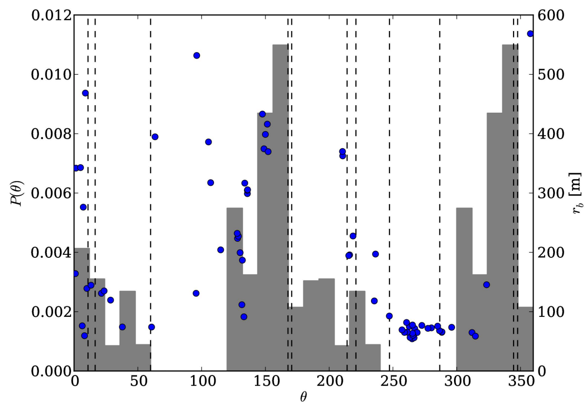

Fig. 2: Length-weighted histogram of orientations of fracture-aligned troughs (gray bars, as prob. density function), and crater rays (dashed lined). Blue dots indicate range to ejecta blocks from crater center.

Structure: Stratal attitudes in the crater walls have been measured along with associated errors using the method described in [4]. Stratal attitudes are locally consistent over the scale of several meters on the north wall of an alcove in the NW corner (Fig. 3, B). Bedding planes here dip craterward, and indicate an abrupt scissors-like discontinuity interpreted as a tear fault. The same relationship (craterward dip in crater corner adjacent to a tear fault) was observed in the southmost corner of Endurance crater [4]. A second tear fault may occur in the southeast corner (Fig 3, part C) where a shelf has formed above what we tentatively interpret as dropped blocks bounding a corner rim notch [see 4]. Imagery acquired from two positions of the southwest wall (blue rectangle, Fig. 3, A) reveal that beds have a nearly vertical dip. The flap hinge is thus preserved along a portion of the southeast wall. Color Pancam imagery of the south wall also suggests inverted strata in an overturned flap.

References: [1] Shoemaker, *Int. Geo. Congress* 21 (1960); [2] Shoemaker et al., *Aus. J. Earth Sci.* 52 (2005); [3] Poelchau et al. *JGR* 114 (2009); [4] Watters et al., *Icarus* in press (2011); [5] Grant et al. *JGR* 111 (2006); [6] Grant et al. *JGR* 113 (2008); [7] Golombek et al. *JGR* 111 (2006); [8] Golombek et al. *JGR* 115 (2010)

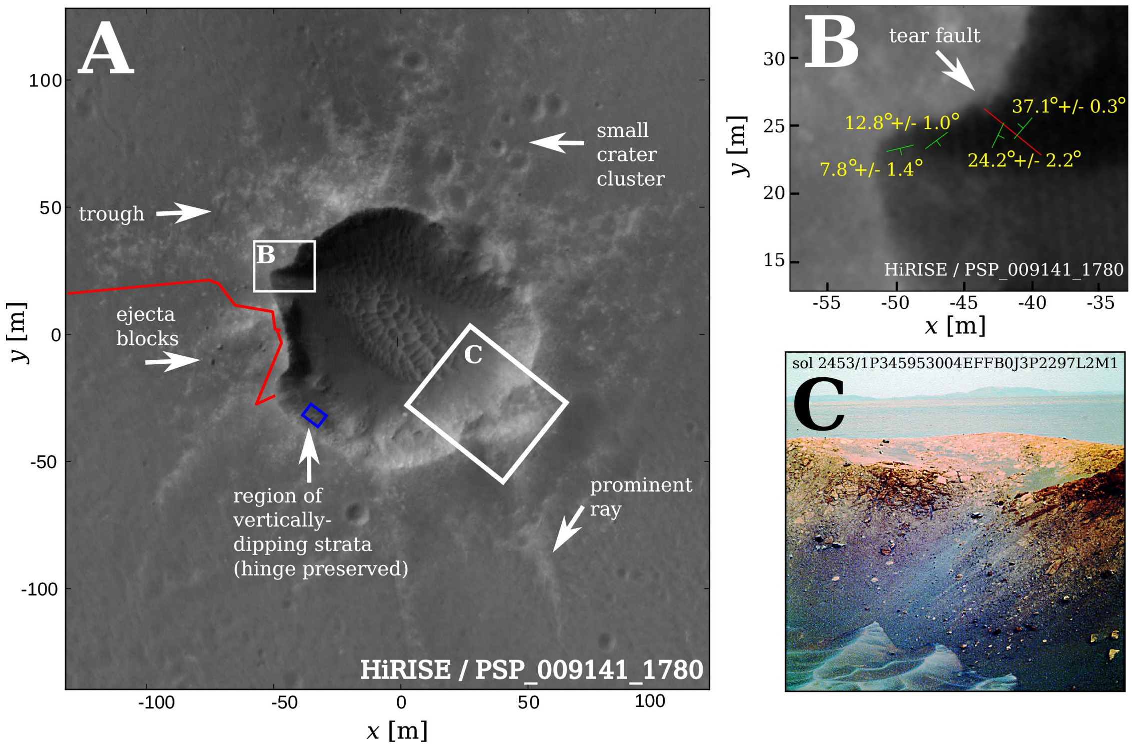

Fig. 3: A. Map of significant features. Rover traverse path up to sol 2467 is shown in red. B. Stratal attitudes (dip and 2σ uncertainty printed in yellow) in northwest corner-alcove. C. Possible tear-fault in southeast corner.