**INVERTED CHANNELS ON THE FLOOR OF MIYAMOTO CRATER, MARS, VIEWED BY THE HIRISE CAMERA.** H. E. Newsom[1], N. L. Lanza[1], A. M. Ollila[1], S. M. Wiseman[2], T. L. Roush[3], G. A. Marzo[3], L. L. Tornabene[4], L. S. Crumpler[5], C. H. Okubo[6], M. M. Osterloo[7], and V. E. Hamilton[8], [1]Univ. of New Mexico, Inst. of Meteoritics, MSC03-2050, Albuquerque, NM 87131, USA (newsom@unm.edu), [2]Dept. of Earth & Planet. Sci., Washington Univ., St. Louis, MO, USA, [3]NASA Ames Research Center, Moffett Field, CA, USA, [4]Lunar & Planetary Laboratory, Univ. of Arizona, Tucson, AZ, USA, [5]New Mexico Museum of Natural History & Science, Albuquerque, NM, USA [6]U.S. Geological Survey, Flagstaff, AZ, USA, [7]Hawai'i Inst. of Geophysics & Planetology, Univ.of Hawai'i at Manoa, Honolulu, HI, USA, [8]Southwest Research Inst., Boulder, CO, USA.

**Introduction:** Miyamoto crater in southwestern Terra Meridiani is a 160-km-diameter impact crater of Noachian age (Fig. 1). The Mars Exploration Rover Opportunity has been studying the layered deposits and regolith that bury the northeastern half of the crater. The southwestern floor of the Miyamoto crater is a potential site for studying ancient aqueous processes on Mars, and was a candidate for the Mars Science Laboratory (MSL) landing site [1]. The floor of the crater contains raised curvilinear features that are suggestive of past fluvial activity. Imagery from the High Resolution Imaging Science Experiment (HiRISE) provides important evidence for the nature and origin of these raised curvilinear features.

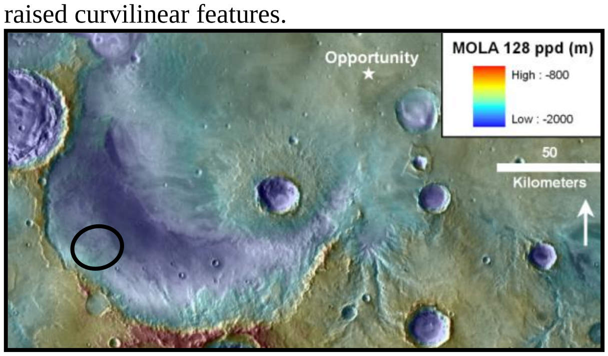


**Fig. 1.** Location of Miyamoto crater and proposed landing ellipse in southwestern Meridiani Planum, MOLA topography overlain on THEMIS day IR.

**Morphology of the western floor of Miyamoto crater:** On the basis of geologic mapping of the area using HiRISE images, there are three principal units: (1) a lower phyllosilicate-bearing unit [2] with fractures spaced meters to tens of meters apart, which contains large areas of exposed outcrop, suggesting that this unit has been stripped of material and then locally covered by more recent mobile fines, (2) a middle horizon "unit" that appears to be a residual surface or capping unit remaining after stripping of the basal unit, and (3) an upper plains-forming unit that onlaps the residual surface and basal unit from the east and is characterized by significantly greater impact crater retention. The middle unit forms distinct curvilinear positive-relief features (Fig. 2) that shall be referred to here as 'ridges' or 'ridge complexes.' An example of a curvilinear ridge complex is a narrow, sinuous, flat-topped ridge about 25 km in length, north of the proposed landing site (Fig. 2A, also noted by [3]). Topography from the Mars Orbiter Laser Altimeter (MOLA) digital elevation model (DEM) suggests a height of approximately ~30-50 m. In HiRISE images, the sides of the feature are formed by a lighter colored fractured basal unit, capped with a material darker than the surrounding terrain. HiRISE images and stereo anaglyphs of this feature reveal layering in the upper walls (Fig. 3).

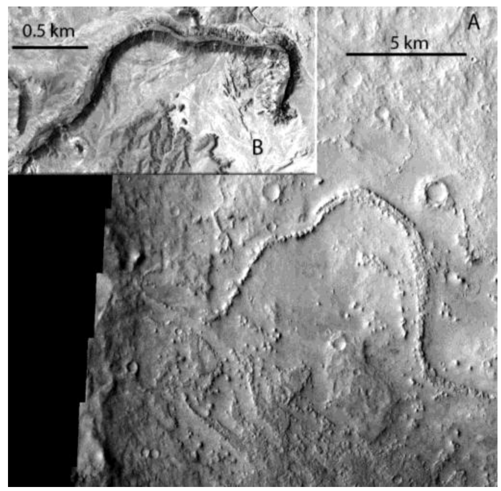


**Fig. 2.** A) THEMIS VIS image of showing materials on the floor of Miyamoto Crater, which slopes gently toward the east. A number of positive-relief ridge or mesa features with rough-textured surfaces are interpreted as a complex of inverted paleochannel deposits. Most notably, a long sinuous ridge runs from near the wall of the crater to the eastern edge of this image. B) Inverted paleochannel deposit in the Cedar Mountain Formation near Green River, Utah (Google Earth).

**Inverted channel origin for the Miyamoto ridge complex:** The Miyamoto ridge complexes appear similar to positive relief channel deposits seen on Earth [e.g. 4] that are interpreted as exhumed, inverted, fluvial paleochannel deposits (Fig. 2B). A spectacular set of inverted paleochannels can be seen in the Cedar Mountain Formation near Green River, UT, USA [5]. The morphologies of the Cedar Mountain examples are remarkably similar to the Miyamoto crater structures, including flat-topped ridges and areas where the ridges are breached or eroded into a series of buttes. Topography from the High Resolution Stereo Camera

(HRSC) indicate that the Miyamoto structures have a surface slope of < 2 m/km, which compares with gradients of paleochannel segments in Utah, ranging from 0.23 to 0.4 m/km [6, 7]. The Cedar Mountain paleochannels consist of sediments with large gravel-sized particles and are largely carbonate cemented [6, 7, 8] although silica cement has also been reported [8].

**Fig. 3**. HiRISE image showing layering in the capping deposit of one of the ridges and possibly in the underlying basal unit. Image width ~100m, resolution 27 cm/pixel. Image PSP_009985_1770. Credit: NASA/JPL/Univ. of Arizona.

The Miyamoto ridges therefore appear to represent a classic inverted terrain where the dark, indurated capping material has armored and protected some areas of the basal material from erosion processes that ablated adjacent unconsolidated material. In some areas the capping layer is undercut, and the edges of the ridge are strewn with dark boulders, indicating the competent nature of the capping layer (Fig. 3). The thickness of the cliff forming capping unit is less than ~20% of the height of the ridge based on the HiRISE anaglyphs. The sub-linear pattern of the ridges is consistent with depositional control by fluid flow, supporting the interpretation that these are alluvial deposits.

The most likely cementing materials on Mars are iron oxides, silica, and sulfates [4]. Mechanisms may include evaporation of surface water soon after sediment deposition, fluid mixing during regional groundwater flow, or cooling of hydrothermal or basinal fluids as they near the surface [4]. Chlorides may also be important given the high Cl abundance in the martian soil and the discovery of chloride deposits [9]. Cementation can be preferentially localized to the channels by the cooling or evaporation processes. Given spectral observations of alteration minerals in the region, all of these mechanisms are plausible.

Formation of the Miyamoto features by other processes is unlikely. Eskers usually have rounded or sharp crests and do not generally have a resistant top layer, in contrast to the Miyamoto ridge complex [10]. The features also do not exhibit the features of lava flows or lava-filled channels, including flow lobes, levied channels, and pressure ridges. The formation of channel deposits by surface runoff released by an impact into a water/ice-rich subsurface target [e.g. 11] is unlikely given the evidence that the underlying phyllosilicate bearing material is a widespread relatively flat deposit that probably post-dates the formation of the Miyamoto crater. Documentation of many alluvial fans by [12] also suggests that deposits formed by relatively long-lived fluvial activity are widespread on Mars. Based on the available evidence, a fluvial origin for the inverted features in Miyamoto seems most likely.

**Conclusions:** The HiRISE camera has enabled the investigation of putative inverted paleochannel deposits on the western floor of Miyamoto crater. The curving ridges appear to be capped with a competent layer that is resistant to erosion. The deposits appear remarkably similar to terrestrial examples, as seen in the Cedar Mountain Formation near Green River, UT. In this interpretation, the capping material represents cemented river paleochannel deposits. CRISM spectral observations [2, 13] indicate the presence of Fe/Mg phyllosilicates in close association with the putative fluvial deposits, supporting a fluvial origin for the ridge features. Interpretations of the ridge morphologies that do not invoke fluvial processes are difficult to support in the context of both the spectral data and the regional morphology. The absence of either glacial or unambiguous evidence for volcanic land forms in the available images argues against the ridges originating as eskers, lava flows, or volcanic dikes. The possibility that this area was originally buried and exhumed by Meridiani Planum layered rocks suggests an early age for the fluvial episode, consistent with that of nearby incised ancient river valleys at ~3.74 Ga [14].

**References:** [1] Vasavada A. R., et al. (2007) *7th Int. Conf. on Mars*, Abs. #3031. [2] Wiseman S. M. et al. (2008) *GRL* 35, L19204. [3] Edgett K. S. (2005) *Mars* 1, 5–58. [4] Pain C. F, et al. (2007) *Icarus* 190, 478-491. [5] Williams R. M. E. (2007) *LPS XXXVIII*, Abs. #1821. [6] Derr M. E. (1974) *Brigham Young Univ. Geology Studies* 21, 3-39. [7] Harris D. R. *IBID.* 27, 51-66. [8] Lorenz J.C. et al. (2006) *AAPG* 90 (9), 1293-1308. [9] Osterloo M. M., et al. (2008) *Science* 319 (5870), 1651-1654. [10] Kargel J. S. and Strom R. G. (1992) *Geology* 20, 3-7. [11] Tornabene L. L., et al. (2008) *LPS XXXIX*, Abs. #2180. [12] Moore J. M. & Howard A. D. (2005) *JGR* 110, E04005. [13] Marzo G.A. et al., *LPS XXXX* (2009) this issue. [14] Hynek B. M & Phillips R. J. (2001) *Geology* 29, 407-410.

**Acknowledgements**: Supported by NASA PGG NNG 05GJ42G and NNX 08AL74G (HEN), the NASA/JPL/LANL/MSL-ChemCam project (HEN, Co-I.), and NASA/MRO/CRISM (TLR).