deposited there by its primary emplacement mechanism (it may have been merely redistributed by the wind). Similarly, morphological features present in the deposit, including the appearance of jointing and layering, may provide important information about the original formation, emplacement and induration mechanisms for the MFF. However, our data suggest that such features could also have been created during subsequent modification of the deposit. We conclude that it is highly likely that much of the surface of the MFF as it is seen today does not reflect the conditions of its primary emplacement. The variety in degradational states observed in MFF TARs suggests that TAR formation, induration, and degradation is a significant and ongoing process within the formation.

Acknowledgments—LK gratefully acknowledges financial support provided by NASA Graduate Student Research Program (GSRP) grant NNX09AJ11H; JWH gratefully acknowledges financial support as part of the NASA/ESA participation in the Mars Express High-Resolution Stereo Camera Team under JPL Grant 1237163, and the Mars Data Analysis Program, MDAP Grant NNX09A146G. We also thank the two helpful anonymous reviewers who contributed to this manuscript, and JL Dickson and LM Garcia for technical assistance.

References

Bagnold R. 1941. *The Physics of Blown Sand and Desert Dunes*. Methuen: London.

Balme M, Berman DC, Bourke MC, Zimbelman JR. 2008. Transverse aeolian ridges (TARs) on Mars. *Geomorphology* **101**: 703–720.

Berman DC, Balme MR, Rafkin SCR, Zimbelman JR. 2011. Transverse aeolian ridges (TARs) on Mars II: distributions, orientations, and ages. *Icarus* **213**: 116–130. DOI: 10.1016/j.icarus.2011.02.014

Bosworth TO. 1922. *Geology and Paleontology of Northwest Peru*. Macmillan: London; 269–311.

Bourke MC, Edgett KS, Cantor BA. 2008. Recent aeolian dune change on Mars. *Geomorphology* **94**: 247–255.

Bourke MC, Wilson SA, Zimbelman JR. 2003. The variability of TARs in troughs on Mars. *Lunar and Planetary Science Conference* **35**: Abs. 2090.

Bradley BA, Sakimoto SEH, Frey H, Zimbelman JR. 2002. Medusae Fossae Formation: new perspectives from Mars Global Surveyor. *Journal of Geophysical Research* **107**: E8.

Breed CS, McCauley JF, Whitney MI. 1989. Wind erosion forms. In *Arid Zone Geomorphology*, Thomas DSG (ed). Belhaven Press: London; 284–307.

Bridges NT, Bourke MC, Colon CM, Diniega S, Geissler PE, Golombek MP, Hansen CJ, Mattson S, McEwen AS, Stantzos N. 2011. Planet-wide sand movement on Mars as documented by the HiRISE camera. *Lunar and Planetary Science Conference* **42**: Abs. 1215.

Bridges NT, Geissler PE, McEwen AS, Thomson BJ, Chuang FC, Herkenhoff KE, Keszthelyi LP, Martinez-Alonso S. 2007. Windy Mars: a dynamic planet as seen by the HiRISE camera. *Geophysical Research Letters* **34**: L23205. DOI: 10.1029/2007GL031445

Carter LM, Campbell BA, Watters TR, Phillips RJ, Putzig NE, Safaeinili A, Plaut JJ, Okubo CH, Egan AF, Seu R, Biccari D, Orosei R. 2009. Shallow radar (SHARAD) sounding observations of the Medusae Fossae formation, Mars. *Icarus* **199**: 295–302. DOI: 10.1016/j.icarus.2008.10.007

Desen T, Peterson J. 1992. Mapping the Australian duricrusts: can distribution be derived from terrain maps? *Australian Geographical Studies* **30**: 87–93.

Edgett KS, Malin MC. 2000. Examples of martian sandstone: indurated, lithified, and cratered eolian dunes in MGS MOC images. *Lunar and Plantery Science Conference* **31**: Abs. 1071.

Fenton LK. 2006. Dune migration and slip face advancement in the Rabe Crater dune field, Mars. *Geophysical Research Letters* **33**: L20201. DOI: 10.1029/2006GL027133

Fenton LK, Hayward RK. 2010. Southern high latitude dune fields on Mars: morphology, aeolian inactivity and climate change. *Geomorphology* **121**: 98–121.

Geissler PE, Stantzos NW, Bridges NT, The HiRISE Science Team. 2011. Shifting sands on Mars: 3 case studies. *Lunar and Planetary Science Conference* **42**: Abs. 2537.

Goudie AS. 2007. Mega-yardangs: a global analysis. *Geography Compass* **1**: 65–81.

Greeley R, Guest J. 1987. Geologic map of the eastern equatorial region of Mars. USGS Misc. Inv. Series Map I-1802-B, scale 1:15 M.

Greeley R, Iversen JD. 1985. *Wind as a geological process: on Earth, Mars, Venus and Titan*. Cambridge University Press: New York.

Greeley R, Lancaster N, Lee S, Thomas P. 1992. Martian aeolian processes, sediments, and features. In *Mars*, Kieffer HH, Jakosky BM, Snyder C, Matthews MS (eds). University of Arizona Press: Tucson; 730–766,

Hartmann WK, Neukum G. 2001. Cratering chronology and the evolution of Mars. *Space Science Reviews* **96**: 165–194.

Hayward RK, Mullins KF, Fenton LK, Hare TM, Titus TN, Bourke MC, Colaprete A, Christensen PR. 2007. Mars Global Digital Dune Database and initial science results. *Journal of Geophysical Research* **112**: E11007. DOI: 10.1029/2007JE002943

Head JW, Kreslavsky M. 2004. Medusae Fossae Formation: ice-rich airborne dust deposited during periods of high obliquity? *Lunar and Planetary Science Conference* **35**: Abs. 1635.

Hedin S. 1903. *Central Asia and Tibet*. Charles Scribner's Sons: New York; 608.

Hodgson RA. 1961. Regional study of jointing in Comb Ridge-Navajo Mountain Area, Arizona and Utah. *AAPG Bulletin* **45**. DOI: 10.1306/0BDA6278-16BD-11D7-8645000102C1865D

Hynek BM, Phillips RJ, Arvidson RE. 2003. Explosive volcanism in the Tharsis region: Global evidence in the martian geologic record. *Journal of Geophysical Research* **108**: E9.

Kerber L, Head JW. 2010. The age of the Medusae Fossae Formation: Evidence of Hesperian emplacement from crater morphology, stratigraphy, and ancient lava contacts. *Icarus* **206**: 669–684.

Kerber L, Head JW, Madeleine JB, Forget F, Wilson L. 2011. The dispersal of pyroclasts from Apollinaris Patera, Mars: Implications for the origin of the Medusae Fossae Formation. *Icarus* **216**: 212–220.

Kocurek G. 1991. Interpretation of ancient eolian sand dunes. *Annual Reviews of Earth and Planetary Science* **19**: 43–75.

Kreslavsky MA, Head JW. 2000. Kilometer-scale roughness of Mars: results from MOLA data analysis. *Journal of Geophysical Research* **105**: 26,711–26,.

Livingstone I, Warren A. 1996. *Aeolian Geomophology: an Introduction*. Addison Wesley Longman Limited: Singapore; 32–34.

Malin MC, Carr MH, Danielson GE, Davies ME, Hartmann WK, Ingersoll AP, James PB, Masursky H, McEwen AS, Soderblom LA, Thomas P, Veverka J, Caplinger MA, Ravine MA, Soulanille TA, Warren JL. 1998. Early views of the martian surface from the Mars Orbiter Camera on Mars Global Surveyor. *Science* **279**: 1681–1685.

Malin MC, Bell JF, Cantor BA, Caplinger MA, Calvin WM, Clancy RT, Edgett KS, Edwards L, Haberle RM, James PB, Lee SW, Ravine MA, Thomas PC, Wolff MJ. 2007. Context Camera investigation on board the Mars Reconnaissance Orbiter. *Journal of Geophysical Research* **112**: E05S04. DOI: 10.1029/2006JE002808

Malin MC, Edgett KS. 2000. Sedimentary rocks of early Mars. *Science* **290**: 1927–1937.

Mandt KE, de Silva S, Zimbelman JR, Crown DA. 2007. A synoptic approach to evaluating the origin of the Medusae Fossae Formation, Mars. *Lunar and Planetary Science Conference* **38**: Abs. 1823.

Mandt KE, de Silva SL, Zimbelman JR, Crown DA. 2008. Origin of the Medusae Fossae Formation, Mars: Insights from a synoptic approach. *Journal of Geophysical Research* **113**: E12011. DOI: 10.1029/2008JE003076

McCauley JF, Breed CS, El-Baz F, Whitney MI, Grolier MJ, Ward AW. 1979. Pitted and fluted rocks in the western desert of Egypt—Viking comparisons. *Journal of Geophysical Research* **84**: 8222–8232.

McCauley JF, Ward AW, Breed CS, Grolier MJ, Greeley R. 1977. Experimental modeling of wind erosion forms. *National Aeronautics and Space Administration Technical Memorandum X-3511*; 150–152.

McEwen AS, Eliason EM, Bergstrom JW, Bridges NT, Hansen CJ, Delamere WA, Grant JA, Gulick VC, Herkenhoff KE, Keszthelyi L, Kirk RL, Mellon MT, Squyres SW, Thomas N, Weitz CM. 2007. Mars Reconnaissance Orbiter's High Resolution Imaging Science Experiment (HiRISE). *Journal of Geophysical Research* **112**: E05S02. DOI: 10.1029/2005JE002605

McLennan SM. 2003. Sedimentary silica on Mars. *Geology* **31**: 315–318.