



## **Geologically recent small-scale surface features in Meridiani Planum and Gale Crater, Mars**

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Enigmatic small scale (<1m) depositional and erosional features have been imaged at several locations in the equatorial Meridiani Planum region by the rover Opportunity. They occur in loose, dark basaltic sands partly covering exposures of light-toned bedrock. Leveed fissures are narrow, elongate, steep-sided depressions flanked by raised levees or half-cones of soil, typically 2–10 cm wide and up to 50 cm long in most cases. Some cross-cut and are therefore younger than eolian ripples thought to have last been active c. 50,000 years ago. Gutters are elongate, straight or sinuous surface depressions, typically 2–10cm wide and 1–5 cm deep, sometimes internally terraced or with a hollow near one end, and in one case seem to give way to small depositional fans downslope; they have the appearance of having been formed by liquid flow rather than by wind erosion. Leveed fissures were imaged at more than 25 locations by Opportunity between 2004 and 2013, particularly near the rims of Endurance, Erebus and Endeavour craters, but also on the plains between Santa Maria and Endeavour craters; sharply-defined gutters are less common but examples were imaged close to the rim of Endurance and on the approach to Endeavour, whereas subdued, possibly wind-softened examples are more widespread. Scrutiny of images obtained by the rover Spirit in Gusev Crater between 2004 and 2010 has so far failed to find any leveed fissures or gutters, but examples of both types of features, as well as numerous small holes suggestive of surface sediment falling into underlying voids, were imaged by the rover Curiosity in the Yellowknife Bay region of Gale Crater during 2013. Leveed fissures appear to have been formed by venting from beneath. Ground disturbance by the rover can be ruled out in many cases by the appearance of features in images taken before close approach. Blowholes seem plausible close to crater rims (where wind might enter a connected void system through a crater wall) but less so in plains areas between craters. Fumaroles seem unlikely since there is no other evidence of geologically young volcanic activity in the region. There is evidence elsewhere that contemporary ground-ice thaw and consequent transient surface run-off may occur occasionally under present conditions in low, near-equatorial latitudes on Mars; short-lived (even for just a few minutes) meltwater emission and flow at the surface could erode gutters before evaporating. The decomposition of buried pockets of methane clathrates, which theoretical considerations suggest might be present and stable even in equatorial regions, could give rise to both methane venting (leveed fissures) and transient surface water (gutters). Another possibility is the decomposition, due to local changes in thermal conditions, of hydrated magnesium sulphates in the bedrock, releasing liquid water. Whatever their explanation, these features hint at previously unrecognized, young martian surface processes which may even be active at the present day; in this context, the apparent downslope extension of a discrete dark dust streak on Burns Cliff (inside Endurance Crater), during Opportunity's approach to that locality, is particularly thought-provoking.