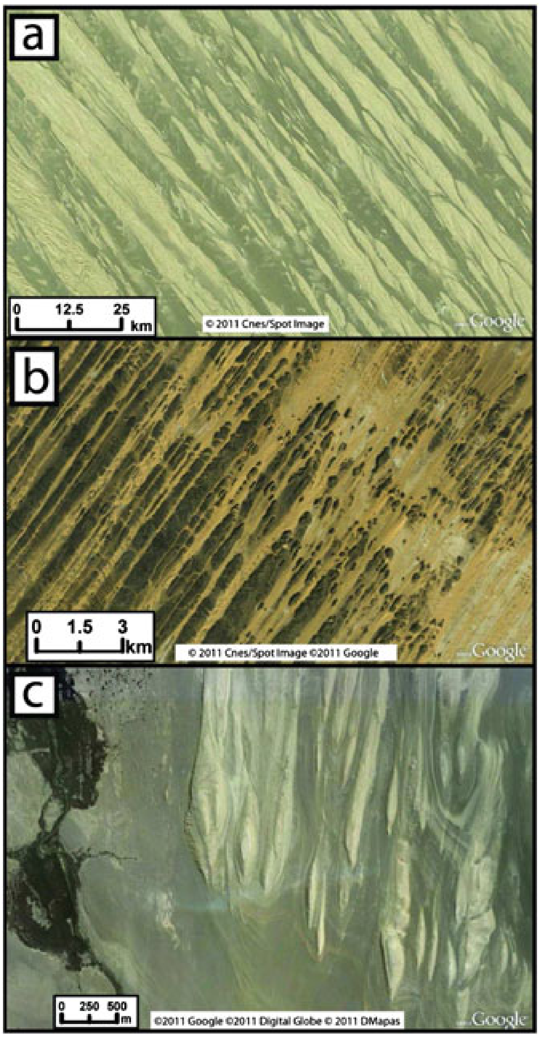


**Figure 5.** Terrestrial yardangs. (a) Yardangs up to 60–80 m in height in the Lut region of Iran, carved into indurated silty clays and gypsiferous sands (Goudie, 2007). A portion of SPOT 5 image from Google Earth, taken 12/03/10. lat: 30.71º N, lon: 58.26º E. (b) Mega-yardangs in the Borkou region of Chad, which cut into highly lithified sandstones (Livingstone and Warren, 1996). A portion of SPOT 4 image accessed through Google Earth, taken 12/05/10. lat: 18.80 N, lon: 19.33 E. c) Yardangs of the Peruvian coastal desert, carved into horizontally bedded siltstone (Bosworth, 1922). SPOT 5 image from Google Earth, taken 03/28/11. lat: 14.57 S, 75.60 W. This figure is available in colour online at wileyonlinelibrary.com/journal/espl

capping rock, as suggested by Zimbelman and Griffin (2010). Simple TARs can be seen between the yardangs (Figure 6(b)).

In northern Zephyria Planum, at the edge of the MFF, there occur flat-topped yardangs with a multitude of flat faces, or facets (Figure 6(c)). 'Faceted' yardangs were described by Zimbelman and Griffin (2010) in the eastern MFF (Figure 1). The facets were compared by Zimbelman and Griffin (2010) with similar features (at much smaller scales) found on ventifacts, which are caused by secondary complex flow. Similar erosion and fluting has been documented on yardangs, as discussed above, but on a much smaller relative scale to the yardang, and usually characterized by flutes that are elongated in the direction of wind-flow (Breed *et al*., 1989). Faceted yardangs are surrounded and occasionally buried by TARs. Additional faceted yardangs with concave backs and more gently-sloping sides can be found in far eastern Amazonis Sulci (Figure 6(d)). TARs accumulate in the inter-yardang troughs.

Yardangs in western Apollinaris Sulci (Figure 1), at the foot of Apollinaris Patera (Figure 6(e)), are cut into a substrate with swirling, discontinous layers. Unlike the yardangs in the horizontally bedded Pisco formation in Peru (Figure 5(b)), the layers in Apollinaris Sulci do not appear to dip at a consistent angle, and were probably not originally horizontally emplaced.

Further to the east in the MFF, small, faceted yardangs known as 'bidirectional' yardangs are observed (Bradley *et al*., 2002; Mandt *et al*., 2008) (Figure 6(f)). Bidirectional yardangs are much smaller than other martian yardangs. They tend to curve around topography, and can be found in patches as well as large fields. These features are often found in thin layers overlying older, unmodified terrain. Bidirectional yardangs are not observed on Earth; their presence in the MFF is attributed to funneling of wind by pre-existing bidirectional joint sets (Bradley *et al*., 2002).

Sakimoto *et al*. (1999) documented several generations of yardangs in the MFF, sometimes superposed on one another, which these authors interpreted as an indication of several periods of yardang formation under evolving surface winds.

While both yardangs and TARs are often long, linear features, yardangs are usually easily distinguished from TARs (compare Figure 4 and Figures 5, 6). First, yardangs are cut into the bedrock while TARs lie on top of bedrock or other sediment. Secondly, yardangs are generally much larger than TARs (hundreds of meters to kilometers versus meters to tens of meters). Third, yardangs are oriented parallel to dominant winds, while TARs are normal to wind directions; thus yardangs are often perpendicular to TARs where the two landforms occur together.

## Survey and Observations

A comprehensive survey was conducted of all 270 High Resolution Imaging Science Experiment (HiRISE; McEwen *et al*., 2007) images available as of December, 2010, that included a portion of the MFF. This was done in order to characterize depositional bedforms such as TARs and how they relate to yardangs and other MFF surface features. Mars Orbiter Camera (MOC; Malin *et al*., 1998), Context Imager (CTX; Malin *et al*., 2007) and High Resolution Stereo Camera (HSRC; Neukum and Jaumann, 2004) images were consulted in areas where HiRISE images were not available. It was observed that light-toned TARs are common in the formation, appearing between yardangs, on plains, and at the edges of the deposit. MFF TARs appear to be directly derived from eroding MFF yardangs, as shown in Figure 7, where MFF yardangs in northern Zephyria Planum can be seen eroding into loose material, which is organized by the wind into TARs. We can be confident that the MFF is the source of sediment for these TARs because they are cut off from alternative sediment supply sources by a vast, pristine lava plain. The accumulation of the TARs on the surface close to outlying yardangs suggests that not all of the MFF is made up of dust, which can be carried to great distances by the wind. The conclusion that the MFF is the source for this fine-grained material is consistent with the hypothesis that TARs are essentially coarse-grained granule ripples (Ward, 1979; Zimbelman and Griffin, 2010), as coarse-grained ripples are covered by >1 mm grains (Squyres *et al*., 2004), which would be expected to be found in close proximity to their sources.

While morphologically fresh TARs are common in the MFF, many appear to be moderately indurated (Figure 8). Fresh TARs are distinguished by an albedo higher than or similar to their surroundings, sharp crests, sharp secondary bedforms, smooth, uncratered surfaces, and an absence of fluting or grooves (Figure 3). Nearly all TARs elsewhere on the Martian surface are morphologically fresh, as described above. Indurated TARs identified here are characterized by rounded, broken, or etched