



Fig. 4. Lobate deposits in Protonilus Mensae. a) Digitate lobes with steep flow fronts (arrows). b) Lobate flow fronts deflected around underlying topography (arrows). c) Narrow (left) and broad (right) lobe fronts. d) Complexly stacked lobe fronts are highlighted in the white box. All images excerpted from PSP_007148_2245, with north towards image top, down-slope towards image bottom, and illumination from the lower left.

and broaden, either gradually or abruptly, downslope and as the slope steepens (Fig. 5a). Typically, deeper and wider gully channels are present in areas of thick pasted-on terrain, while finer channels occur in thin pasted-on deposits (Figs. 5a and 6). Pasted-on terrain appears thickest towards the base of the mesa, and thins towards the top of the gullied portion of the mesa, disappearing completely in some instances (Figs. 5a and 6). Some gully channels have minor sinuosity on meter to tens of meter scales (Mangold et al., 2008b), however, the gully channels are generally extraordinarily straight and parallel (Figs. 3b and 5a) compared to other gully channels on Mars (Malin and Edgett, 2000; McEwen et al., 2007). Protonilus Mensae gully channels are commonly cut-off or cross-cut by other channels, similar to those described elsewhere by Malin and Edgett (2000) and Schon et al. (2009). Anastomosing between channels is rare, as are dendritic tributaries (Fig. 5b). Fans are present at the bases of most gullies, and commonly have a complex, fluted, and sculpted texture (Malin and Edgett, 2000; Schon et al., 2009). As with gully fans elsewhere on Mars, many of the observed gully fans have multiple digitate or triangular depositional

aprons (Malin and Edgett, 2000; Schon et al., 2009) (Fig. 5c, d). Gully fan surfaces immediately beneath Protonilus Mensae gully channels have a rubbly texture with scattered boulders present—the source of these large clasts can be traced up-channel to eroding outcrops of bouldery mesa material present beneath the pasted-on terrain.

The most striking geomorphological element in the study site is a collection of lobate features located down-slope of the gully fans (Figs. 4 and 7). These features have not been identified in previous high-resolution gully observations (e.g., McEwen et al., 2007; Dickson and Head, 2008; Levy et al., 2009b). The features are convex-up with steeply sloped snouts. The features terminate in lobate fronts or in leveed fronts (where only a curved band of elevated material is discernable) (Figs. 4 and 7). These features will be referred to as “lobes” or “lobate fronts.” Lobes are smooth-surfaced at HiRISE resolution and boulder-sized clasts are exceptionally rare in lobe deposits (Figs. 4 and 7)—most observed boulders can be traced to erosion from upslope scarps, and the presence of boulder tracks implies boulder emplacement after lobe formation. No meter-scale blocks of coherent pasted-on terrain or mesa material are