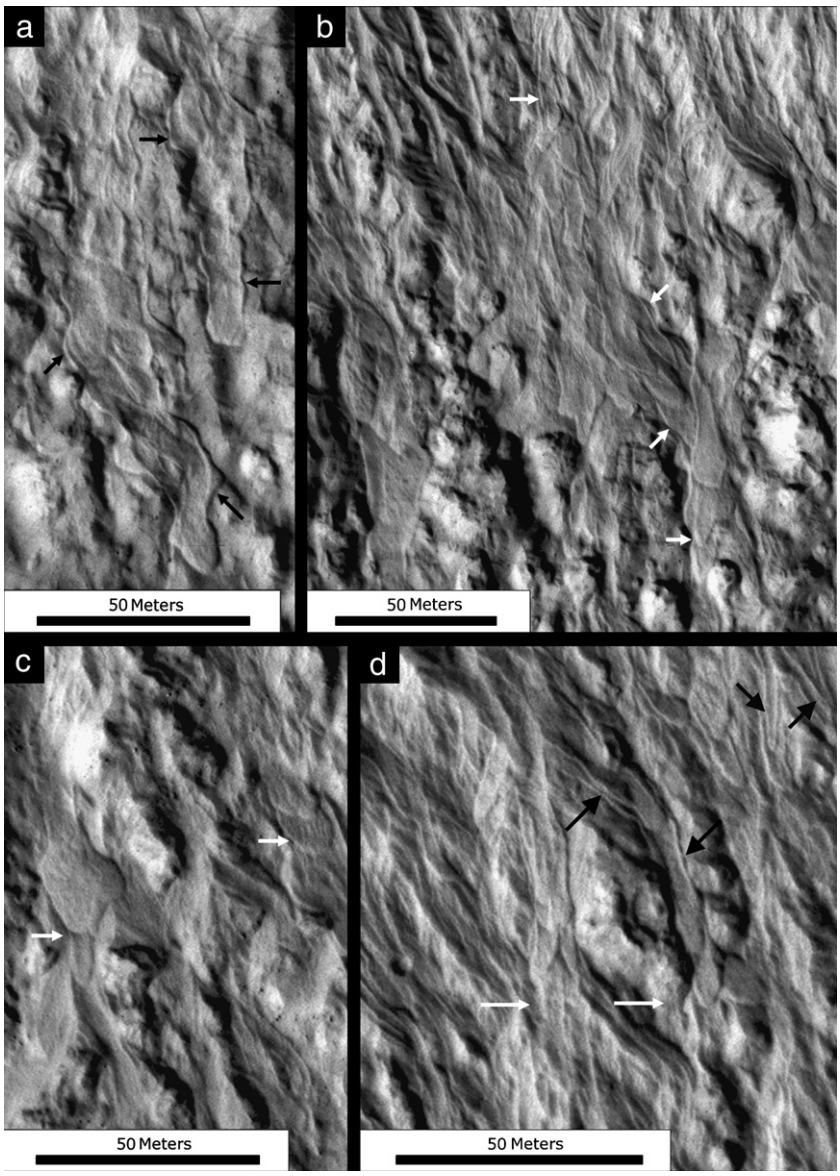

Fig. 7. Details of lobe morphology. In all frames, white arrows indicate overlapping flow fronts, suggesting stacking of lobes or pulsations in flows. Black arrows indicate topographically high deposits of lobe material on obstacles or leveed lobe margins. All images excerpted from PSP_007148_2245, with north towards image top, down-slope towards image bottom, and illumination from the lower left.

and show few or none of the channel bedform morphologies present in typical gullies (e.g., bars, lenticular islands, terracing, channel braiding) that are interpreted to indicate fluvial gully modification (Dickson et al., 2007a; McEwen et al., 2007; Dickson and Head, 2008; Head et al., 2008; Schon et al., 2009).

The most striking difference between the Protonilus Mensae gullies and typical martian gully features is in the depositional environment. Protonilus Mensae fans start on slopes that are high (~21°) compared to typical gully fans (Parsons et al., 2008), and are unusually fluted (linear, downslope sculpture). Additionally, the small lobes observed on Protonilus Mensae gully fans are atypical of martian gully fans. Lastly, and most strikingly, the Protonilus Mensae mesa gullies are continuous with the lobate flow features described above, which extend hundreds of meters from the fan termini (Figs. 5 and 6). While deposition of gully fans around local topography has been observed in the form of digitate or crenulated fan termini (Malin and Edgett, 2000; Schon et al., 2009), such long run-out and lobate deposits have not been observed in any classic martian gullies. In particular, typical gully-related deposits commonly terminate at the toe of the fan. The presence of extended gully-related deposits (the lobes) for hundreds of meters from the main fans is a notable feature of the Protonilus Mensae gullies in this study, and is not typical of classic gullies.

In contrast to classic martian gullies, a class of features have been observed on martian dunes ("dune gullies") that commonly lack alcoves, initiate at dune crests, have closely-spaced and notably straight channels (although some dramatic sinuosity can be present), and typically terminate in small leveed and lobate snouts (Mangold et al., 2003; Miyamoto et al., 2004). Analysis of martian "dune gullies" suggests that a debris flow—the mobilization of dune sediments, enhanced by interactions with surface frost (CO_2 or H_2O), and possibly entraining a liquid or vapor phase—may best explain the origin of these landforms (Mangold et al., 2003; Miyamoto et al., 2004). Given the morphological similarities between martian "dune gullies" and the Protonilus Mensae mesa gully and lobe system, we now outline the morphological properties of terrestrial debris-flows. Evaluating