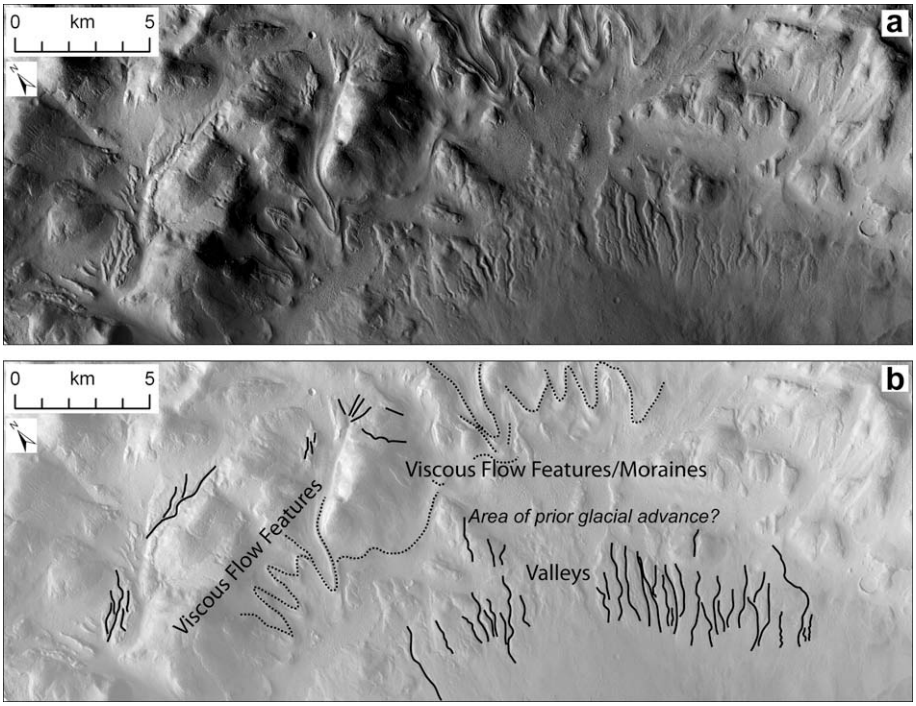

Fig. 7. (a) Image and (b) sketch of numerous small, parallel valleys found beneath viscous flow features (113°E, 39°S) (CTX images P02_001964_1416 and P03_002320_1413). At some point in the past, ice was probably more extensive, possibly extending to the source area of these valleys.

Neukum isochron system; Ivanov, 2001) or ~110 Myr (in the Hartmann isochron system; Hartmann, 2005). Thus, the valley itself must also be young (Late Amazonian) (Fig. 3d).

The valley begins near the north wall of the fossae, at the lobe front (ice flow in this fossae was approximately from south to north). It then continues across the debris apron surface, with a direction consistent with the topographic gradient measured with MOLA gridded topography; the valley is expressed in a series of tight meanders (with typical wavelength ~400 m). Presently, the valley is less than 10 m deep and 100–150 m wide, widening slightly downstream. Near the eastern margin of the lobe where the valley ends (Fig. 8c and d), it transitions into a ridge, similar to the positive sections in Fig. 2, although without a distinct depositional fan. The most probable process for inversion is that the valley sediments were preferentially preserved as ice downwasted due to sublimation, resulting in inversion of relief. Alternatively, the ridge may have formed by englacial or subglacial processes, although evidence for wet-based behavior is otherwise lacking. A small, degraded valley is also observed off the apron to the west of this inverted ridge which may also be glaciofluvial in origin (Fig. 8d).

A distinct albedo boundary along the northern wall of the fossae may mark a past highstand of ice (Fig. 8b, dotted line). This feature is continuously exposed along the wall for 40 km, consistent with this explanation, suggesting that 100–200 m of ice may have been lost from the lobate-debris apron.

2.2.2. Coloe Fossae: Valleys from lobate-debris aprons, 55.7°E, 39.9°N

The Coloe Fossae/Protonilus Mensae region along the northern dichotomy boundary has been a site of extensive glaciation during the Late Amazonian (Kargel, 2004; Dickson et al., 2006b, 2008; Head et al., 2009). Evidence from past ice flow direction requires that some valleys had ice thicknesses of at least 920 m (Dickson et al., 2008). Near where the marker for this thick ice is found, Dickson et al. (2006b) and Head et al. (2009) noted the existence of a series of small valleys (1–7 km in length) trending away from lobate-debris aprons from a trough wall. New CTX data (Fig. 9) provide an enhanced view of these valleys, which are morphologically similar to valleys in Fig. 5 in the southern hemisphere. The stratigraphy here is complicated as the valleys have clearly been mantled by recent material, perhaps from atmospheric deposition of ice (stippled texture in Fig. 9c; see, e.g., Mustard et al., 2001), which now appears similar to 'brain terrain' seen elsewhere on Mars (Levy et al., 2009). Given this post-fluvial mantling, it is challenging to directly constrain the timing of valley formation.

CTX and MOLA data suggest that all the valleys here start at approximately the ~−2300 m elevation contour, ~1 km from the end of the present glacial lobe. The valleys begin at nearly their full width (150–300 m), and have slopes of ~1–3°. The elongate depressions at the distal margins of the lobate-debris aprons that separate the glacial remnant from the valleys may have resulted from preferential loss of ice at the front of the glacier. Nonetheless, the valleys localized nature, limited extent, and proximity to the remnant glacial deposits support a glaciofluvial origin.

2.2.3. Eastern Hellas plateau: Melting of the "Hourglass"-shaped glacier, 102.5°E, 39.1°S

One of the most striking features interpreted as a glacier on Mars is a lobate-debris apron with a distinctive appearance adjacent to a ~4 km high massif east of the Hellas basin (Head et al., 2005) (Fig. 10). The head of the lobate-debris apron is in the upslope 10 km crater and flows through a narrow gap into an adjacent 16 km crater (Head et al., 2005). Fine flow lineations on the lobate apron surface trace across the apron surface and constrict as they pass through the gap (Head et al., 2005).

CTX data reveal that the rim on the lower (16-km) Hourglass crater is incised or breached, and valleys are present south and west of this rim (Fig. 10c and d). These valleys outside the rim are up to ~800 m wide and 12 km long, and erode the crater's ejecta and surrounding plains; these valleys are most deeply incised beginning ~6 km away from the rim. Nearer to the rim is a fan-like