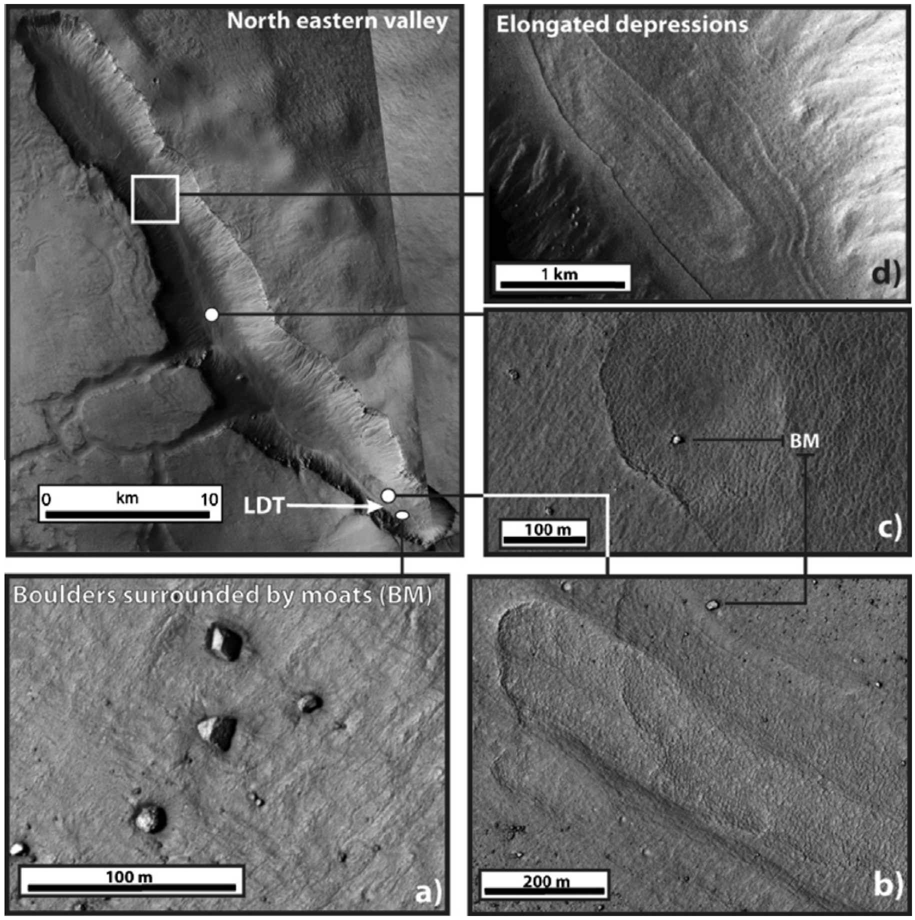


**Fig. 16.** Features interpreted to be ice-related, along the surface of LDT and the floors of the adjacent valleys. (a) Large boulders (>5 m) on the surface of the LDT have moats surrounding them; these may be formed due to the loss of near-surface ice, via sublimation as a result of the thermal properties of the rocks. (b) Elongated troughs, 200 m wide that are parallel to the long axis of the LDT. The troughs may have been formed by the lowering of the LDT surface as a result of the loss of subsurface ice through sublimation. (c) Similar trough to (b) along the floor of the valley to the north of the LDT. (d) Further to the north, concentric troughs form 50 m wide stepped terraces. Boulders with moats are also present along the floor of the valley. The occurrence of these features on LDT and the floor of the valleys suggest that both features contain near-surface ice and presumably formed in the same manner via the accumulation of ice and debris. Context image and (d) CTX image: P07_003880_1327. Other images, subsets of HiRISE image: PSP_003880_1325.

rules out a groundwater source and suggests that the LDT were formed by an atmospherically derived source of ice. The outstanding questions are what is the volume of the ice involved and when did it accumulate in Mars history? For example, could the LDT be deflated debris-covered glaciers formed by post-emplacement loss of ice by vapor diffusion through the overlying sublimation till?

#### 4.2.3. Age of lobate debris tongues

The superposition of gullies along the upper portions of the LDT (with the exception of possibly one gully, see Figs. 17 and 18) indicates that the gullies are predominantly younger than the LDT. Thus a period of gully formation is interpreted to have followed the emplacement of the LDT. The larger scale and lower slope of the surface of the LDT relative to the gully systems makes it possible to make crater count surveys to provide minimum age estimates. Crater counts and crater size–frequency distributions were compiled for a lobate debris tongue in order to derive an age for the surface of the feature. One hundred craters were identified on the surface of the LDT; the largest crater had a diameter of ~30 m.

The position of the largest diameter crater bin falls on the 8 Ma isochron suggesting that this represents a minimum age for the surface (Fig. 19). The significant rollover in smaller craters (<10 m D) is possibly due to a modification of the surface since the LDT was emplaced (this might be related to ice loss as is hypothesized for the formation of the linear troughs on the surface of the LDT, Fig. 16). Thus the age above relates to the modification of the surface, so the actual age of the formation of the LDT is likely to be significantly older than this.

## 5. Discussion: interpretation of the local climate history

The age of the LDT inferred from crater counting (surface age >8 Ma, Fig. 19) suggests that they are older than the most recent period of ice-rich mantle formation associated with the last martian 'ice age' (0.4–2.1 Ma, obliquity ~35°; Head et al., 2003) and thus the LDT could not have formed during this time as has been suggested for other small lobate flow features (Milliken et al., 2003; Arfstrom and Hartmann, 2005, see Table 1 and Fig. 20). The age of the LDT overlaps with that of the youngest glaciers deposits, superimposed on the debris-covered piedmont glaciers at the base of Olympus Mons (Neukum et al., 2004; Head et al., 2005; Milkovic et al., 2006). These younger glacial lobes are very similar to debris-covered glaciers in Antarctica (Head et al., 2005, their Fig. 3; Marchant and Head, 2007). The crater counts also place the formation of the LDT prior to the increase in average obliquity to ~35° (Fig. 20) that occurred ~5 Ma (Laskar et al., 2004). At obliquities higher than 45° the redistribution of ice is expected to have become more pronounced and the resulting migration in ice stability (Mellon and Jakosky, 1995) may have facilitated the deposition