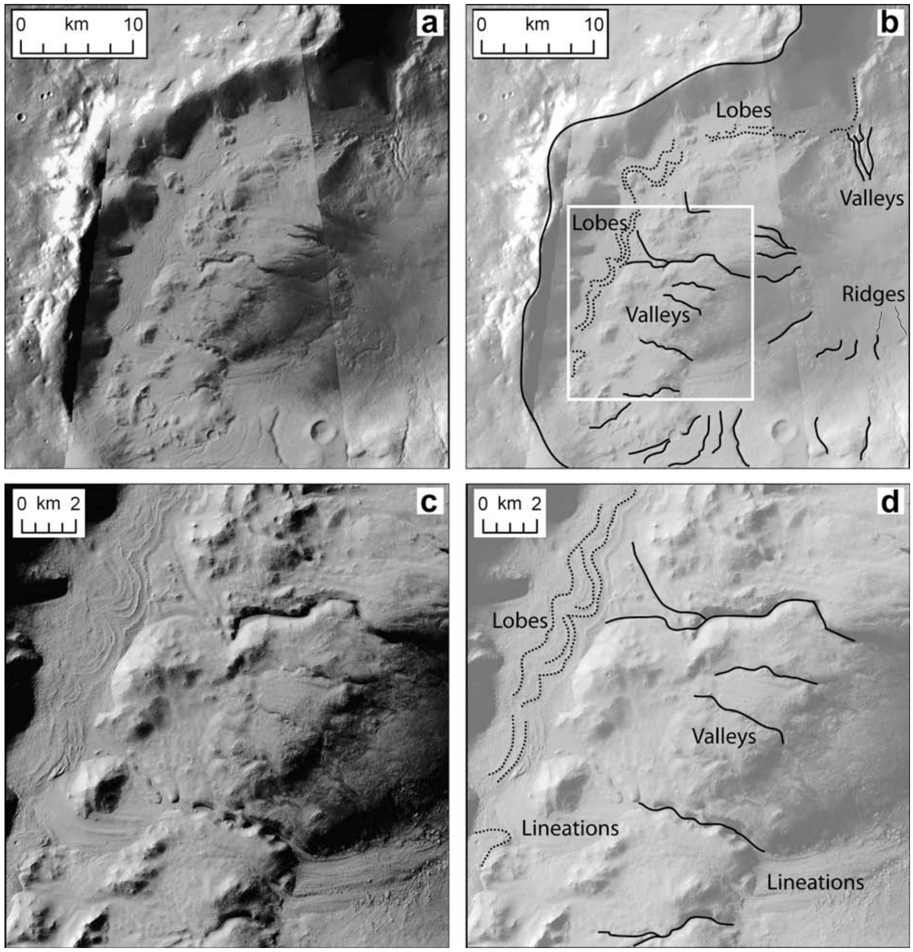

Fig. 6. (a and b) Image and sketch showing the western interior of a ∼45-km degraded crater in the southern highlands (31.4°E, 31.7°S); concentric fill material is found at the base of the wall. THEMIS VIS images V09811002, V15352007, V26958009. (c and d) Details of the valleys emanating from lobes of concentric crater fill on the crater interior (CTX image P14_006503_1473).

and beneath viscous flow features in this area. A well-developed example of such features is observed in the 70-km crater shown in Fig. 7 (Berman et al., 2009). During the most recent period of glaciation, marked by the current extent of the viscous flow features in this crater (Fig. 7), ice apparently did not extend to the headwater of the valleys in the center of the crater. However, crater counts suggest that these viscous flow features are very young (perhaps only ∼1–10 Myr; Arfstrom and Hartmann, 2005). During earlier periods of glaciation, still probably dating to the Late Amazonian, thick deposits of ice may have extended much farther downslope, an interpretation supported by rough-textured fill material between the viscous flow features and the observed valleys, which may be a remnant of this past glacial advance.

The dense, sub-parallel valleys seen here support the interpretation that they formed via ice-related melting, as they have a poorly-integrated planform pattern, a very immature drainage system consistent with a transient melting mechanism. Direct timing constraints on the formation of these valleys is difficult because of the small surface area (and thus poor crater statistics), and the rapid degradation and destruction of small craters on Mars (and thus the possible preferential loss of the few craters that do accumulate). However, there are very few superposed craters on these valleys, and none is larger than 400 m (in a count area of 60 km^2). Assuming that craters larger than 400 m superposed on the valleys would survive from their time of origin, which is a reasonable assumption given that the 200-m wide valleys remain sharp, this implies that the valleys are younger than the Hesperian/Amazonian boundary. The valleys may actually be significantly younger (Middle to Late Amazonian) on the basis of the superposed crater-size frequency distribution relying on small craters (Fig. 3c).

2.2. Valleys associated with regional-scale ice deposits

Several lines of evidence suggest that some locations on Mars have experienced widespread glaciation, including integrated flow patterns in valley and trough systems in Acheron Fossae and Deuteronilus Mensae (Head et al., 2006; Head and Marchant, 2009), flow between interconnected craters (e.g., the "Hourglass" craters; Head et al., 2005), and broad glacial-like aprons (lobate-debris aprons) on plains surfaces. As with deposits localized on the interior of craters, some of these systems appear to have melted at their margins forming valleys. Here, we describe several examples of glaciofluvial valleys associated with regional-scale ice deposits.

2.2.1. Acheron Fossae: Valleys on the surface of lineated valley fill, 230°E, 35.9°N

Lobate-debris aprons interpreted as debris-covered glaciers are common in the troughs of Acheron Fossae (e.g., Dickson et al., 2006a; Head and Marchant, 2009; Head et al., 2009) (Fig. 8). In one of the fossae troughs, a single small sinuous valley is directly superposed upon a lobate apron, traversing across its surface for approximately 10 km, apparently parallel with flow lineations (Fig. 8c and d). The surface it incises has a Late Amazonian crater retention age, with best fit age estimates of ∼80 Myr (using the