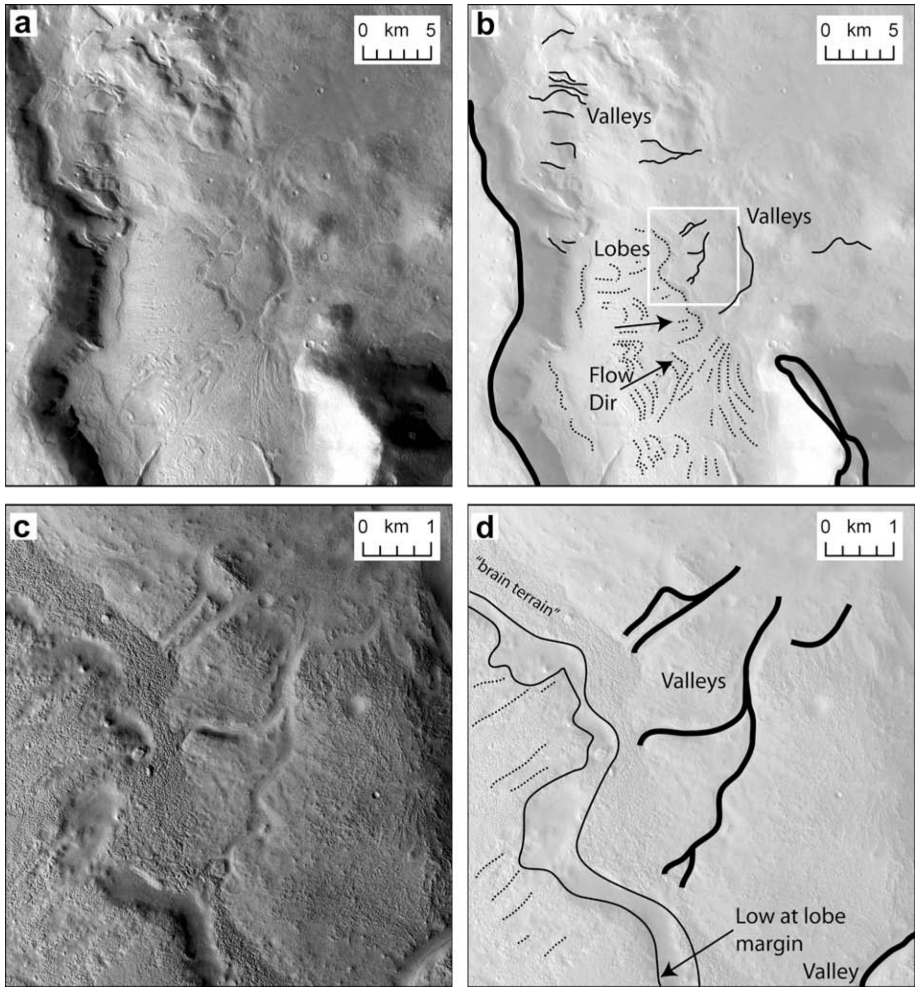

Fig. 9. (a and b) Lobate-debris aprons along a plateau margin in the Coloe Fossae region where small valleys are found at apron termini (55.7°E, 39.9°N). HRSC nadir image h5299 and CTX image P16_007161_2209. (c and d) Close-up view of the valleys. The stippled "brain terrain" texture material (Levy et al., 2009) appears to be superposed upon the valleys and thus to post-date fluvial activity.

The valleys around the Hourglass glacier incise a surface with a Hesperian crater retention age (Head et al., 2005). The surface of the Hourglass glacier itself is much younger (Late Amazonian), in the same age range as other lobate-debris aprons (Head et al., 2005). Thus, the best estimate for when the observed valleys formed is during the Amazonian, when the Hourglass glacier must have been thicker and more active, and post-dating the Hesperian plains and the ejecta from the larger Hourglass crater. A few other valleys besides those directly sourced from the gap in the Hourglass crater are also found on the surrounding plains. Although these have an uncertain timing and origin, they may also relate to melting of glacial ice during a more extensive past glacial phase, earlier in the Amazonian.

2.3. Geographic and elevation distribution

We have assessed the probable geographic distribution of these features by examining CTX images through mission phase P22. Although the features we describe in detail in this paper are some of the best examples of valleys related to the melting of Amazonian glaciers on Mars, many other candidate features exist. The broader geographic distribution of potential glaciofluvial valleys is shown in Fig. 11.

The geographic distribution of the features conforms directly to the regions of Mars where features interpreted as glacial in origin are most prevalent (Squyres, 1979; Squyres and Carr, 1986; Milliken et al., 2003; Head and Marchant, 2009; Head et al., 2009). Indeed, almost all areas at low-to-mid-latitudes where ice appears to have been concentrated in the past show at least some signs of possible small glaciofluvial valleys. This broad distribution suggests that conditions that allowed transient melting were not uncommon although there is a latitude dependence that is probably a direct function of where Amazonian glaciation occurred. The geographic distribution in Fig. 11 conforms well to the latitudes where gullies are also the most dense (Malin and Edgett, 2000), although the features we map here are on lower slopes (<10°) than gullies, which erode slopes of 15–35° and these candidate glaciofluvial landforms are also older.

Along with their geographic range, the elevation range for the glaciofluvial features is similar to gullies. There are very few high elevation features (>2000 m above the datum), despite the existence of several large glacial deposits at these elevations. The glaciers on the west flank of the Tharsis Montes (Head and Marchant, 2003; Shean et al., 2005, 2007) and Olympus Mons (Head et al., 2005; Milkovich et al., 2006) all lack evidence for glaciofluvial valleys similar to the others we describe. At present, the only candidate glacial valleys associated with these glaciers appear to involve ice–volcano interaction (Shean et al., 2005; Head and Wilson, 2007; Kadish et al., 2008). At these high elevations, the low pressure may have posed a barrier to the initiation of melting under typical conditions despite available ice reservoirs.