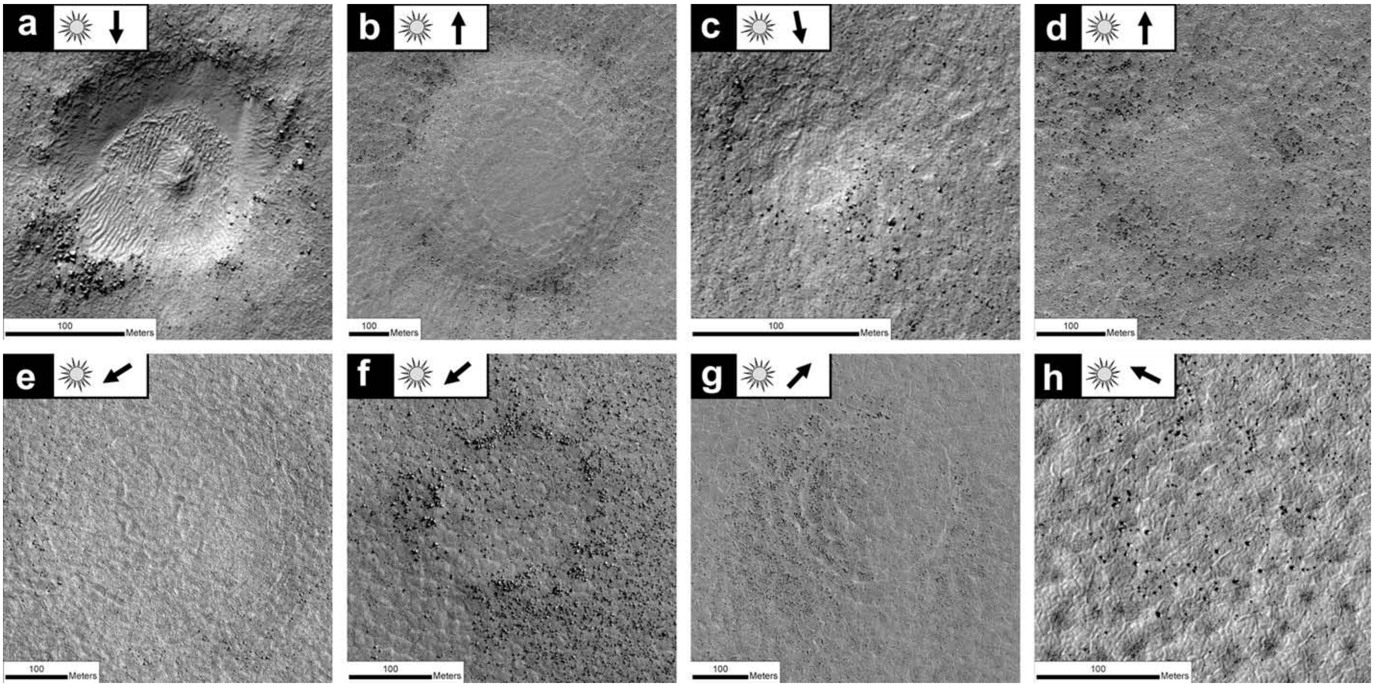

Fig. 11. "Boulder halo" craters (after Levy et al., 2008a) on the northern plains of Mars. Note the presence of meter to multi-meter boulders in proximity to impact craters (and crater-like forms), overlying thermal contraction crack polygons. Some boulders are concentrated in topographic lows between polygonally-patterned high ground, or in troughs between large polygons. Other boulders are present on top of polygon interiors. Dry cryoturbation processing of meter-scale boulders through meter-scale polygons is improbable. Instead, the observations suggest surface slumping, rolling, or sliding of clasts into their present positions. (a) Portion of PSP_001985_2470. (b) Portion of PSP_001477_2470. (c) Portion of PSP_001576_2460. (d) Portion of PSP_001477_2470. (e) Portion of PSP_001803_2485. (f) Portion of PSP_002417_2420. (g) Portion of PSP_001413_2495. (h) 1343_2510.

et al., 2008; Levy et al., 2009b,c; Schon et al., 2009b). At such locations, contacts between surfaces displaying different polygon morphological groups, for example, between "flat-top small" and "irregular" polygons (Fig. 13a) or between mixed-center polygons and underlying (non-polygonally patterned) "brain terrain" surfaces (Fig. 13b) are visible across topographic steps. Changes in elevation between LDM layers are typically on the order of a few meters at high latitude (Arvidson et al., 2008; Levy et al., 2009c) or up to tens of meters in thick LDM accumulations at lower latitudes (Levy et al., 2009b). Similar changes in polygon morphology between surface levels in scalloped terrain are observed in depressions several meters deep (Lefort et al., 2009). Terrace-like layering in polygonally-patterned LDM material typically outcrops as rounded or sinuous exposures of high terrain, hundreds of meters across, stepping down to more broadly distributed low-lying terrain, or as rounded "windows" into the lower mantle levels (Fig. 13a), possibly associated with underlying crater topography. The removal of several meters of LDM material from such windows strongly argues that the polygonally-patterned substrate has a high enough ice content to sublimate extensively on local scales, leaving little evidence of mantle cover behind.

Smaller-scale processes than those producing large windows or terraces through LDM layers provide unique access to the subsurface of the LDM. Small, fresh impact craters have been shown to have formed on Mars within the past decade (Malin et al., 2006; Byrne et al., 2009). Small impacts into mid-latitude (~45–55°N) polygonally-patterned LDM terrain have exposed bright material buried beneath a lower albedo surface cover; CRISM observations confirm that the bright material is water ice (Byrne et al., 2009). Over time, the exposures of buried ice darken, achieving a color and albedo comparable to the surrounding, polygonally-patterned terrain, suggesting that the patterned LDM substrate is exceptionally ice-rich, but contains a sufficient percentage of lithic fines to produce a sublimation lag deposit along the surface in contact with the martian atmosphere (Head et al., 2003; Schorghofer and Aharonson, 2005; Schorghofer, 2007; Byrne et al., 2009; Levy et al., 2009c).

4.2.1. The martian polygonally-patterned permafrost ice reservoir

How much ice is actually present in the latitude-dependent mantle? The morphological lines of evidence presented here strongly argue for an ice-rich latitude-dependent mantle, containing intermixed dust or lithic fines. This composition for the LDM is consistent with an atmospheric origin (condensation of ice and precipitation of snow and frost) of massive beds of ice that surficially exchange water vapor with the present atmosphere (Kreslavsky and Head, 2000; Mustard et al., 2001; Head et al., 2003; Schorghofer and Aharonson, 2005; Schorghofer, 2007). The formation of overlying sublimation lag deposits implies that the lithic component of the LDM ice is greater than 0% (Marchant et al., 2002), however, placing a firm upper bound on the ice content required to form windows or scallops is difficult (and is largely controlled by the efficiency of aeolian removal of lag deposits).

Taking the presence of thermal contraction crack polygons as a proxy for the presence of subsurface ice, a conservative estimate of the magnitude of the martian ice reservoir locked in LDM deposits can be made by taking the product of the surface area dominated by polygonally patterned ground, the depth of the icy layer, and a mixing ratio between ice and the lithic fraction. Surface area was mapped in a sinusoidal equal-area projection, including the spaces between HiRISE images containing polygonally patterned ground (Levy et al., 2009c) as also "permafrost-covered," and avoiding large physiographic features that appear non-patterned, such as the crest of the dichotomy boundary, Hellas basin, etc. This yields a total spatial extent of 4.9×10^7 km^2 (2.5×10^7 km^2 in the northern hemisphere, and 2.4×10^7 km^2 in the southern hemisphere), confined between 30° and 80° in both hemispheres. We take a conservative depth of the icy portion of the LDM at 10 m (Head et al., 2003; Mellon et al., 2009). We set the ice/rock mixing