ing is observed on fractured mounds in Utopia Planitia (Dundas et al., 2008), many mound fracture patterns are similar to cracking patterns observed on inverted "oyster shell" (Mangold, 2003) or "ring-mold" (Kress and Head, 2008) craters, that are in some places surfaced by polygonally-patterned LDM, and which are not interpreted as liquid–water-related features (Dundas and McEwen, 2009). Additionally, the possibility of late Amazonian, widespread active layer or talik conditions in proximity to Utopia Planitia fractured mounds is inconsistent with the preservation of underlying glacial surface textures ("brain terrain") on Utopia Planitia concentric crater fill (that has been dated to 10–100 Ma) (Levy et al., 2009b). Widespread thermokarst formation would likely have disrupted these fine-scale textures, which are observed to emerge pristine from beneath eroded exposures of, or windows through, polygonally-patterned LDM material. Lastly, the preservation of tens of meters of ice-rich material within preserved pedestal craters concentrated in Utopia Planitia, argues for the protection of ice deposits at the martian surface over tens to hundreds of Ma under cold and arid conditions resulting in the formation of marginal sublimation pits but no melt features (Kadish et al., 2008). Thus, both morphological and stratigraphic arguments suggest that the Utopia Planitia region has remained cold and dry over at least the past ~100 Ma, inconsistent with the formation of active layer landforms. Accordingly, recent observations of fractured mounds across a range of latitudes by Dundas and McEwen (2009) suggest that ice cores produced by segregation ice formation are not detectable in potential pingo landforms and that caution should be exercised in interpreting these landforms as pingos. Rather than invoking a recent and shallow integrated hydrological system in Utopia Planitia, a complex, sublimation-driven erosion of ice-rich layered material may better account for the observed morphologies (Dundas and McEwen, 2009).

To summarize, analysis of a range of polygon morphological properties and interactions with nearby landforms indicates that geologically young polygons present in the LDM have not formed in conditions permitting the widespread presence of standing or flowing liquid water. Instead, the observed relationships between polygonally patterned ground and associated landforms may be plausibly explained by primarily solid–vapor phase transitions under cold and dry conditions. Globally distributed polygonally patterned ground morphology (Fig. 1) reflects zonally averaged, cold and dry climate conditions within at least the past 1–2 Ma, and likely extending back several tens to hundreds of Ma to preserve glacier-like surface textures. Model results predicting ground temperatures sufficient to produce an active layer (>0 °C) during periods of high (>35–40° obliquity) (e.g., Mangold, 2005; Kreslavsky et al., 2008) provide critical insight into the limited magnitude of surface reworking accomplished by wet and dry active layers under martian surface conditions. Gully–polygon interactions may reflect peak surface and atmospheric temperature conditions occurring within short-lived, localized microclimate zones. The morphology of a wide range of small thermal contraction crack polygons on Mars is most consistent with widespread sublimation polygon formation, exposures of sand-wedge polygons, and rare (gully-related) occurrences of composite-wedge polygons. No active ice-wedge polygons are likely to be forming under current martian conditions (Kreslavsky et al., 2008). In Fig. 14, the Levy et al. (2009c) morphological classification of martian polygons is mapped onto an inferred terrestrial classification on the basis of martian polygon morphology.

Has liquid water played any role in the modification of polygonally patterned ground at any scale during the most recent Amazonian? In contrast to geomorphologically dry conditions (insufficient surface water to produce characteristic saturated active layer features) at the meters scale, recently acquired spectroscopic and geochemical data suggests that at the micron scale, thin-film water alteration of martian minerals may have occurred over much of the late Amazonian (Wyatt and McSween, 2007; Boynton et al., 2009; Hecht et al., 2009; Poulet et al., 2009). Microphysical processes producing water-film alteration conditions on the surfaces of rocks in the Antarctic Dry Valleys are well-described (Staiger et al., 2006; Marchant and Head, 2007) and may be analogous to processes operating on Mars (Head and Kreslavsky, 2006). Thin-film altered martian rocks and minerals may represent the maximum extent of widespread liquid water-related processing in martian thermal contraction crack polygon terrains (Wyatt et al., 2004).

4.4. Determining the age of martian polygon networks

Polygonally patterned ground on Mars has been shown to be an exceptionally young surface feature (Head et al., 2003), characterized by ongoing thermal contraction cracking (Mellon, 1997). A baseline for the age of the martian LDM of ~0.4–2.1 Ma was developed by Head et al. (2003) based on correlation of mantle-related deposits with well-dated, obliquity-driven climate models. Given that polygonally-patterned surfaces on Mars may currently be undergoing modification, can crater counting be used to give a reliable estimate of the age of the polygonally patterned surface of the LDM? Previous crater-count age estimates of the LDM have

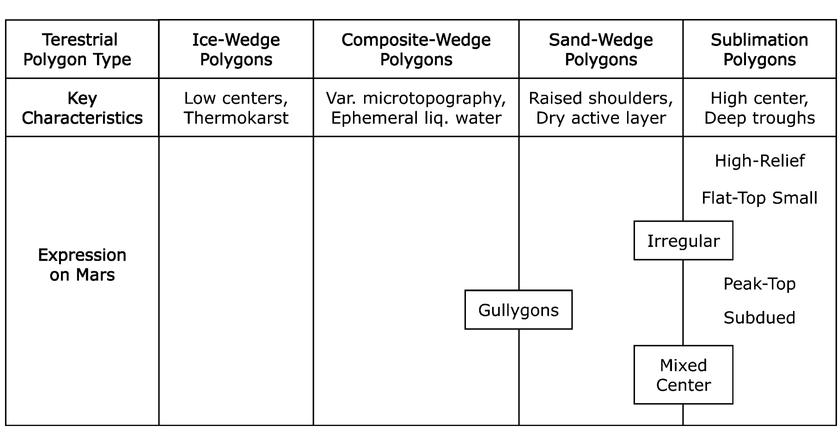

Fig. 14. Top row: polygon types on Earth (e.g., Marchant and Head, 2007) (see Fig. 2). Second row: key morphological characteristics of terrestrial polygon types. Third row: interpreted classification of martian polygon morphological groups defined by Levy et al. (2009c) (Fig. 1) into terrestrial polygon types, based on morphology and microtopography. Martian groups spanning more than one terrestrial polygon type show characteristics of both types. Clear examples of active ice-wedge polygons have not been documented on Mars in high-resolution studies.