attempted to count "fresh" craters that show minimal or no signs of thermal contraction cracking, using MOC image data to derive ages ranging from ~0.1 Ma (Kostama et al., 2006) to ~1 Ma (Mangold, 2005). Recent counts (Kostama et al., 2006; Levy et al., 2009c) have shown a latitude dependence of the age of polygonally-patterned surfaces, ranging from ~1 to 2 Ma at middle latitudes (~45°), to ~100–300 ka at higher latitudes (~55°), and finally to < 100 ka near 65°. Counts on HiRISE images between 60°S and 70°S have shown an exceptionally young surface age: 1–3 ka (Kreslavsky, 2009). The former counts (~2 Ma to <100 ka) have been interpreted to indicate a reduction in the deposition age of the LDM (younging) with increasing latitude (Levy et al., 2009c), while the exceptionally young, high-latitude counts may require a resurfacing process to remove small craters at polar latitudes (Kreslavsky, 2009). Determining the factors responsible for altering the apparent age of polygonally patterned units on Mars is critical for evaluating the age and origin of LDM deposits.

Crater counting on polygonally patterned mantle terrain is complicated by the obscuration and disruption of craters by polygons (Mangold, 2003; Kostama et al., 2006; Levy et al., 2009b). For mantle surfaces displaying small thermal contraction crack polygons, a reduction in the abundance of ~20 m diameter craters on mantle surfaces is typical, and may result from the removal or obscuration of craters with diameters comparable to polygon diameters (Levy et al., 2009c).

Thermal contraction crack polygons can form during permafrost development, forming "syngenetic wedges" that grow upwards towards an aggrading permafrost surface (MacKay, 1990). Alternatively, polygons can develop in stable permafrost that is undergoing little surface change (forming "epigenetic" polygons), or on degrading surfaces or slopes, forming "anti-syngenetic wedges" that propagate downwards into the permafrost at a rate controlled by surface ablation (MacKay, 1990). Thus, counting only fresh, unfractured craters yields a minimum age for the cessation of mantle emplacement (emplacement of additional mantle material would likely resurface existing craters, and promote syngenetic thermal contraction cracking). Accordingly, crater counts on polygonally patterned mantle surfaces indicate that many high-latitude fracture networks began forming as recently as several ka to several hundred ka, while lower (mid-latitude) networks have not undergone significant aggradation in 1–2 Ma, consistent with "ice age" emplacement of mid-latitude LDM deposits (Kreslavsky and Head, 2000; Mustard et al., 2001; Head et al., 2003). Even the youngest populations of polygons (e.g., polewards of 60°) form on timescales comparable to the most rapidly forming terrestrial polygons (Lachenbruch, 1962; Washburn, 1973; Sletten et al., 2003); however unlike quick-forming (years to decades) (Lachenbruch, 1962) terrestrial ice-wedge polygons, such high-latitude martian polygons have been interpreted to be analogous to terrestrial sublimation polygons (Levy et al., 2008c, 2009c) and are more likely to represent rapid trough expansion due to fracture-focused sublimation (Marchant et al., 2002; Kowalewski and Marchant, 2007; Kowalewski, 2009) than present-day, liquid–water processing (Baker, 2001). This rapid emplacement of mantle terrain and growth of polygons is inconsistent with models for excess ice emplacement by vapor diffusion (e.g., Fisher, 2005). Such vapor-diffusion ice emplacement models may require several hundred thousand (to over one million) years to generate the excess ice sufficient to produce the observed surface features (Fisher, 2005).

4.5. Are martian thermal contraction crack polygons equilibrium landforms?

In considering permafrost landforms, Marchant and Head (2007) define equilibrium landforms as, "landforms produced by specific geomorphic processes endemic to, and in balance with, local microclimate conditions." Are martian thermal contraction crack polygons active or relict landforms? Of the active landforms, can martian polygons be considered equilibrium landforms?

Several processes occurring at present on the martian surface are endemic to ice-rich substrates and are occurring in balance with current climate conditions. Notable examples of endemic processes include thermal contraction cracking due to seasonal thermal stresses polewards of ~30° latitude (Mellon, 1997; Mellon et al., 2008b) and seasonal exchange of water vapor from the ice table to the atmosphere (Mellon et al., 2008b). Examples of polygon-related phenomena in balance with current climate conditions include the widespread concurrence of martian ice table depth and subsurface ice stability as a function of latitude, insolation, albedo, thermal inertia, atmospheric temperature, and atmospheric relative humidity (Mellon and Jakosky, 1993, 1995; Mellon et al., 2004; Hudson et al., 2009b); frost accumulation and snowfall in the vicinity of the Phoenix lander (Searls et al., 2009; Whiteway et al., 2009); and frost accumulation in gully environments (Gulick et al., 2007; Head et al., 2008; Levy et al., 2009d). Conversely, observations indicate that some geomorphic processes are not currently occurring on the martian surface due to insufficiently warm and wet climate conditions. Notable among these phenomena are widespread liquid water surface stability and flow (which might produce regional gully activity or cause ice wedge formation) (Kreslavsky et al., 2008).

Thus, to the extent that many kinds of small martian polygons are likely still undergoing seasonal thermal contraction cracking driven by the endemic response of ice-rich permafrost to seasonal cooling, they are active, equilibrium landforms. To the extent that martian ice table depth in the latitude-dependent mantle is set by current climate conditions, the LDM is an equilibrium terrain. To the extent that sublimation polygons and sand-wedge polygons are interpreted to be the dominant polygon type on Mars (to the exclusion of ice-wedge polygons (e.g., Levy et al., 2009c)), martian thermal contraction crack polygons are equilibrium landforms. Likewise, some landforms not in equilibrium with the current martian climate are observed to be undergoing modification towards equilibrium conditions. For example, observations that different sections of polygons at the Phoenix landing site (see next section) have different ice table depths over tens of cm length scales suggests that individual polygons are responding to changes in ice table depth caused by slumping of sediments, rock presence (e.g., Sizemore et al., 2009), or local micro-topography (Levy et al., 2009e). Likewise, exposed ice produced by impacts through overlying lag deposits (e.g., Byrne et al., 2009) undergoes sublimation to produce surficial lag deposits, suggesting that where disruptions occur, many ice-related martian landforms are undergoing modification in order to achieve equilibrium with prevailing climate conditions. Accordingly, many portions of the polygonally patterned latitude-dependent mantle may be well described as equilibrium landforms.

In contrast, some polygon-related landforms do not show evidence of current activity. "Rubble piles" (Fig. 12) and windows through mantle layers (Fig. 13) are interpreted as evidence of the removal of large volumes of LDM material (see previous sections). Accordingly, given the general concurrence of martian ice table depth and ice stability prevailing at present (Jakosky and Carr, 1985; Mellon and Jakosky, 1995; Mellon et al., 2004, 2009) these landforms may be considered relict landforms—features preserved by the cold and arid martian climate, but not currently developing. Likewise, some gully–polygon systems appear to be relict landforms, preserved pristinely on pole-facing slopes, but undergoing slow degradation and removal on warmer, equator-facing slopes (Levy et al., 2009d). Although polygons are common in craters containing recently formed bright gully deposits (e.g., Kolb et al., 2008; Pelletier et al., 2008) these deposits cannot be linked to current polygon-mediated activity.