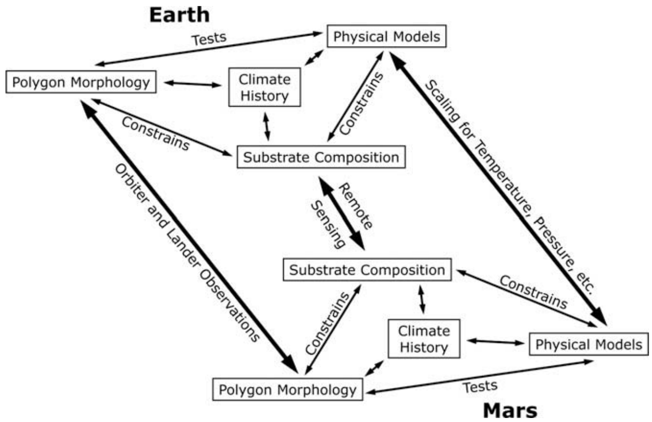

Fig. 3. Schematic illustration of the strategies and goals of thermal contraction crack polygon analysis. Exploration of polygonally patterned ground on Earth requires the combined expertise of geomorphologists, geocryologists, physical modelers, and climate modelers. Each element of polar science provides critical tests and predictions for the associated disciplines. The exploration of martian thermal contraction crack polygons is focused on the goal of interpreting Amazonian climate history. This goal can be accomplished by combined orbiter and lander geomorphological observations, remote sensing and in situ substrate analysis, and the application of physical models describing the response of martian permafrost to climate processes.

thermal contraction cracks is critical to assessing polygon development over time. Long-term studies of ice-wedge cracking have shown that fractures form on annual to inter-annual timescales, but that predicting whether a specific crack will open during a particular year, based on available climate data, remains an elusive goal (Berg and Black, 1966; MacKay, 1992). Further, crack propagation direction (i.e., from the top of buried ice-wedges up or from the ground surface down) has been shown to be a complex function of surface cover, wedge properties, climate, and age (MacKay, 1992, 2000). These observations, coupled, with thaw-slumping in ice-wedge polygons, and non-homogeneous removal of ice-cemented material by sublimation in sublimation and sand-wedge polygons (Marchant et al., 2002; Kowalewski and Marchant, 2007; Kowalewski, 2009), confound efforts to use polygon wedge dimensions or cracking frequency as a metric of polygon age or development (Berg and Black, 1966; MacKay, 1992, 2000; Sletten et al., 2003). One approach, crater counting on polygonally patterned martian surfaces (see Section 4.4) is a planetary solution to the lack of an intrinsic polygon chronometer, and is functionally comparable to terrestrial cosmogenic nuclide exposure age dating used to determine the age of Antarctic permafrost features (e.g., Brown et al., 1991; Brook et al., 1993; Schäfer et al., 2000; Stone et al., 2000; Smith et al., 2001; Marchant et al., 2002; Staiger et al., 2006; Swanger, 2009).

2.2. Polygon forms as a proxy for local microclimate conditions

Detailed geomorphological analysis of terrestrial thermal contraction crack polygons suggests that polygon morphology is strongly diagnostic of local microclimate conditions (e.g., air and ground temperature, atmospheric humidity, and ground/soil water content) (Marchant and Denton, 1996; Marchant and Head, 2004, 2005, 2007; Kowalewski et al., 2006; Kowalewski and Marchant, 2007; Kowalewski, 2009). As features typical of permafrost (ground that has a mean annual temperature <0 °C over inter-annual periods) (Washburn, 1973; French, 1976; Yershov, 1998), terrestrial thermal contraction crack polygon morphology is strongly influenced by the range of periglacial (e.g., non-glacial, cold climate, Washburn, 1973) processes acting over local, regional, and global scales (Washburn, 1973; Bockheim, 2002; Marchant et al., 2002; Kowalewski et al., 2006; Kowalewski and Marchant, 2007; Marchant and Head, 2007), which, in turn, are influenced by local microclimate conditions. Thus, well-developed varieties of contraction crack polygons can be considered proxies for local environmental conditions (Fig 2) and can be used to distinguish between polar climate zones (e.g., Antarctic Dry Valley microclimate zones (Marchant and Head, 2007) or High and Low Arctic environments).

Terrestrial thermal contraction crack polygons are commonly classified by the material properties of the subsurface wedges that form the polygonal network: criteria that are strongly dependent on subsurface rheological properties (including ice content), and climate-driven environmental factors, including the presence or absence of an active layer (the layer of a permafrost surface that is seasonally warmer than 0 °C) and soil moisture (Péwé, 1959;

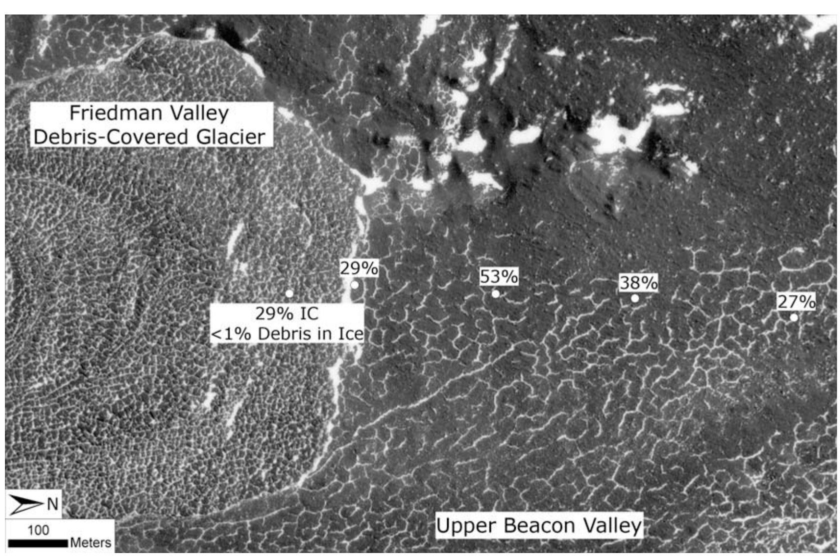

Fig. 4. Sublimation polygons on the Friedman Valley debris-covered glacier (left) and sand-wedge polygons in upper Beacon Valley (right). White circles indicate measurement locations of substrate ice content (typically ice-cemented sediment) made using gravimetric analysis. Ice content is given as the percent ratio of ice mass to sediment mass. Friedman Valley debris-covered glacier ice is nearly pure ice, with a lithic fraction of <1%. "IC" indicates a measurement of ice-cemented sediment capping glacier ice in an adjacent polygon. Cracking substrate rheological properties such as ice content have a strong effect on polygon morphology.