distinguish meters-thick accumulations of massive ice (Head et al., 2003) from pore-ice-cemented terrain (Mellon et al., 2008a,b)? From terrestrial examples, high-centered polygons are strongly indicative of the removal of excess ice at polygon margins (Jahn, 1983; MacKay, 2000; Marchant et al., 2002; Matsuoka and Hiraka, 2006; Levy et al., 2008c, 2009c). There are two models that can produce the relief typical of high-centered polygons, and each requires very different subsurface-ice concentrations and melting or sublimation histories. For an extremely cold and dry Mars, e.g., without significant melting, high-centered polygons can form in regions with widespread excess ice if sublimation preferentially removes ice at polygon margins/thermal-contraction cracks (a model initially described for Beacon Valley, Antarctica, by Marchant et al., 2002). In contrast, high-centered polygons can also form in regions with limited excess ice in which ice is locally concentrated at the margin of ice-wedge polygons (e.g., MacKay, 1990). In this case, local melting of the ice at polygon margins can create deep troughs that surround high-centered polygons. Localized thermokarst of this type has been used to infer recent warming for some sites in the Arctic (MacKay, 2000; Matsuoka and Hiraka, 2006). Can these two alternatives be distinguished with HiRISE image data?

The morphology of clusters of small, high-centered and flat-topped polygons (the "flat-top small" group of Levy et al., 2009c) (Fig. 1) can help distinguish excess ice in the polygon-forming substrate, from excess ice concentrated at polygon troughs. Between ~60° and ~70° (a latitude range containing the Phoenix lander) in both hemispheres, flat-top small polygons are commonly present in clustered groups on topographically high mounds or knolls (~20–30 m in diameter) (Levy et al., 2008c, 2009c; Mellon et al., 2009). HiRISE stereo image topographic profiles (Kirk et al., 2007) across these polygonally-patterned knolls indicate that the knolls have pole-facing (north-facing) slopes that are approximately twice as steep as their equator-facing (south-facing) slopes (Fig. 9), an asymmetry typical of individual sublimation polygons and "megagon" groups of sublimation polygons present in Beacon Valley, Antarctica (Figs. 2 and 10) (Marchant et al., 2002). Levy et al. (2008c) interpreted the observed slope asymmetry in the martian polygonally-patterned knolls to indicate the preferential sublimation of subsurface ice on warmer, equator-facing slopes (resulting in slumping and shallowing of the knoll slopes) relative to enhanced preservation of shallower ice on colder, pole-facing slopes (cementing the knoll slopes and maintaining the relatively steep profiles). In particular, Levy et al. (2008c) conclude that unless the polygonalized knolls contain uniformly distributed excess ice within the mound (and by extension, within the polygon interiors) no topographic asymmetry would develop (i.e., the knolls would be sediment-supported). This, coupled with the high-centered morphology typical of flat-top small polygons, suggests that the martian flat-top small polygons are analogous to terrestrial sublimation polygons (Marchant et al., 2002), and form in a substrate containing distributed excess ice rather than excess ice concentrated along fractures or wedges.

Not all polygons forming in latitude-dependent mantle material are high centered, however; what do polygons with raised shoulders indicate about local differences in permafrost ice content and polygon development? "Mixed-center" polygons (polygons transitioning between high- and low-centered examples over horizontal length scales of 1–5 polygon diameters, Fig. 1) (Levy et al., 2009c) are common at martian mid-latitudes (~45° in both hemispheres) and are particularly common on the walls and floors of "scalloped terrain" in Utopia Planitia, and circum-Hellas (Lucchitta, 1981; Seibert and Kargel, 2001; Lefort et al., 2007, 2009; Soare et al., 2008; Zanetti et al., 2008), and in thick (tens of meters) mantle deposits atop concentric crater fill (Levy et al., 2009b). Some workers have suggested that scalloped, polygonally patterned units represent regional thermokarst-like melting prior to LDM emplacement (Costard and Kargel, 1995; Soare et al., 2007, 2008). Alternatively, analyses combining HiRISE image and topography data (HiRISE stereo and HRSC) (Zanetti et al., 2008; Lefort et al., 2009), have demonstrated that the formation of scallops (and the thermal contraction crack polygons present in and around the scalloped depressions) is more consistent with locally enhanced sublimation of near-surface ice on slopes receiving heightened insolation and subsequent slumping of desiccated sediments. In particular, Lefort et al. (2009) suggests that polygons in Utopia Planitia scalloped depressions (mixed-center polygons) formed contemporaneously with the scallops by sublimation-driven geo-

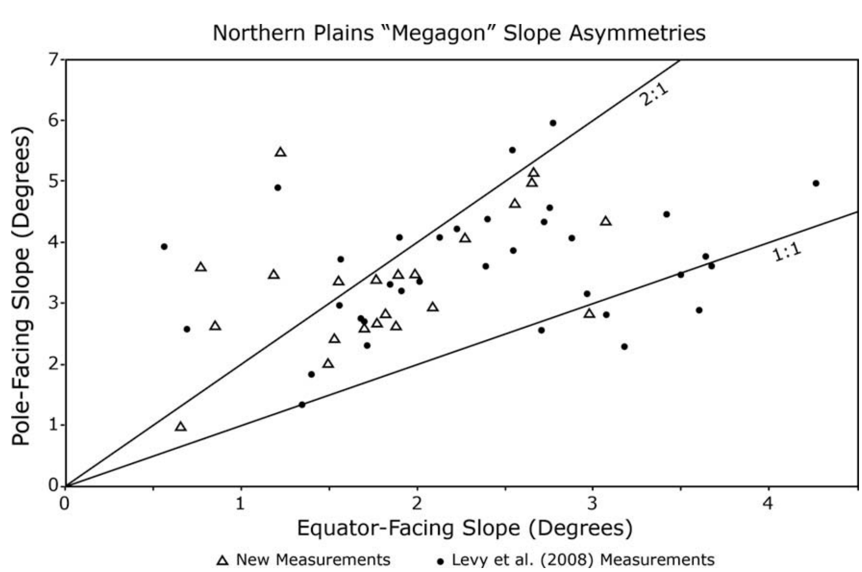

Fig. 9. Slope asymmetries measured for pole-facing and equator-facing surfaces on rubble-pile-topped, polygonally-patterned knolls in the martian northern plains. Martian knolls may be analogous to terrestrial "megagon" clusters of sublimation polygons (Levy et al., 2008c). Closed circles represent measurements reported by Levy et al. (2008c) on HiRISE image PSP_001958_2485, using HiRISE stereo topography produced by the USGS Astrogeology Branch. Open triangles indicate new measurements made on HiRISE image PSP_001919_2470 using HiRISE stereo data produced by the USGS Astrogeology Branch. Pole-facing knoll slopes are approximately twice as steep as equator-facing knolls slopes, interpreted to indicate removal of excess ice on warm, equator-facing slopes.