same tracks, troughs are typically beaded, but continuous. In some tracks, the beaded nature of the troughs is subdued and boulder tracks appear as almost linear troughs (tracks 7, 8, and 13).

These along-track variations in appearance are interpreted to be related to changes in the nature of the encounter between the rolling boulder and the regolith surface. In the initial parts of the boulder tracks (Fig. 13a), which typically feature steeper slopes and higher velocities, the boulder will have a tendency to bounce, and thus will interact in different ways with the underlying regolith. If the boulder leaves the ground during a bounce, its successive landings will be marked by a row of elongated, beaded, raised-rim troughs. If the boulder does not completely leave the ground between bounces, a narrow trough will be formed between the beads caused by the bouncing impact. As the boulder decreases in velocity in the medial to distal parts of the track, these beads become progressively more connected, as rolling dominates over bouncing, and the boulder track becomes more trough-like.

A significant component of the variation in appearance of the medial to distal parts of these boulder tracks is due to the second factor, the shape of the causative boulder. For very fresh examples (Fig. 13b), clearly repetitive patterns are seen on the floors and sometimes the walls of these tracks. For example, the 10.5 m-diameter boulder located at the end of track 7 has an irregular shape, and a distinctive, repetitive pattern is seen on the trough floor along the last ~200 m of the track. Six consecutive paired mounds (each about 12 m wide, along-track) occur spaced about 20 m apart, and hints of two similar structures are seen in the last 50 m of the trough. Repetitive patterns along the medial and distal parts of boulder track 5 are also striking. Here, a series of ~8 to −12 m long, lunate depressions (convex toward the image bottom), arrayed shoulder to shoulder, and oriented with their long axis along-track, is observed. Similar types of repetitive variations in track appearance are visible in track 10, where its ~5 m-wide boulder is elongate. Smaller and more rounded boulders (i.e., in tracks 7 and 8) appear to have formed much more linear and groove-like troughs.

These very fresh examples of along-track variations in trough morphology are interpreted to be due to the effects of the shape of the boulder as it rolls along the surface and displaces the underlying regolith. Large, irregularly shaped boulders tend to produce distinctive variations in both trough-floor topography and the linearity and shape of boulder track walls and rims. Smaller, more rounded boulders tend to form more linear boulder track troughs, with less beaded planform appearances (unless they are bouncing), and less distinctive floor and wall topography.

3) *Cross-cutting and superposed boulder tracks*: Numerous examples of cross-cutting and superposed boulder tracks are observed (Fig. 13a and b). In Fig. 13e, six different major boulder tracks (tracks 2–7) are observed. Tracks 4 and 6 are the most prominent and extend across the image, paralleling its boundaries. The smaller track 3 crosses the image at an angle and cross-cuts (and is thus younger than) track 4. As track 3 encounters track 4, its direction deviates slightly as it passes into and then out of the interior of track 4, and resumes a course along the same azimuth but is slightly displaced. Track 3 extends for another ~80 m until it encounters the rim of track 6, which is beaded along strike. Track 3 enters track 6 between two of the regularly spaced rim beads, and then is captured by the larger floor of track 6, changing course and extending along the floor of track 6 for about 25m until it comes to rest on top of a septum between two track 6 beads. Track 6 clearly cross-cuts, and is thus younger than, track 5, and track 7 cross-cuts both track 5 and track 6. Thus, some of the smallest and least prominent tracks (tracks 3 and 7) post-date some of the most prominent tracks (tracks 4 and 6). This size-dependence of initial morphologic prominence presents challenges in making age determinations on the basis of the morphological degradation states of boulder tracks alone.

4) *Relationship to pre-existing topography*: What effect does pre-existing topography (e.g., impact craters, hills, and swales) have on the orientation and morphology of troughs? Several examples are seen in Fig. 13f, a typical part of the terrain and topography in the boulder-track field. The general slope of the terrain is down toward the right. On the basis of the observed photometric variation in the image, the terrain is seen to be characterized by the broadly hummocky long-wavelength, low-amplitude, meters-scale undulations typical of the "elephant-skin" texture of highland regolith topography. At least some of this topography is due to old, highly degraded impact craters, as well as to general downslope creep of regolith. Several 5–10 m-diameter, relatively fresh, bowl-shaped craters are also observed, and in one case (center top of Fig. 13f), a boulder track crosses a fresh impact crater ~10 m in diameter.

Analysis of Fig. 13f shows little evidence of the effect of pre-existing topography on boulder track along-strike orientation. For example, the unnumbered narrow track between the larger tracks 5 and 7 is superposed on a fresh ~10 m-diameter impact crater, and no deviation is seen as the boulder enters and exits the crater. Tracks 4 and 6 (lower left) show no major deviations as they cross the background hills and swales typical of the "elephant skin" texture. Track 5 (center) shows a broad curvature near its terminus, but this seems unrelated to any specific surface topography and is likely to represent the influence of local slopes on the slowing the boulder as it comes to rest.

Only in the most distal portions of some boulder tracks are any perturbations from a generally linear track observed (Fig. 13f). For example, in track 7 (the top track), there is a small perturbation in the track direction about 55 m from the distal end, as the boulder passed across a small ~15 m-wide crater-like depression. Between tracks 5 and 7, in the right central portion of Fig. 13f, a narrow boulder track terminates where the boulder meets the raised rim of a pre-existing track (lower left boulder in group of three arrayed in a triangle). The boulder that formed track 3 (lower left) turned down along track 6 in its distal part, and came to rest within 50 m of its entrance into track 6.

We interpret these relationships to mean that over the vast majority of the lengths of these tracks, boulder velocities were sufficiently high that the forward momentum vector was not meaningfully perturbed by whatever pre-existing topographic variations were present. As boulders slowed to a stop in the distal parts of the tracks due to the cumulative effects of frictional forces, their forward velocities were low enough that local topography was able to have an effect, capturing boulders in pre-existing tracks (e.g., Fig. 13f, boulder track 3) or causing slight curvatures at the distal tips of troughs as boulder responded to local slopes or asymmetries in the shape of the boulders themselves (e.g., Fig. 13f, boulder track 5). In general, boulders dislodged from outcrops on the Moon that roll downslope are likely to be traveling much more slowly than boulders ejected by the Stickney impact on Phobos (see Sections 2–5), and thus along-strike deviations in track linearity are expected to be even less apparent on Phobos than those observed on the Moon (Fig. 13).

7.2. Comparison with Phobos tracks

In Sections 2–5 we outlined predictions for the process of groove formation by rolling and bouncing of boulders ejected by