TOPOGRAPHIC MAPPING OF PATERAE AND LAYERED PLAINS ON IO USING PHOTOCLINOMETRY.

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Introduction: No instrumentation specifically designed to measure the topography of a planetary surface has ever been deployed to the Galilean moon Io. Available methods that exist to perform such a task in the absence of the relevant instrumentation include stereo imaging [1], photoclinometry [2], and shadow length measurement [3,4]. In addition, Galileo limb profiles provide the only available global topographic 'ground data' [5].

Photoclinometry-derived (PC) digital terrain models (DTMs) are primarily used for mapping local-scale topography, displaying significant topographic undulations over longer distances. PC mapping can also be hindered by surface albedo variations and phase variability. This abstract describes our efforts to refine the PC mapping process (which has previously been applied to Io [6]) and produce new PC DTMs for seven locations on Io's surface using Voyager and Galileo imagery, from which we have made measurements of the vertical relief of 23 paterae and 12 units of layered plains. We consider these measurements to support the hypothesis that a volatile-rich surface layer (or layers) extends across Io, the thickness of which influences the depths of paterae and the heights of layered plains.

Methods: PC mapping is derived directly from the well-tested line profiling PC tool described in [7], and ideally involves reprojecting a high-Sun image of Io to the same lighting conditions as a low-Sun image, so that slope and topographic relief may be determined through comparison of the shading of corresponding pixels in the two images. PC DTMs are often afflicted by topographic undulations on regional scales, which the use of the high-Sun image compensates for to some degree, as a means of providing an initial estimate of local albedo variations [8]. However, suitable high-Sun images are not always available, which is especially common for terrain at high latitudes. The success of the PC method is also dependent on the accuracy of the model of the photometric function [9], which can be unique for each geologic unit on Io, so no global photometric model of Io exists on the kilometer-scale.

We have since tested the effects on PC-derived topography of varying the photometric function, as well cropping images to a fraction of their original coverage such that topography is generated only for selected landforms of interest, with minimal albedo variation across the scene. Results are compared with shadow length measurements in order to determine what combination of photometric function and cropping extent yields height measurements that most closely match the shadow length values. Twelve PC DTMs of Echo Mensa, a unit of layered plains located at 79.9°S, 354.5°W, were created for combinations of six photometric function values and for two scene sizes, one including the entire Voyager 1639301 image and the other cropped around Echo Mensa (Figs. 1a and 1b). The variation of the scarp height with photometric function is shown for both scenes in Fig. 1c, alongside the shadow measurement. A scarp height considerably lower (by 250 to 400 m) than the shadow measurement is obtained for the entire scene as opposed to the cropped scene around Echo Mensa (by 0 to 100 m), indicating the importance of creating specific PC maps for individual features where the apparent brightness range is constrained by doing so. The effect of changing the photometric function is evidently not as drastic, with the scarp height varying by <100 m for each scene, less than the error bars on the shadow measurement.

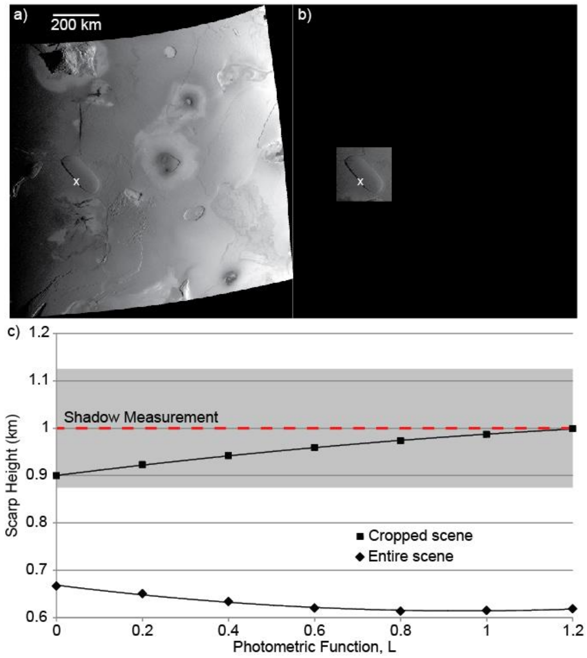

Fig. 1. (a) Voyager image 1639301, north is to the right. White cross marks the location of the shadow measurement. (b) The same image as in (a), cropped around Echo Mensa. (c) Variation in the measured PC scarp height with changing photometric function for both the entire and cropped versions of image 1639301. Red dashed line represents the shadow measurement, and the gray area represents error bars for the shadow measurement.

Mapping results: We have so far generated individual DTMs for 23 paterae and 12 layered plains outcrops within seven Voyager and Galileo PC images using the methods detailed in the previous section. For all but one of the PC images, we have corresponding albedo images. For each of the paterae, we have compared our PC topography with shadow measurements. We find that shadow-derived heights of the patera wall scarps are higher than the corresponding PC measurements by a mean factor of 1.0, with an overall range of 0.3 to 1.8 and a σ of 0.4, indicating generally good agreement between the shadow and PC measurements, especially given the low resolution of the PC and albedo images at the scale of the paterae.

The 23 paterae show a mean PC wall scarp height of 0.98 km (σ = 0.33 km), and the 12 layered plains outcrops show a mean scarp height of 1.09 km (σ = 0.44 km). Example DTMs with accompanying topographic profiles are show in Fig. 2.

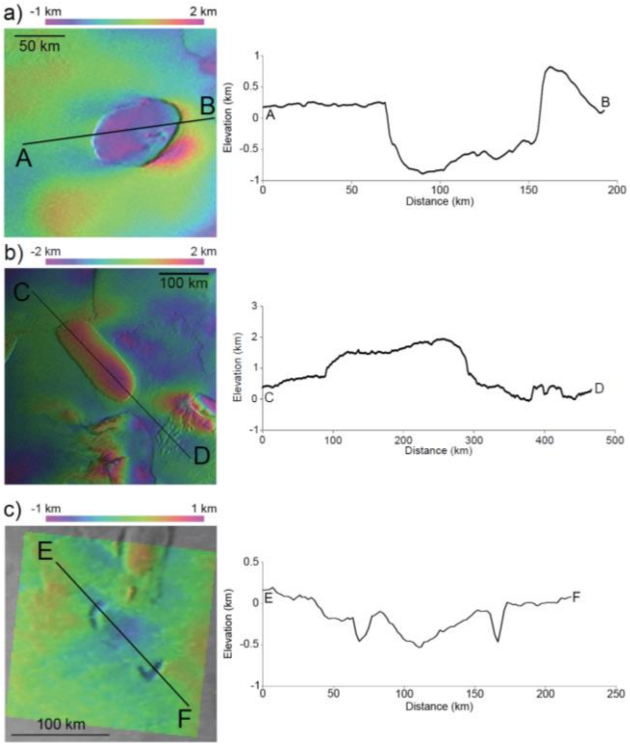

Fig. 2. Three PC DTMs showing (a) Hiruko Patera at 64.7°S, 328.3°W, (b) Echo Mensa, an outcrop of layered plains at 79.9°S, 354.5°W, (c) troughs possibly representing patera collapse initiation at 9.7°N, 125.5°W. DTMs with overlain profile groundtracks are shown at left, topographic profiles at right.

Implications for Io's near-surface: There are several instances across Io where paterae appear to be associated with layered plains, e.g. the cluster of paterae including Thomagata, Reshef, Chaac, Balder, and Michabo that appear to be surrounded by layered plains units. The combined observations of coincidence of paterae with layered plains, and a mean thickness for the layered plains units that is very similar to the mean depth we have obtained for paterae (~1 km), lend weight to the notion that patera depths and layered plains heights may indicate the thickness of a volatile-rich surface layer (or layers) extending across Io [10,11]. A hypothesis has been proposed to explain patera formation on Io whereby heat from silicate intrusions locally removes a volatile-rich surface layer and promotes collapse, essentially categorizing paterae as exhumed sills [12]. We envisage a scenario whereby a surface layer comprising a heterogeneous silicate-volatile mixture of thickness ranging between several hundred meters to a few kilometers overlies a low density crust. Intrusion of magma into the base of this surface layer would remobilize volatiles within it, destabilizing the layer sufficiently to promote collapse and form a patera, the depth of which is expected to be comparable to the thickness of the surface layer at that location. Based on numerous observations of clusters of curved troughs that together appear to define the rim of a future patera, initiation of such collapse may preferentially occur at what will become the patera rim (Fig. 2c). In addition, sapping of the volatile element in the same surface layer [13,14] would result in its erosion (in combination with gravity-driven slumping and other mass-wasting processes), forming the bounding scarps that define the edges of the layered plains units.

For further analysis of these results the reader is directed to another poster in this session [15], which addresses related topics including the energy necessary to heat and melt the volatile element contained within the patera volumes, as well as the volume of silicate magma needed to mobilize the volatile materials.

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