HYPOTHETICAL HYPERION. A. D. Howard[1], J. M. Moore[2] and P. M. Schenk[3], [1]Department of Environmental Sciences, University of Virginia, P.O. Box 400123, Charlottesville, VA 22904-4123 (ah6p@virginia.edu), [2]NASA Ames Research Center, M.S. 245-3, Moffett Field, CA 94035 (jeff.moore@nasa.gov), [3]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058 (schenk@lpi.usra.edu).

Introduction: Hyperion is a unique Saturnian satellite in several respects. Its landscape of sharp-edged, shoulder-to-shoulder concave craters has been likened to that of a sponge [*1*] (Fig. 1). It is relatively small (270 km mean diameter), highly irregular in shape with an old prominent basin (121 km diameter) occupying one side, and it has an eccentric orbit with chaotic rotation [*2*-*8*]. Its density is about half that of ice, indicating a high porosity. Here we interpret the surface morphology of the satellite through simulations using a landform evolution model, MSLM [*9*-*11*].

Surface Morphology: The highest resolution images of Hyperion taken by the *Cassini* orbiter are of the region dominated by the big 121-km impact basin. The interior walls of the basin are steep, with the upper slopes featuring a crenulated surface suggestive of mass-wasting erosion of cohesive bedrock. The lower slopes are smooth and appear to be angle-of-repose accumulations of debris released from the superjacent steep slopes. This ancient impact basin is densely covered with craters, most of which are strongly degraded as well. Most of Hyperion's craters feature a smooth, strongly concave basin floor. A few craters feature hummocky floor deposits that may be landslide debris derived from the crater walls, possibly occurring immediately after their formative impact (Fig. 4). Many of the older craters superimposed on or exterior to the big basin appear to be strongly degraded, with smooth, concave interiors and sharply rounded rims. These degraded craters often share exterior walls with adjacent degraded craters, giving an irregular honeycomb appearance to the landscape (Fig. 1). Some craters, however, exhibit morphology of steep, crenulated upper slopes and smoother, less steep lower slopes characterizing the interior walls (Figs. 1&4). Such craters appear to represent a population of relatively young impacts formed subsequent to extensive degradation of the big basin and most of its superimposed impacts.

Portions of Hyperion's surface are mantled with an irregular dark blanket probably derived from infalling particulate debris possibly derived from Phoebe or Titan. This blanketing is primarily but not exclusively concentrated in basin interiors (Fig. 1), but it appears to be a thin, recent mantle whose origin is unrelated to the mass wasting landforms investigated here.

Simulation Modeling: We hypothesize that the unique landforms of Hyperion have resulted from a combination of sublimation weathering and long-term mass wasting of craters with an initial topography differing from impacts on larger bodies because of loss of most of the cavity debris being ejected to space [*1*].

Cratering. We utilize the cratering portion of the MSLM landform evolution model [*9*-*12*] to create a saturated initial cratered surface. For preliminary simulations we utilize depth-diameter statistics for fresh Martian craters [*10*], but we modify the exterior crater morphology by retaining only 20% of the excavated interior bowl material as external ejecta deposits. In addition, we reduce the rim height relative to surrounding terrain by 2/3rds relative to Martian craters, inferring that most of the rim on larger planetary surfaces is due to ejecta deposition as opposed to rim uplift. We use a production function with a diameter-frequency slope of -2.

Weathering and Mass Wasting. We hypothesize that the degradation processes on Hyperion are sublimation weathering of refractory debris-laden icy bedrock coupled with non-linear mass wasting. We assume that the volatiles in the bedrock comprise intergranular cement, so that weathering is isovolumetric, producing an equal quantity of debris that is then mass wasted. If surface gradients are steeper than a limiting slope angle of 38° (common on the upper slopes of the simulated impacts) we assume that the strength of the bedrock is exceeded and the bedrock fails as small slips that contribute to the mass wasted debris on the lower slopes. When the slope angles are reduced below 38° the exposed bedrock slowly weathers, also contributing debris to the subjacent debris-covered slopes.

Material that has been loosened by weathering or bedrock failure is subject to non-linear creep using the relationship [*13*, *14*]:

$$q_m = KS \Big/ \left[1 - \left(S/S_c\right)^2\right] \qquad (1)$$

Where qm is the flux rate, S is slope gradient, K is mass wasting diffusivity, and Sc is a critical maximum slope gradient (here assumed to be 22°). Mass wasting may be driven by seismic shaking resulting from impacts elsewhere on the surface or by micrometeorite impact gardening.

Simulation scenario. Because the surface of Hyperion appears to comprise a population of highly-degraded craters with a superimposed population of less-degraded craters we have undertaken a two-stage simulation. Our initial surface is a saturated cratered surface. The first stage of modification comprises a long period of bedrock weathering and mass wasting that is continued to the point that no bedrock is exposed and the entire surface is covered with loose debris that has been reworked into a smooth surface consisting of concave basin floors and slightly rounded crater rims (Fig. 2). Note that weathering and backwasting have caused interior crater walls to retreat to the point that adjacent crater walls merge into thin septa.

The second stage of modification consists of superimposing a non-saturated population of new impacts followed by weathering and mass wasting that do not entirely eliminate bedrock exposures on the upper interior crater rims (Fig. 3).

Discussion: The resemblance of the composite simulation to Hyperion's surface is striking (compare Fig. 3 with Figs. 1&4). This result is consistent with our initial hypothesis that sublimation weathering coupled with mass-wasting of the released particulates explains Hyperion's surface morphology. The critical components of the model that produces Hyperion's unique morphology is the non-retention on the surface of most of the impact bowl debris coupled with low crater rim heights compared to the surrounding terrain. An alternative scenario also fits the simulations. That is, that the bedrock is only weakly cohesive (if at all) and that the steep, crenulated upper slopes on fresh craters are at the static angle of repose whereas the steepest subjacent slopes do not exceed a considerably lower dynamic angle of repose. Recent laboratory simulations have indicated that the difference in surface inclination for dynamic versus static angles of repose can be quite large under low gravity situations [15].

In future work we will quantitatively compare relief and slopes in our simulations with DEM data derived from stereo images of Hyperion.

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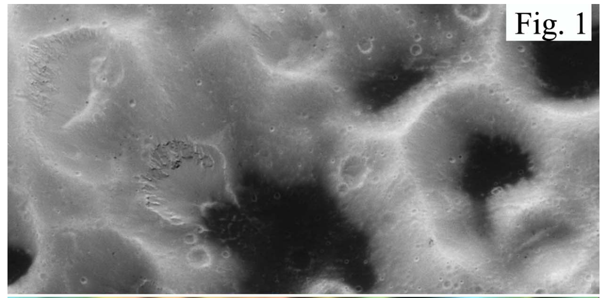

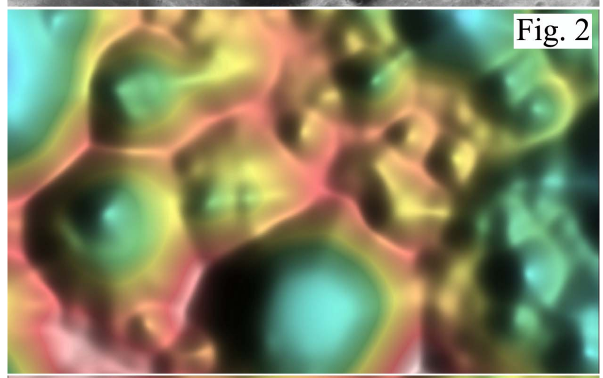

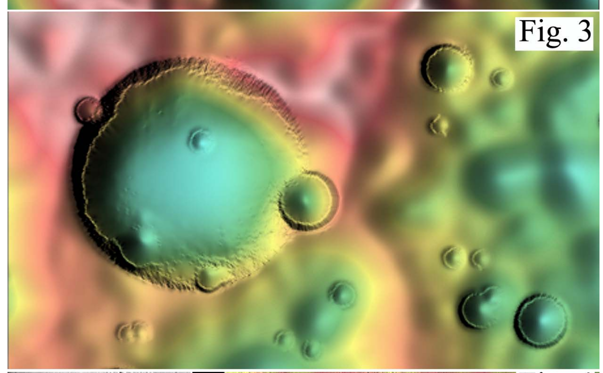

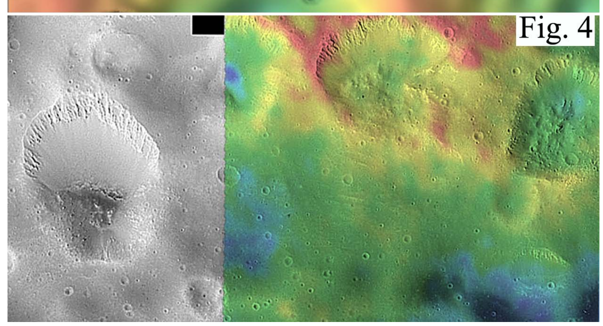

Fig. 1. Excerpt from NASA Planetary Photojournal image PIA07741, width 33 km. Fig. 2. Simulated degraded craters, simulated with 50 km. Total relief about 2.6 km. Fig. 3. Simulated degraded craters with superimposed slightly degraded craters, simulated width 45 km. Fig. 4. Excerpt from PIA07741, elevation cued from derived DEM where stereo coverage available. Image width 27 km.