BUTO FACULA, GANYMEDE: PALIMPSEST EXEMPLAR. J. M. Moore[1], O. L. White[1,2], P. M. Schenk[3], D. G. Korycansky[4], A. J. Dombard[5], and M. L. Caussi[5]. [1]NASA Ames Research Center, Moffett Field, CA, 94035 (jeff.moore@nasa.gov), [2]SETI Institute, Mountain View, CA, 94043, [3]Lunar and Planetary Institute, Houston, TX, 77058, [4]University of California, Santa Cruz, CA, 95064, [5]University of Illinois at Chicago, Chicago, IL, 60607.

Introduction: The Galilean satellites with icy surfaces (Europa, Ganymede, Callisto) are host, among other things, to a variety of large impact features that are, if not unique to these bodies, rarely encountered on planetary and satellite surfaces in the Solar System. These features include impact basins with central pits, domed floors, and so-called "pene-palimpsests" and "palimpsests" [1]. The authors have conducted a multi-disciplinary approach to study how these features formed [2]. It is likely that the particular combination of geophysical factors and impactor characteristics that is shared by these satellites is responsible for these features. One component of this study has been to derive the topography of a number of these features, and then use these Digital Terrain Models (DTM) as a fundamental tool in producing facies maps of a range of these features for which adequate data exist. Here we present the analysis of Buto Facula, Ganymede.

Observations: Buto Facula (13.2°N°, 203.5°W), classified as a palimpsest [1], displays a roughly circular expanse of undulating plains ~240 km in diameter, within which rise concentric arcuate ridges of eroded hills (Figs. 1 & 2). The concentric ridges of Buto (pink in Fig. 1) form a noticeably squared-off planform that appears to align with a pre-existing northeast-southwest-oriented structural fabric that characterizes this region. The undulating plains unit (UP, cyan in Fig. 1), which makes up most of Buto's surface, embays the concentric arcuate ridges so we infer that these ridges are blocks of the upper crust that were promptly inwardly rotated by slumping during and immediately following the impact event.

At the center of Buto is a smooth plain (green in Fig. 1) enclosed by a low, inward-facing scarp. This plains material superposes the surrounding plains of unit UP, and is littered with small blocks reminiscent of "small chaos" on Europa. This morphology is strikingly different to the central morphologies of smaller impact features on Ganymede and Callisto, which are dominated by light toned domes rising from often deep central pits. Conversely the morphology of a scarp-enclosed smooth central plain surrounded by a large annulus of UP is observed for all other palimpsests on Ganymede that we have mapped.

Buto does not display an elevated rim at all: the boundary of the UP is indicated by a transition to exterior terrain of higher relief and a generally lower albedo. The UP unit encroaches onto the cratered pre-impact landscape.

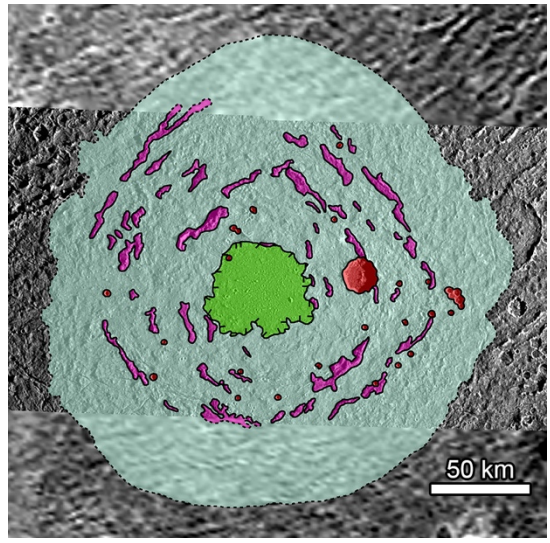

Figure 1. Facies map of Buto Facula superposed on a Galileo SS1 base. Cyan unit is undulating plains (UP); green unit is smooth plains; pink unit is concentric, arcuate ridges; red unit is subsequent impact craters.

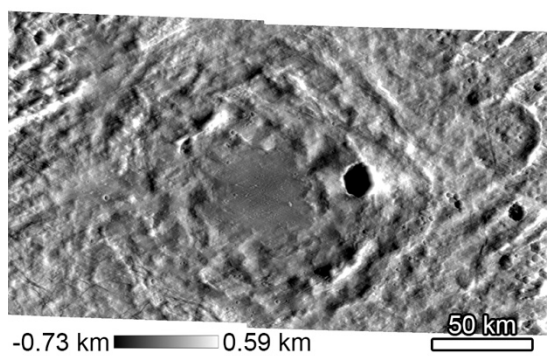

Figure 2. DTM of Buto Facula generated from photoclinometry applied to Galileo SSI images of Buto taken under optimal lighting conditions for this technique [3].

Thickness of the Undulating Plains Unit: We are able to derive a good estimate of the thickness of the UP unit by the fortuitous existence of a large (average radius of 19.1 km), well defined, pre-existing impact crater of which roughly the western half was encroached by the UP (Fig. 3). We took 12 radial profiles across the encroached crater (in which the blue profiles are the six radial profiles taken across the crater's unmantled eastern half, and the red profiles are the six radial profiles taken across the mantled western half. In our profile plot (Fig. 4) the thick blue profile is

the averaged unmantled profile, and the thick red profile is the averaged mantled profile. The rim crest is much lower in the mantled portion than the well-preserved portion (by about 220 m), but the most informative difference in terms of how much UP material from the palimpsest is covering the crater is the portion of the mantled part of the crater interior (indicated by the green outline in Fig. 3 and dashed lines in Fig. 4), which is much shallower compared to the unmantled side. We integrated between the averaged mantled and exposed profiles between 10.8 km and 17.5 km to obtain a total volume of deposited material within the green outline of 27.7 km^3, spread over an area of 288 km^2, which equates to a mean thickness of 96 m. Importantly, the profiles indicate that UP material is not spread equally across the underlying crater, as would occur for uniform accretion, but rather it concentrates in the annular depression that forms the outer portion of the crater floor. There may be little to no material covering some segments of the subdued western crater rim. As such, 96 m would represent a maximum thickness at this distance from the palimpsest center, although it would be expected to increase towards the center. The mapped area of Buto (excepting the central plains and concentric hills) is 38,040 km^2, equating to a volume of material for unit UP of ~3650 km^3 assuming a constant thickness of 96 m.

Discussion and Conclusions: The surface morphology of the UP exhibits characteristics that indicate the material composing this unit behaved similar to a Bingham viscoplastic at the time of emplacement, which we interpret to result from a substantial component of fluid or "slush," in agreement with several other studies [e.g., 4,5]. The very large volume of UP material substantially exceeds the amount of target material that could have been both melted *and* excavated by the impact event itself [e.g., 6]. Therefore, we conclude that the UP material was derived from a fluid or "slushy" layer in the near-surface target at the time of impact. The recognition of UP as the dominant unit in Memphis and Nidaba, the other palimpsests we have mapped (which display highly variable crater counts, with Buto being the least cratered) leads us to a working hypothesis that these features only form where and when the target has substantial near surface fluid or "slush." By extension, all other impact features on Ganymede and Callisto, such as those with central pits and central domes formed in targets with no or, at most, inconsequential amounts of fluid or "slush." Supporting this conclusion, modeling by members of our group [7] indicate that the present topography of impact features with central pits and domes can been largely explained by the behavior of ice. Our study supports explanations for the formation and final appearance of palimpsests (and some features sometimes referred to as pene-palimpsests) that are entirely applicable to this feature class, and sharply distinct from explanations for other impact features on Ganymede and Callisto.

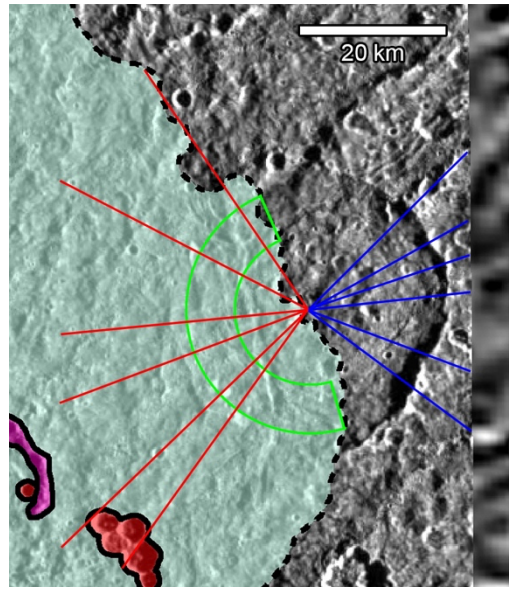

Figure 3. Portion of Buto UP unit partially mantling a preexisting crater which permitted a derivation of UP thickness from profiles across the DTM (shown below).

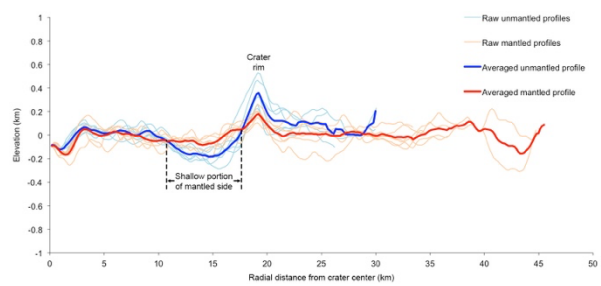

Figure 4. Topographic profiles taken across partially mantled crater in Fig. 3 from which we infer that the unit UP is ~100 m thick in this locality.

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References: [1] Passey Q. R. and Shoemaker E. M. (1982) in *Satellites of Jupiter*, U. AZ Press, 379–434. [2] Moore, J. M. et al. (2017) *LPS XLVIII,* abstract 2535. [3] Schenk, P. M. et al. (2004) *Icarus, 169*, 98-110. [4] Greeley, R. et al. (1982) in *Satellites of Jupiter*, U. AZ Press, 340–378. [5] Thomas P. J. and Squyres, S. W. (1990) *JGR, 95,* 19,161-74. [6] Korycansky, D. G. et al. (2022) *LPS LIII,* abstract 1310. [7] Caussi, M. L. et al. (2022) *LPS LIII,* ibid.