



Stratigraphic relationships of different terrain units on Ganymede and possible implications towards their evolution

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Introduction

The formation of Ganymede's light terrain and its possible interaction with a subsurface ocean, have made its investigation one of the top goals of the upcoming JUICE mission [1, 2]. In this study we present a detailed stratigraphic analysis of areas that were observed by the Galileo SSI camera at highest possible spatial resolution (scales of ~ 11 m/pxl) in order to see what information of the light terrain's stratigraphic position in Ganymede's surface evolution can be gained from mapping and crater counting results and to identify what still has to be done in order to prepare for the upcoming JUICE mission.

Study areas

Based on the available data set, we selected four major regions (Region A, B, C and D) that are covered by more than one high-resolution SSI image for our study (Fig. 1): Region A and D from the anti-Jovian hemisphere and Region B and C from sub-Jovian hemisphere. Region A comprises of Byblus Sulcus (G2GSGRVLNS01), Nippur and Philus Sulcus (G2GSNIPPUR01) and the Transitional region (G2GSTRANST01) with the context info provided by the SSI observation G8GSREGCON01. Region B is dominated by Arbela Sulcus (28GSARBELA01+02/ G7GSNICHOL01), Region C is the Harpagia Sulcus region (28GSBRTDRK02, 28GSCALDRA02 and 28GSSMOOTH02) and Region D comprises Erech Sulcus (G8GSERECH01), Mummu and Sippur Sulci (G8GSCALDRA01).

Mapping results

Geologic maps are prepared for the four regions using ArcGIS. The naming/categorization of geological units follows from [4, 5] but are refined and modified wherever necessary (Fig. 2). Among the light terrain units, ls and lg are the most commonly occurring than li.

Stratigraphic correlation:

On the whole, the relative ages from crater density measurements (Fig. 5) follow the mapping results. In brief, in Byblus Sulcus the two light terrain units are of similar age from crater counts while lg_3 is younger than lg_2 from crosscutting relationships. (Fig. 2). In case of Region B (Arbela Sulcus), we could find that the age relationship of the two light terrain units and two dark terrain units agree with the relative age inferred from crosscutting relationship (Fig. 3a) In more extensively resurfaced areas of the light terrain the situation appears to be more complex. In Region C, the terrain units ls also have comparatively higher age than lg terrain units (Fig. 3b-3d). In Region D the terrain units (Fig. 4) are highly interrupted by the secondary craters formed during the Osiris and Melkart impact events [6].

Discussion

We used two most favored chronology models LDM (Lunar Derived Model by [7]) and JCM (Jupiter Comets Model by [8]) (Fig.6). In general, based on the LDM ages the crater densities point to a relatively high age of the light terrain units not much younger than the ancient dark terrain and could imply a relatively short time period of formation for most of our mapped light terrain units. This relatively high age fits into the theory that the light terrain could have formed as a direct result of internal differentiation followed by a global expansion [9]. On the contrary, the JCM derived ages point to a longer formation period of light terrain units around 2 Ga [9]. While the impact chronology in the Jovian system and of its satellites is still not fully solved, newest results infer that the craters on these bodies were created from members of a collisionally evolved impactor family, similar to those in the inner solar system [10]. This does not straightforwardly support the lunar-derived chronology model (LDM) by [7] but allows to derive a Ganymede-specific crater production function empirically from the lunar one. We used this production function to fit our crater distributions and to derive absolute model ages for both model chronologies [7][8].

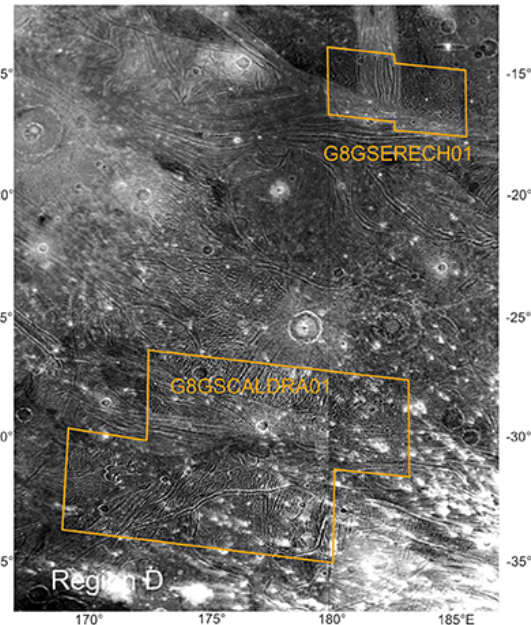
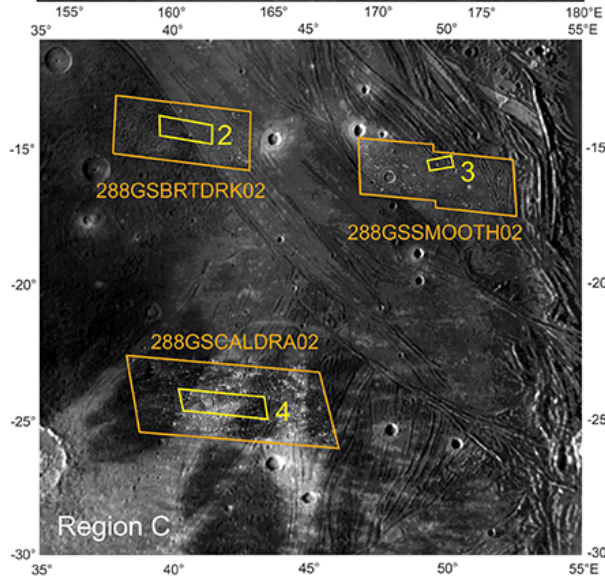
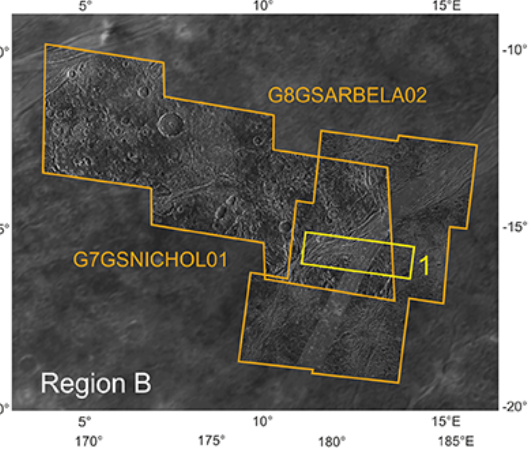
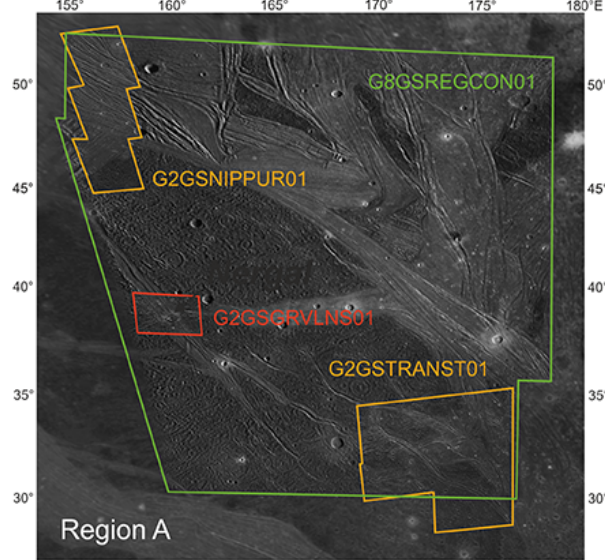
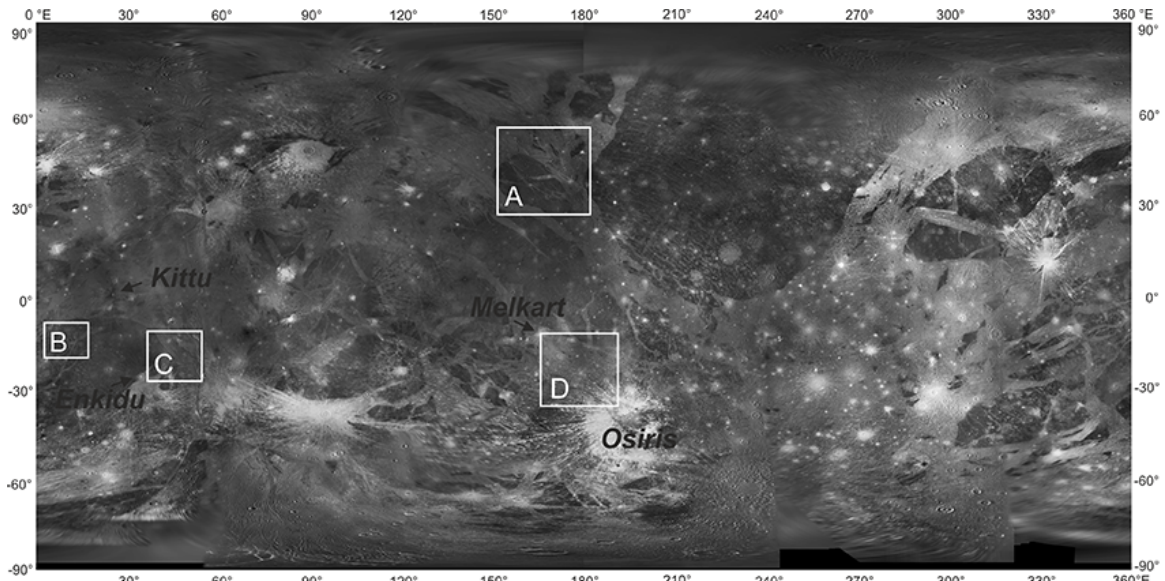


Image resolution:

600 - 1000 m/pixel 50 - 100 m/pixel 100 - 300 m/pixel 10 - 50 m/pixel

Figure 1: Regions of Interest in this study with the available Galileo SSI coverage indicated.

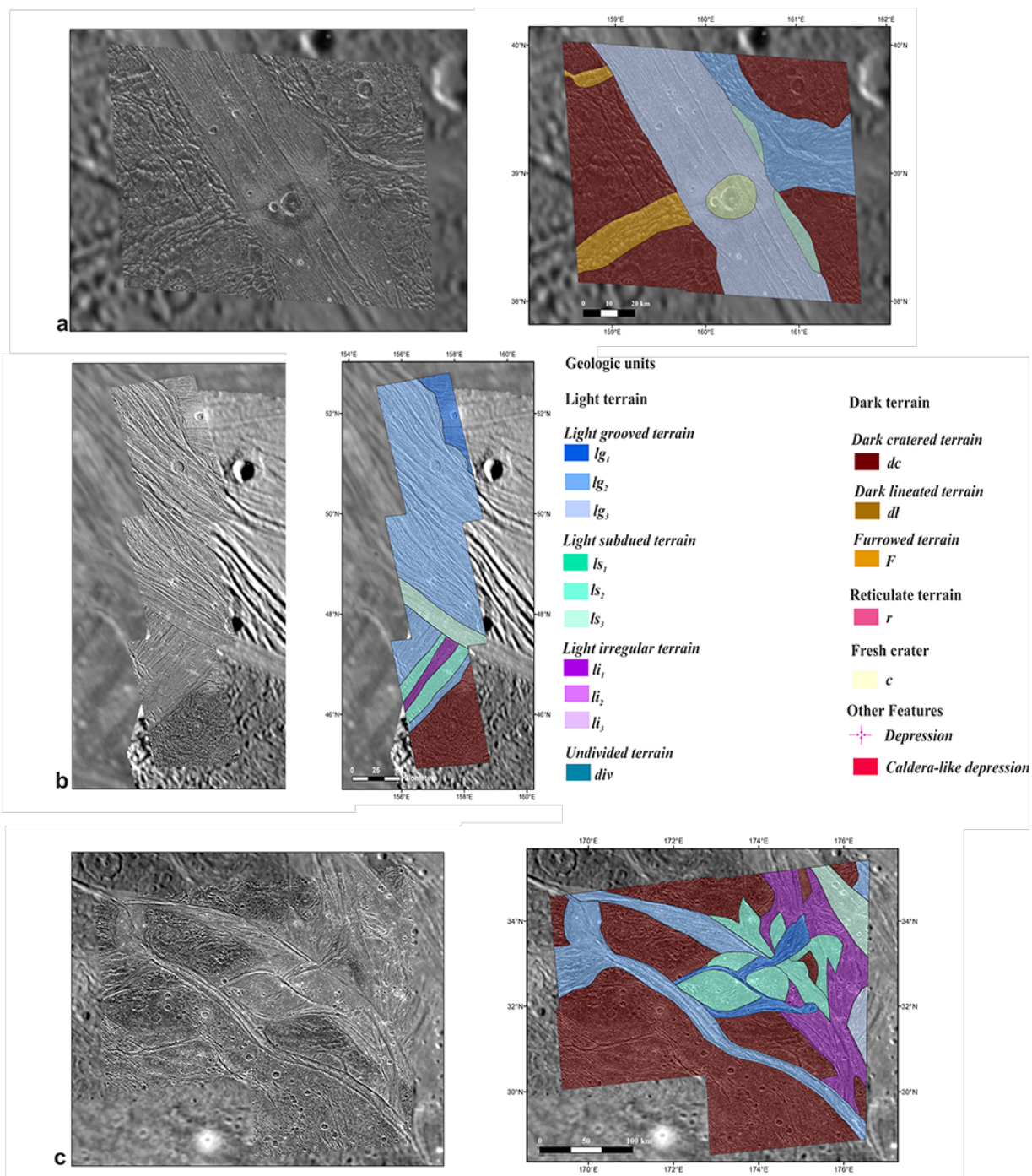


Figure 2: Geologic mapping results for Region A: a) Byblus Sulcus (G2GSGRVLNS01), b) Nippur and Philus Sulcus (G2GSNIPPUR01) and c) the Transitional region (G2TRANST01). The legend applies also to Figures 3 and 4.

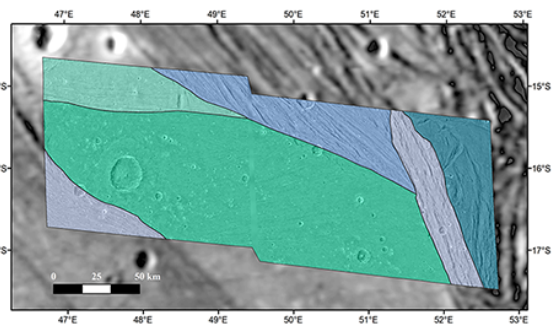
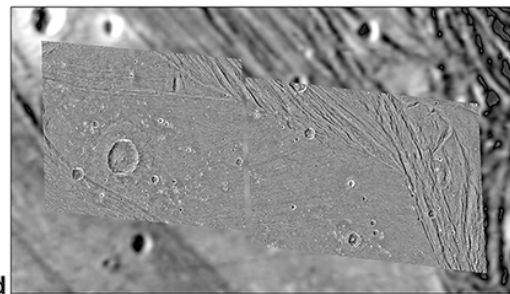
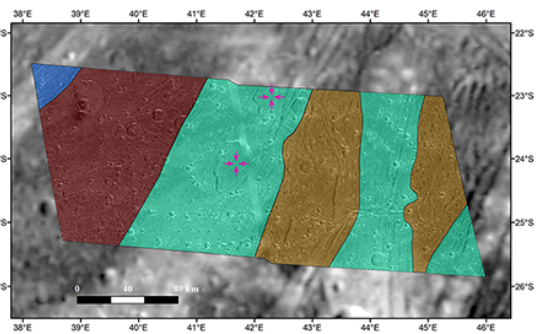
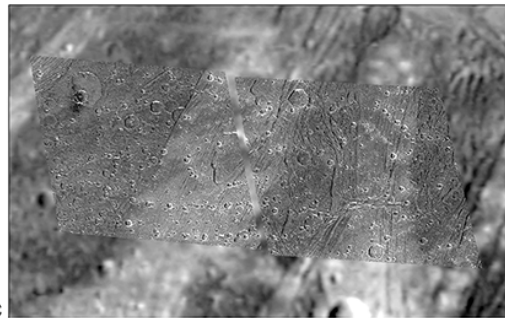
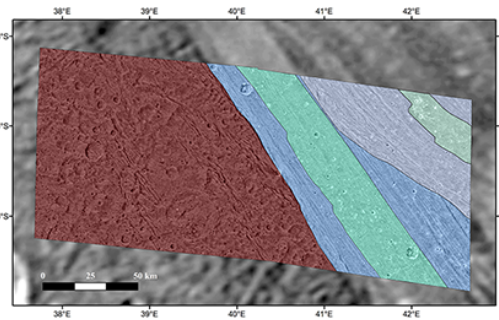
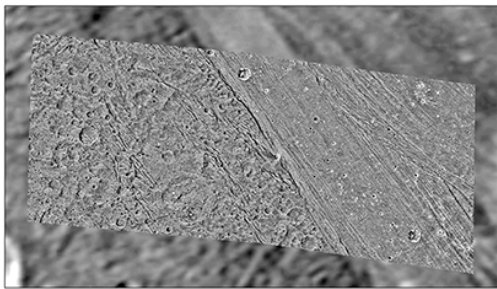
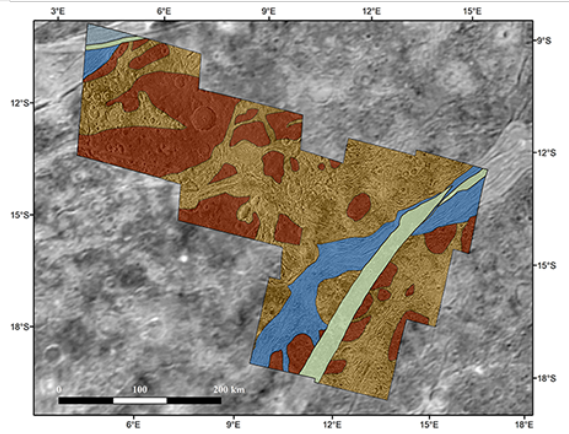
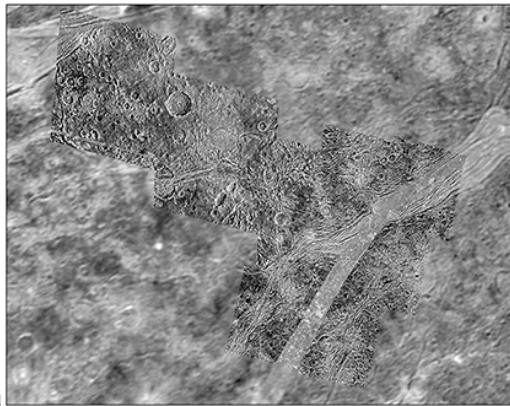


Figure 3: Geologic mapping results for Region B dominated by Arbela Sulcus (28GSARBELA01+02/ G7GSNICHOL01) and Region C by Harpagia Sulcus (b) 28GSBRTDRK02, c) 28GSALDRA02 and d) 28GSSMOOTH02).

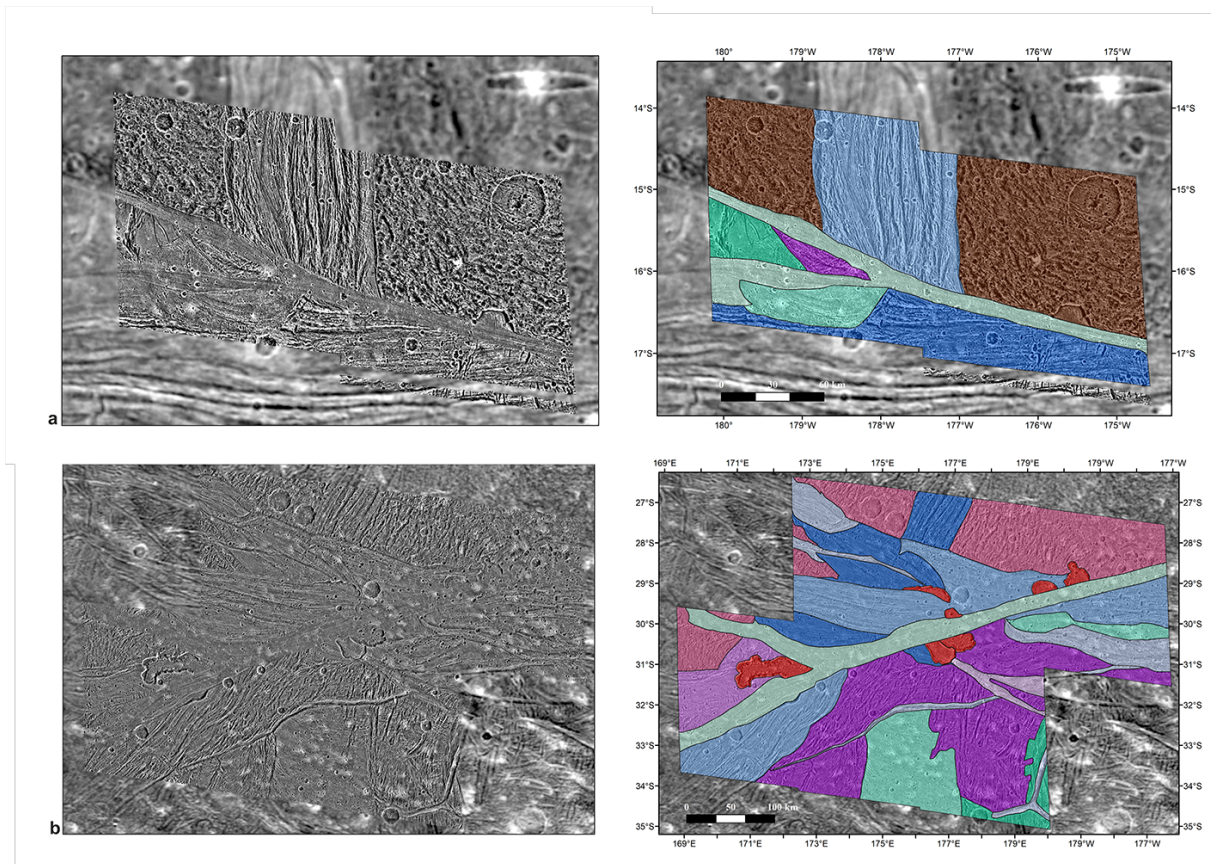


Figure 4: Geologic mapping results for Region D comprises of a) Erech (G8GSERECH01) and b) Mummu and Sippar Sulci (G8GSALDRA01).

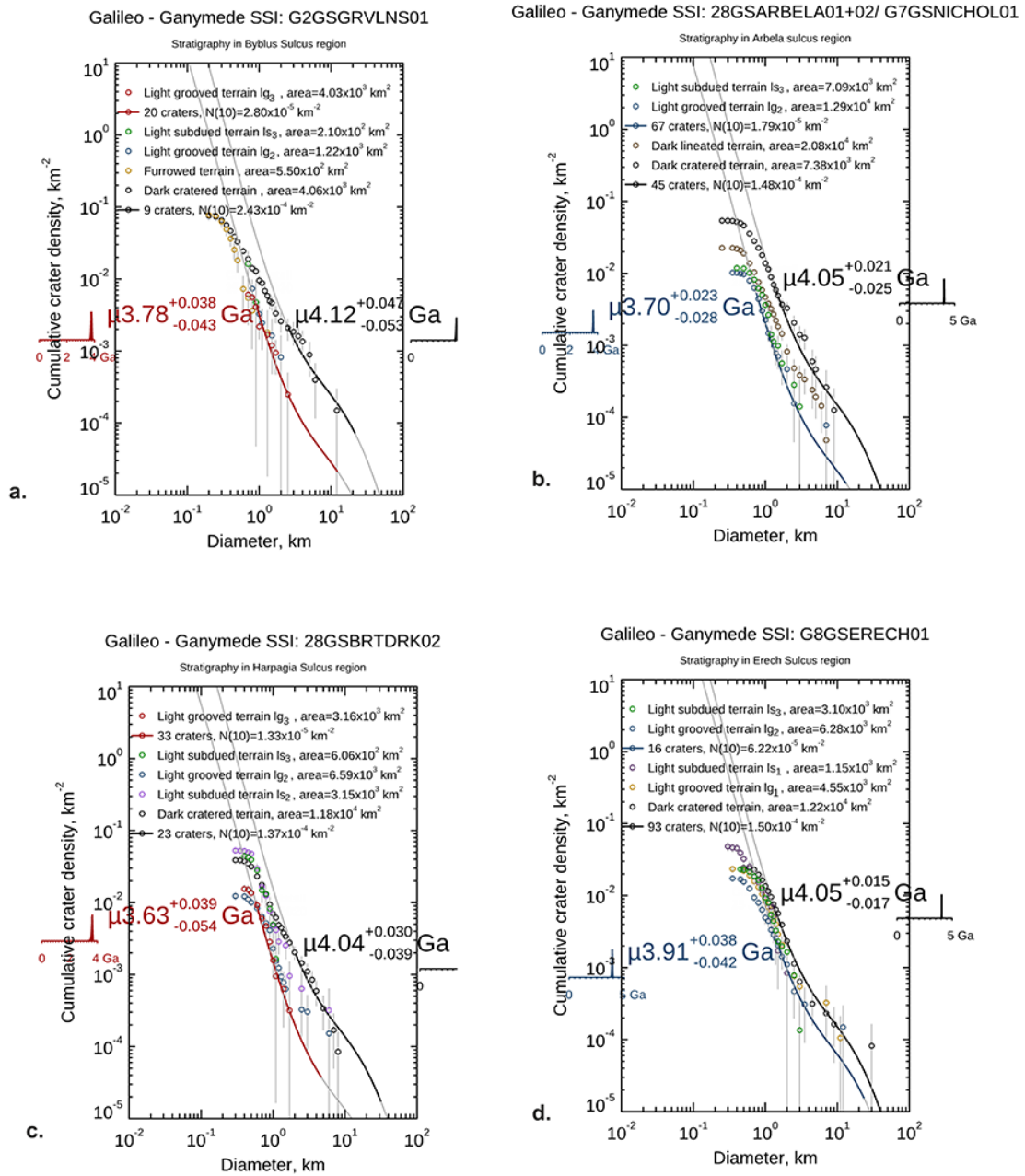


Figure 5: Comparison of relative ages of different terrain units from a) Region A (Byblus Sulcus), b) Region B (Arbela Sulcus), c) Region C (Harpagia Sulcus - 28GSBRTDRK02) and d) Region D (Erech Sulcus) based on crater size frequency distributions.

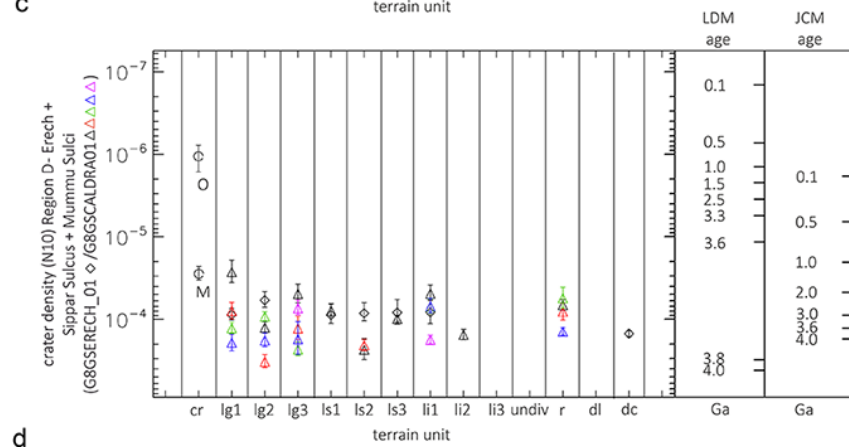
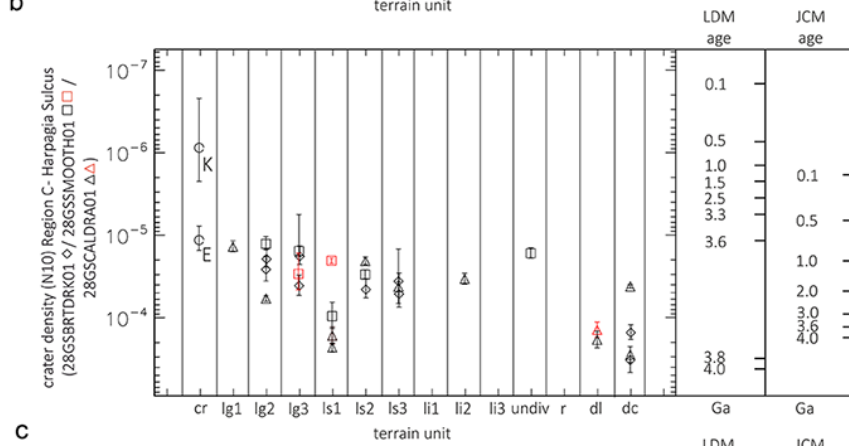
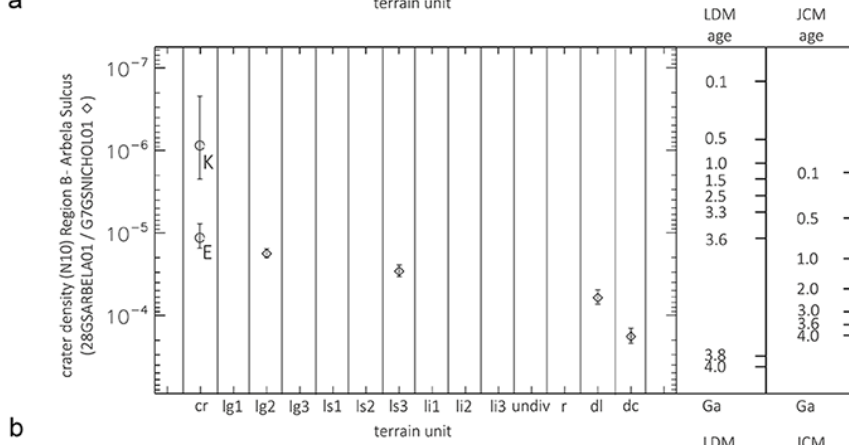
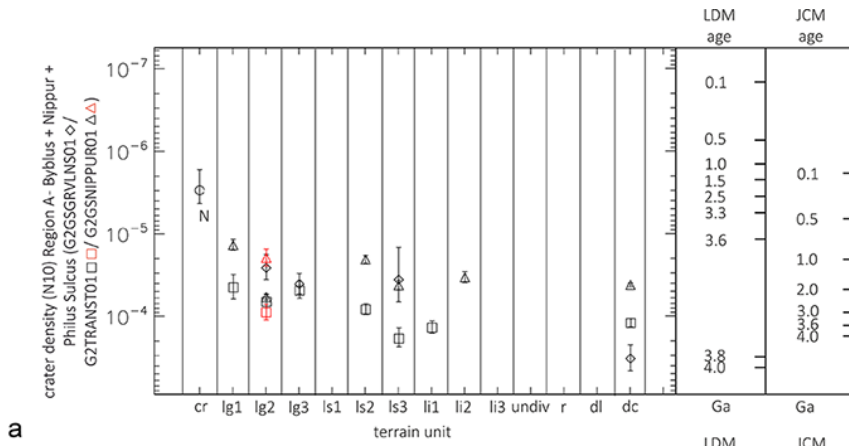


Figure 6: Stratigraphic correlation of Region a) A, b) B, c) C and d) D in which relative ages are determined by plotting the N(10) values with respect to each terrain units and corresponding ages based on LDM [7] and JCM [8]models. Please note that ages of fresh impact craters such as Nergal (N), Kittu (K), Enkidu (E), Melkart (M) and Osiris (O) have been added as additional stratigraphic markers. Since terrain types often appear more than one time in a geologic map the different facies are indicated by different colors.

References:

[1] Grasset, O., et al.: Planetary and Space Science, 78, 1-21, 2013. **[2]** Stephan, K., et al.: Planetary and space science, 208, 105324, 2021. **[3]** Pappalardo, R. T., et al.: Jupiter: The Planet, Satellites and Magnetosphere, 363-396, 2004. **[4]** Collins, G.C., et al.: Global geologic map of Ganymede (p. 3237), US Geological Survey, 2013. **[5]** Patterson, G. W. et al.: Icarus, 207, 845-867, 2010. **[6]** Baby, N. R., et al.: LPI Contributions, 2678, abstr. #1350, 2022. **[7]** Neukum, G., et al.: LPSC XXIX, abstr. #1742, 1998. **[8]** Zahnle, K., et al.: Icarus 163, 263-289, 2003. **[9]** Bland, M. T. et al. : Icarus 200, 207- 221, 2009. **[10]** Bottke et al.: LPSC, #2638, 2022.