EROSIONAL PROCESSES ON CALLISTO: GALILEO SSI RESULTS, OPEN QUESTIONS, AND REQUIREMENTS FOR NEW CAMERA DATA. R. J. Wagner[1] and G. Neukum[2], [1]Inst. of Planetary Research, German Aerospace Center (DLR), Rutherfordstrasse 2, D-12489 Berlin, Germany, e-mail: roland.wagner@dlr.de; [2]Inst. of Geosciences, Freie Universitaet Berlin (FUB), D-12249 Berlin, Germany.

Introduction: The second-largest satellite of Jupiter, Callisto, is characterized by a unique surface geology almost entirely dominated by impact and erosional processes [1, 2]. This puts Callisto in strong contrast to the Jovian satellite Ganymede whose surface was shaped not only by impacts, but also by tectonic forces [3, and ref's therein]. One common feature of these two largest Galilean satellites is the similarity in impact crater forms [1][4] which implies a similar subsurface structure of their outer icy crusts [1][3][4]. At high-resolution, Callisto's surface is characterized by landforms inferring erosion and degradation. These landforms are bright massifs and knobs several tens of meters high, embayed by a smooth, dark, globally abundant blanket [1][2][5]. In this work, we (1) present the characteristics of these erosional and degradational landforms, (2) use measurements of crater distributions and cratering model ages to derive the erosional history of Callisto's surface, (3) discuss open questions and (4) suggest requirements for remote sensing data in an upcoming mission to Jupiter and its satellites.

Image data base: Between 1996 and 2003, Callisto was imaged by the Galileo SSI camera at various resolutions [6][7]. Global coverage for Callisto at resolutions of 1-2 km/pxl is more or less complete, combining imagery from both the Voyager and Galileo SSI cameras [1][7]. However, due to the technical problems of Galileo [7], only a small number of areas on Callisto's surface could be imaged at regional (100 – 500 m/pxl) and especially at high resolution (10 – 50 m/pxl) [1].

Procedure: We used regional- and high-resolution images of the Galileo SSI camera to identify and map landforms on Callisto indicative of erosion and degradation. Where possible, anaglyph images were created to support morphologic mapping. Unfortunately, stereo image coverage of Callisto by Galileo SSI was very limited. Second, crater size distributions were measured on mapped units, and relative ages extracted from cumulative frequencies at a given reference diameter (generally 1 km). Also, the shape of crater distributions could be used to constrain resurfacing processes. To derive absolute time-scales of surface processes, we used two cratering chronology models: one by Neukum et al. [8] with a lunar-like time dependence of the cratering rate, based on the preferential impact by asteroidal bodies, and the model by Zahnle et al. [9], based on a constant cratering rate preferentially by cometary bodies.

Brief summary of crater distributions on Callisto: It has been widely assumed that Callisto's heavily cratered surface is saturated with craters [e.g. 9]. Our measurements show, however, that this is not the case, except for some areas where crater distributions show the characteristic -2 slope in cumulative diagrams indicative of an equilibrium distribution, at least at smaller crater sizes [10][11][2]. Even the most densely cratered plains on Callisto show production distributions [11]. Also, we did not find evidence for any apex-antapex asymmetry of craters on Callisto [2]. Therefore, Callisto was impacted preferentially by projectiles in planetocentric orbits [12]. An alternative, but less likely explanation, is a non-synchronous rotation of Callisto.

Results: Erosion and degradation affected all high-standing landforms [1][2][13]. Such landforms comprise rims of impact craters, ridges and scarps involved with multi-ring basins, and palimpsests. Although tectonism was never as pervasive on Callisto as on Ganymede, Callisto has experienced early tectonic stress outside large impact structures [2, and ref's therein]. These stresses created zones of weaknesses along which the bright high-standing material degraded (***Fig. 1***). The source material is thought to consist of a mixture of ice/non-ice constituents [1]. The material evolved into massifs, hummocks, and knobs, or groups of massifs, most likely by processes of sublimation degradation and separation of highly volatile substances from less volatile material [1, and ref's therein]. These processes eventually formed a globally abundant layer of dark material [1]. Hummocks and massifs are surrounded by debris aprons. While the massifs degraded with time, dark material was accumulated in the aprons. Eventually, the massifs disappeared, and aprons of former massifs merged to create a uniform blanket of dark material that embayed the most resistent hummocks and massifs. Therefore, it is apparent that dark material formed *in situ*. While an exotic transportation process such as electrostatic levitation [e.g. 14] cannot be ruled out, it is actually not needed to explain the emplacement of the global blanket of dark material, despite its "mobile" appearance. At present time, the dominant geologic processes active on Callisto are (1) occasional impacts, (2) erosion and degradation, possibly at very slow rates, and (3)

continuous outgassing of CO_2, creating a tenuous atmosphere around Callisto [15]. In addition, the Jovian magnetosphere is constantly bombarding the trailing hemisphere of Callisto, there creating a very thin deposit of CO_2 on the surface [16].

Open questions: Several issues of Callisto's geologic properties and processes remain unsolved and should be addressed in future missions. (1) The thickness of the dark blanket and its spatial variability is not known. (2) The relative proportions of volatile abundances in the bright host materials and in the dark blanket are not known. (3) The time-scales of erosion and deposition of the dark blanket are not known also. Application of the two cratering chronologies yields large differences in model ages. In the lunar-like asteroidal chronology model [8], the dark blanket has an average model age of 3.5 Gyr while in the cometary constant-cratering rate model [9] ages of this unit are on the order of only 500 Myr. (4) The thermal inertia of the surface materials on Callisto is not known. Measuring the thermal inertia could constrain erosional and degradational rates and help to constrain time-scales for processes of erosion and degradation.

Requirements for future missions: Global image coverage of Callisto should be completed in a future mission, especially at resolutions 100 – 300 m/pxl. Also, high-resolution coverage at resolutions of about 10 m/pxl should be carried out over a much larger surface area, including observations at resolutions less than 10 m/pxl in closest encounters. To provide enough image context, it is mandatory to implement a narrow angle as well as a wide angle camera. Also, color filters should range from the ultraviolet to the near-infrared to account for hemispherical asymmetries in the global color distribution, also of local color and compositional differences.

References: [1] Moore J. M. et al., in: *Jupiter* (eds. F. Bagenal et al.), p. 397- 426, Cambridge Univ. Press, Cambridge/UK, 2004. [2] Wagner, R. J., *PhD Dissertation* (in german), Free Univ. Berlin, Germany, http://www.diss.fu-berlin.de/2007/806. [3] Pappalardo R. T. et al., in: *Jupiter* (eds. F. Bagenal et al.), p. 363-396, Cambridge Univ. Press, Cambridge/UK, 2004. [4] Schenk P. M. et al., in: *Jupiter* (eds. F. Bagenal et al.), p. 427 - 456, Cambridge Univ. Press, Cambridge/UK, 2004. [5] Basilevsky A. T., *LPSC XXXIII*, abstr. No. 1014, 2002. [6] Belton M. J. S. et al., *Space Sci. Rev. 60*, 413 – 455, 1992. [7] Carr M. H. et al., *J. Geophys. Res. 100*, 18,935 – 18,956, 1995. [8] Neukum G. et al., *LPSC XXIX*, abstr. No. 1742, 1998. [9] Zahnle K. et al., *Icarus 136*, 202 – 222, 1998. [10] Neukum G. and H. Dietzel, *Earth Planet. Sci. Lett. 12*, 59 – 66, 1971. [11] Wagner R. et al., *1st International Conference on Impact Cratering in the Solar System*, ESA/ESTEC, Noordwijk, NL, abstr. book 235, 2006. [12] Horedt G. P. and G. Neukum, *J. Geophys. Res. 89*, 10,405 – 10,410, 1984. [13] Wagner R. et al., *LPSC XXXII*, abstr. No. 1838, 2001. [14] Klemaszewski J. et al., *Ann. Geophys. 16* (suppl. III), C992, 1998. [15] Carlson R. W., *Science 283*, 820 – 821, 1999. [16] Hibbitts C. A. et al., *J. Geophys. Res. 105*, 22,541 – 22,557, 2000.

CALLISTO: 10CSSMTHPL01+02 anaglyph image

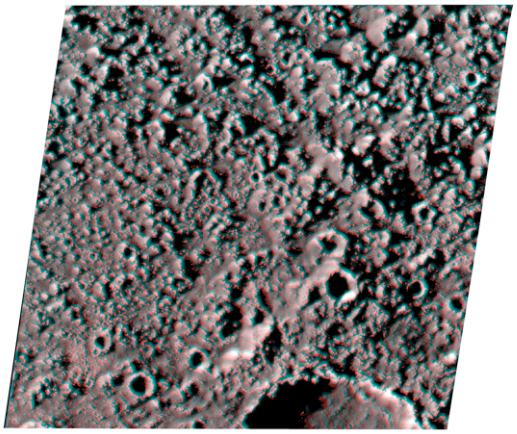

Figure 1: Anaglyph image created with Galileo SSI data from orbit C10, observations 10CSSMTHPL01 (68 m/pxl) and 10CSSMTHPL02 (270 m/pxl). The images cover an old, now heavily degraded palimpsest [2][4][13].