GEOLOGICAL EVIDENCE FOR AN OCEAN ON CALLISTO. J. E. Klemaszewski[1,2] and R. Greeley[2], [1]Arizona Science Center, 600 E. Washington St., Phoenix, AZ 85004; klem@azscience.org, [2]Arizona State University, Dept. of Geological Sciences, Tempe, AZ 85287-1404.

Introduction: One of the unexpected results from the Galileo Mission is the detection of an induced magnetic field at Callisto. The presence of this field is interpreted to be due to the presence of a sub-surface salty ocean up to about one hundred kilometers below the surface [1,2]. Unlike Europa, however, clear, unambiguous evidence of geologic features indicative of the presence of an ocean have not been readily apparent [3,4]. In this paper we present observations we believe are the best geologic evidence to date that are consistent with the presence of a subsurface ocean at the time these features formed.

Background: The record of Callisto's geologic history as expressed on the surface is dominated by two processes: impact cratering and gradation. Features associated with surface degradation and mass wasting are common in Galileo Solid State Imaging (SSI) high-resolution images of Callisto. These features are interpreted to be the result of *in situ* erosion of surface material due to the sublimation of volatile compounds, leaving behind a disaggregated lag deposit. This dark, ice-poor deposit which mantles much of the surface appears to be somewhat mobile, although detailed understanding of the precise mechanism(s) has not been developed. Surface erosion is speculated to be responsible for the paucity of small (<10 km diameter) craters observed in most SSI images. In all images the degradation of larger (10 to ~60 km diameter) craters is apparent, resulting in highly eroded to absent ejecta blankets and crater rims, polygonal crater outlines, and mass wasting deposits derived from crater walls [3, 4, 5, others]. Multiring structures, such as Valhalla and Asgard, are the largest impact features, with diameters of ~4000 and 1640 km, respectively. Comparison of Callisto's multiring structures (including the older and more degraded Adlinda) has allowed for an improved understanding of how these features evolve (i.e., degrade) with time, and the detection of highly degraded, previously unknown multiring structures in Callisto's cratered plains [6]. Based on this work, we looked in detail at Callisto's youngest and largest multiring structures, which, because of their size and relative fresh appearance, were considered the best candidates for preserving geologic information regarding a putative subsurface ocean.

Data: : The multiring structure Asgard was imaged on two orbits, at 1.1 km/pixel under high-sun illumination, and also at 90 m/pixel under low-sun illumination. The low-resolution data were returned with an average compression ratio of about 6:1, while the high-resolution data were returned at about 3:1. Moderate-resolution (~400 m/pixel) data of Valhalla were obtained under intermediate lighting conditions and returned at an average compression ratio of 3:1. Images with higher compression ratios in general contain a greater number of 8x8 pixel "compression artifacts" which tend to obscure finer image details. For this reason, combined with a lack of understanding of multiring structure evolution, features consistent with a Callistoan ocean were overlooked in early SSI image analysis.

Observations: Asgard's prominent concentric rings and central plains unit are easily seen in even the most compressed SSI data. The central plains unit is seen to be brightened locally by a younger dome crater, Doh. The rings surrounding the central plains are seen to consist of high-albedo, inward-facing scarps. These scarps are located within the fault zones (rings), which separate the larger crustal blocks, and are interpreted to be made up of tilted fault blocks. The height of the inward-facing scarps decreases with distance from the central plains and transitions to rings composed of graben. The graben are generally concentric, but exhibit variations along trace, probably due to preexisting heterogeneities in near-surface material strength [7]. The rings have a relatively lower albedo compared to the surrounding plains and central plains unit, interpreted to be the result of down-slope movement and collection of the low-albedo non-ice material, and/or a higher concentration of non-ice material due to enhanced sublimation in the rings.

Close inspection and detailed geologicl mapping of structures in and around Asgard reveals the presence of numerous narrow, discontinuous, linear low-albedo features oriented radially to the Asgard's central plains unit (see Figure 1). These low-albedo features are similar in character to the narrow, discontinuous, arcuate low-albedo features that are concentric to the central plains units of Callisto's multiring structures. The presence of high-resolution data of Asgards central plains and rings, obtained under low-sun illumination, allows for a more robust interpretation. Correlation of the radial low-albedo features seen in low-resolution high-sun images with geologic features in high-resolution low-sun images shows they are in fact narrow fractures (see Figure 2). These fractures crosscut some craters, and are disrupted by others. Further analysis and mapping reveals the presence of similar

Figure 1: Geologic Map of Asgard and Utgard.

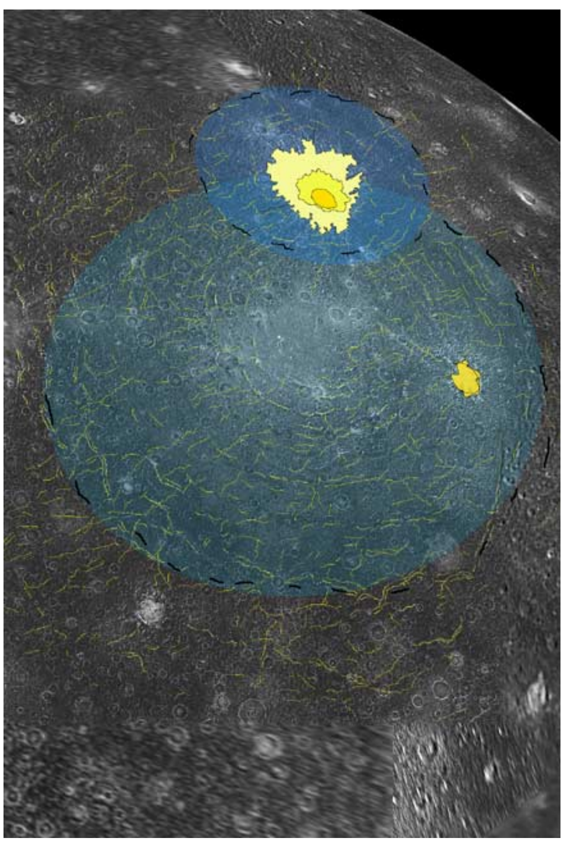

Figure 2: Radial low-albedo fractures.

features oriented radially to the smaller multiring structure to the north of Asgard (provisionally named Utgard), and at Valhalla as well. However, the features are difficult to detect in the moderate-resolution data of Valhalla because the sun illumination is parallel to the strike of the fractures in most locations (not to mention compression artifacts). They are most visible in the southernmost images where sun illumination is lowest and somewhat oblique to lineament strike directions.

Geologic Mapping: Low-albedo linear features are mapped as yellow lines. Although most of these features are interpreted to be troughs/fractures based on extrapolation from limited high-resolution data, this cannot be determined independently from low-resolution high-sun illumination data. Dashed black lines approximate, based on impact crater densities, the outer margins of the continuous ejecta units of Asgard and Utgard. Light blue and dark blue highlight the areal extent of Asgard and Utgard, respectively. Yellow units correspond to units of the younger, bright impact craters Tornasuk and Burr.

Discussion: Several models have been proposed for the formation of multiring structures on rocky and icy objects: Ring tectonic theory [8, 9], vocanic modification [10], megaterrace [11], and nested craters [12]. There are reviewed in general by Melosh [8] and specifically for Callisto (with refinement based on Galileo SSI data) by Klemaszewski and Greeley [7]. Based on modeling by McKinnon and Melosh [9], we interpret the concentric and radial fracture pattern of Asgard, Utgard, and Valhalla (and perhaps others) to reflect the presence of a fluid layer beneath a thin (relative to the scale of the impact) rigid crust.

Future work will consist of completion of mapping Callisto's known multiring structures, seeking to determine a lower size limit for craters that exhibit radial and/or concentric fracture patterns in order to constrain the thickness of the overlying crust at the time of the impact event(s).

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