THE TIMING OF VISCOUS RELAXATION ON GANYMEDE. P. Schenk, Lunar and Planetary Institute, Houston TX 77586 (schenk@lpi.usra.edu)

Introduction: With a return to the Jupiter system, and Europa and Ganymede in particular, under serious consideration, the geology and geophysics of these bodies are being scrutinized anew. One of the earliest revelations dating back to Voyager and even before [1, 2] was that the surface morphology of Ganymede records that satellite’s thermal history. This is manifest in the relaxation of (crater) topography, the study of which has evolved as our understanding of ice and relaxation physics [cf. 3, 4] has evolved slowly over the past three decades. In this report I look back on an issue that has been relatively neglected since the days of Voyager, the spatial distribution and sequence of crater relaxation, the timing and pattern of Ganymede’s heat flow, and the degree to which it correlates with the mappable geologic history of Ganymede.

Methods: Impact craters are the most suitable feature for mapping of relaxation on Ganymede (and Callisto) because of their relative abundance and their known (or assumed) shape prior to relaxation allows for meaning constraints. Mapping the distribution of relaxed features on Ganymede requires regional topographic mapping coverage at suitable resolutions. Stereo imaging is severely limited on Ganymede (mostly of the south pole), so we rely on photoclinometry (PC). PC has improved considerably since the early Voyager investigations, specifically though the use of more realistic photometric models (here the combined lunar-lambertian model [5, 6]). These data are also limited but several sites have been identified where we have sufficient areal coverage of both dark and bright terrain to obtain useful counts. The primary sites are at Enki Catena (500 m/pixel resolution, Tiamat Sulcus (500 m/pixel), Bubastis Sulcus (500 m/pixel) and Northern Marius Regio (950 m/pixel; Fig. 1). Additional sites within Perrine Regio and other areas are being investigated to determine if topographic data can be obtained.

Results: Although mapping coverage is severely limited, several curious features are apparent in the new topographic maps. Relaxed craters show the classic bowed crater floors as well as the sharp crater rim indicative of the partial preservation of short-wavelength features (Fig. 2). However, rather than the continuum of crater depths reported by Passey [2, using an antiquated photometric function], we find that craters tend to be more clearly separated into relaxed and unrelaxed shapes (Fig. 3). This is evident from the imaging and topographic maps (Fig. 1), where fresh craters clearly stand out from the background cratering. It is also apparent that craters as small as 7 km across can be relaxed. Unrelaxed craters follow the standard fresh crater d/D slope [6], but there is a defining limit to relaxation. Most of the identified relaxed craters have rim-floor relief of 250-400 meters, mostly a result of the preservation of the narrow rim scarp feature.

Figure 1: Regional image (top) and PC-derived topographic map (bottom) of Northern Marius Regio, Ganymede. Resolution of base G8 image is 950 m/pixel. The study site is roughly evenly divided between dark and bright terrains.
The regional distribution of relaxed and unrelaxed craters is very distinct. Visual inspection of Fig. 1 suggests that unrelaxed craters are equally distributed across both bright and dark terrains. Statistics for the 4 study sites (Fig. 4) confirm that the spatial density of unrelaxed craters is identical on both terrains despite the factor of 4 or more difference in the spatial density of all craters on the two terrain types.

**Discussion:** The uniform distribution of unrelaxed crater across all terrain types implies that all relaxation must have ceased after bright terrain was emplaced; otherwise more unrelaxed craters would have accumulated on older dark terrain than on younger bright terrain. This implies that elevated heat flows (>>10 mW/m²) occurred across all of Ganymede up to and through the period of bright terrain formation. Whether heat flow was persistently high throughout pre-bright-terrain epochs or only during a shorter elevated heat flow pulse in direct association with bright terrain formation is uncertain. It may not be possible to determine this from the cratering record alone, as a “short” global thermal outburst could have reset the topographic “clock” completely.

Did high heat flow decline rapidly and relaxation shut down as bright terrain formation ceased? Few relaxed craters are observed on bright terrain, suggesting that thermal decay rates were relatively rapid. The most glaring exception appears to be Bubastis Sulcus at the south pole, where several relaxed/modified craters are observed. A small number of modified post-bright-terrain large impact features are also observed globally [7], the most obvious being penelpalimpsests and pene-dome basins (e.g., Epigeus and Neith). These observations indicate that high heat flows persisted for a measurable time after bright terrain formed but not much longer (it may be possible to put a value on this time after a global survey of smaller craters on Ganymede). These data also indicate that all pre-bright terrain topographic features, including furrows, are relaxed from their original state.

The question of the thermal history on Callisto remains open. Galileo’s discovery of the erosionally desiccated state of Callisto’s surface renders topographic measurement of many craters meaningless in the context of relaxation. The observation of significant numbers of “wreath” craters and pene-dome craters [7] similar to those found on post-bright terrain Ganymede suggests that Callisto too may have had a period of elevated heat flow. Topographic mapping of both satellites is very limited, however, and global mapping will probably be required before crater distribution and ages, and hence the detailed thermal histories of these satellites can be fully ascertained.

**References:**