CALIBRATING THE CRATER PRODUCTION CURVE USING TOPOGRAPHIC RELAXATION AND HOW JIMO CAN HELP.

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Introduction: Crater relaxation studies generally possess 2 unknowns: time and thermal state. Standard practice has been to use this process as a thermal probe. That is, a crater's age is inferred by other means (usually crater counts), and relaxation is simulated in order to infer lithospheric thermal state [e.g., 1, 2]. Here, I propose the opposite: to assume thermal state in order to constrain crater age. By comparing these age assessments with those provided by crater counting statistics, I hope to provide an independent "ground-truth" of absolute age and thus calibrate the crater production curve in the outer solar system. Data returned by JIMO will be very valuable to this task.

Background: Schenk [3] measured depths and diameters of "fresh" (ostensibly unmodified) craters on Europa, Ganymede, and Callisto. The resultant depth-diameter curves each exhibited 3 distinct breaks in slope, the last of which (Transition III) was inferred to be due to a liquid water ocean at depths of ~19-25 km on Europa and ~80-105 km on Ganymede and Callisto. Sampling of post-Transition III (PT3) craters (i.e., craters with diameters larger than that of Transition III) is more complete on Ganymede, and these 5 data points display considerable scatter in their depths.

Ruiz [4] showed that the outer ice shell of Callisto, and by extension Ganymede, transfers heat conductively. Using the expected radionuclide budget, he determined a shell thickness of ~105 km, in agreement with Schenk [3]. Given water's freezing point as a function of pressure (i.e., depth), the shell's thermal state can be computed. (Tidal heat complicates the case of Europa.) I assume these PT3 craters were emplaced on this surface and began to relax under this thermal state. So, the calculated time of relaxation to an observed depth equals the crater's absolute age.

Method: I use an elastoviscoplastic finite element analysis to study impact crater relaxation. This application builds upon previous work [2] by simulating an inviscid fluid at the base of the mesh and by calculating thermal state as an input to the relaxation process.

As there are many unknown quantities, I can only place bounds on age. A primary unknown is initial crater depth. Undoubtedly, PT3 craters are shallower than pre-Transition III craters. The shallowest possible initial shape, as determined by depth-diameter relations [3], essentially incorporates all depths of the PT3 craters (within error). Thus, the lower bound on age is zero, and I can only place meaningful constraints on the upper bound. Hence, I hedge input parameters to minimize relaxation. These parameters include using the deepest initial and shallowest final shape, the stiffest rheology, and the coolest thermal state (e.g., thickest ice shell). Another consideration is whether topography is compensated at the shell's base. My simulations show that topography can be largely supported flexurally, so compensation does not appear warranted. Besides, an initial state of isostasy would bring the ice-water interface to shallower depths, thereby locally enhancing heat flow and speeding relaxation.

As a test, I have simulated relaxation of a crater on Ganymede 150 km in diameter, 1 km deep, and sitting on a water ice shell 100 km thick that overlies a pure water ocean. These simulations indicate that ~200 m of depth can be shed in only 10 Myr, even under minimal relaxation conditions. Thus, it appears that significant relaxation over a short time is unavoidable. Unless PT3 craters are very young, they have probably relaxed to some degree, and the scatter seen in the depths could be due to relaxation over different lengths of time (i.e., different ages). There are 2 important caveats, though. First, this age depends on surface temperature and hence latitude of the crater. In polar regions, low temperatures could "lock-in" the craters; however based on geometric arguments, most craters of a given size should not be found in polar regions, as about 71% of a planet's surface area is at latitudes < 45°. Second, suppression of the ocean's freezing point by dissolved salts or ammonia could decrease heat flow by a factor of ~2, thus increasing calculated ages by an order of magnitude. Still, 100 Myr to shed 200 m is a geologically short time period.

How JIMO May Help: Data returned by JIMO will be invaluable to this task. More complete surface imaging may reveal additional PT3 craters, and stereo- and laser-based altimetry will better constrain depths. Geophysical measurements (radar, gravity, magnetics) will provide information on ice shell thickness, including lateral variations, and shell and ocean composition. Surface science packages will provide information on shell composition and surface thermal properties. JIMO may not return a sample that can be dated, but perhaps with this analysis and the data returned by JIMO, we may be able to do the next best thing.

References: [1] Passey Q. R. and Shoemaker E. M. (1982) in *Satellites of Jupiter,* Univ. Ariz. Press, 379–434. [2] Dombard A. J. (2000) Ph.D. thesis, Washington Univ. [3] Schenk P. M. (2002) *Nature, 417,* 419–421. [4] Ruiz J. (2001) *Nature, 412,* 409–411.