FORMATION OF THE SPUTNIK PLANITIA BASIN: MOVING TOWARDS REFINED CONSTRAINTS ON OCEAN THICKNESS. C. A. Denton[1] and B. C. Johnson[1]. [1]Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, West Lafayette, IN, 47907, USA (denton15@purdue.edu).

Introduction: Sputnik Planitia (SP) is a 1200 x 2000 km elliptical basin on Pluto centered close to the Pluto-Charon tidal axis [1, 2]. Its massive size, location, and relationship to local tectonics suggest that SP is associated with a positive mass anomaly (mascon), which induced true polar wander [1, 3]. Recent impact modeling work has suggested that a mascon may develop in SP through uplift of a thick, salt-rich subsurface ocean in an impact-origin scenario, in conjunction with subsequent loading by dense N_2 ice at the surface [4]. Here, we further assess the presence and stability of Pluto's putative subsurface ocean, as it is a primary factor in mascon formation. We utilize impact simulations that introduced the full range of hypothesized thermal conditions for the ice shell [5], including the new potential for sustained colder temperatures [6], producing a suite of possible post-impact thermomechanical structures for the basin. We then compare our results to the more recently updated dimensions and depth of SP [2], as the shallower depth and larger basin size than previously utilized in [4] are more conducive to preserving positive mass and gravity anomalies.

Methods: Following [4], we use the iSALE shock physics code to simulate a 220-km impactor striking a Pluto-like target at 2 km/s [7], with the same model setup, resolution, and internal structure [8-10]. Following [1] and [5], we go beyond the single "hot" and "cold" structures tested in [4] to assess thermal gradients of 0.4-1.7 K/km for Pluto's ice shell. We then utilize the resulting basal temperatures to define appropriate ice thicknesses that permit stability of a thinned shell over geologic time. Colder simulations were incorporated into this stability range following the work of [6], which suggested that a liquid ocean could be sustained under a colder ice shell than previously anticipated if combined with an insulating clathrate layer. Within our defined stability range we test multiple preimpact ocean thicknesses (0, 50, 100, 150, and 200 km) to assess the relationship between preimpact ice shell thickness and target thermal structure in producing the final basin structure. The combined ice shell/ocean thickness is held constant at 328 km [4].

Preliminary Results: By expanding the analyses of [4] to incorporate a greater range of initial thermomechanical conditions for Pluto's ice shell, we can establish a range of postimpact basin states to be used in assessing the formation of a mascon within SP. From our full suite of results, we consider which resulting basin structures align with the updated depth and dimensions of the contemporary SP basin [2], as well as which combinations of preimpact ocean thicknesses and thermal gradients result in subsurface topography most consistent with formation of a positive mass anomaly at basin center.

As expected, basin structure is sensitive to the preimpact thermal structure of the target [e.g., 4, 8, 11]. For ocean thicknesses of 50 and 100 km, ice shell thinning occurs at basin center; however, as noted in [4], the strength of colder ice shells in many cases also produces a sustained central uplift near basin center, reducing thinning overall. Increased ice shell thinning is observed with thicker oceans (100 km and onward), while surface topography transitions from a central uplift to a consistent basin-like profile.

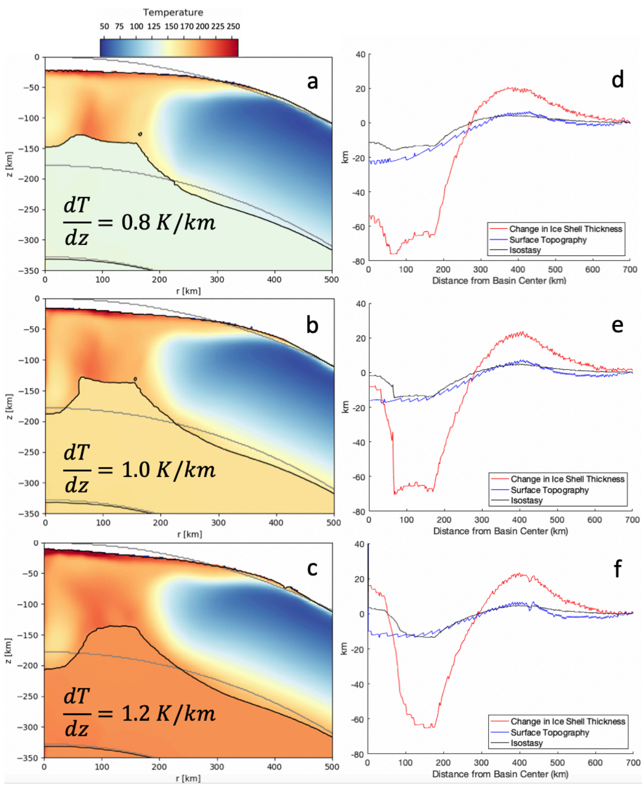

Figure 1a-c. Final thermal structures for an ocean thickness of 150 km and thermal gradients of 0.8, 1.0, and 1.2 K/km, respectively. Temperature range is 44-273 K. Black curves mark material interfaces (e.g., ice-shell-ocean), while gray curves mark the preimpact location of the same interfaces for comparison. **Fig. 1d-f.** Profiles of postimpact topography (blue), change in ice shell thickness (red), and expected topography assuming isostatic equilibrium (black) illustrate the compensation state of the basin for each of the corresponding thermomechanical initial conditions.

Within the thinner ice shell/thicker ocean cases, progressively warmer preimpact thermal structures (1.2-1.6 K/km) facilitate collapse flow during crater formation, reducing ice shell thinning in the postimpact structure. This trend is facilitated by general properties associated with thinner ice shells [4]; as ice shell thickness decreases, collapse becomes more dynamic – for a 150-km ocean, thickening rather than thinning of the ice shell occurs as warm, flowing ice accumulates near basin center (Fig. 1a-c). For a 200-km ocean, extensive thinning of the ice shell is accompanied by incorporation of ocean material into the ice shell during the collapse phase, while the surface basin remains shallower (~10 km in depth) relative to basins produced in thicker ice shells.

These ice shell thickness-dependent trends remain observable at each of the stable thermal gradient configurations tested; however, additional trends can be observed in association with thermal gradient variations. Increasing the thermal gradient for a given ice shell thickness yields more subtle changes in ice shell topography, particularly decreased basin depth and reduced ice shell thinning (Fig. 1). As Figure 1a indicates, the lowest tested thermal gradient for a 150-km ocean (0.8 K/km) produces the greatest amount of ice shell thinning (over 70 km) while also retaining a deeper basin at the surface. As the thermal gradient is increased, both ice shell thinning and basin topography are reduced; in assessing lowest vs. highest stable thermal gradients for a 150-km ocean the basin depth is decreased by over ~10 km at basin center, while ice shell thinning is also reduced by up to 20 km in some locations within the basin (Fig 1d-f). The zone of greatest thinning within the ice shell is also reduced laterally, such that thinning occurs at smaller radii from basin center.

To assess which of the simulated postimpact structures for SP are most consistent with the presence of a mascon, we compare postimpact basin topography with the expected basin topography assuming isostasy (Figs. 1d-f). From this comparison we find that for the 150-km ocean case, variations in thermal gradient and ocean thickness result a series of basins that are all nearly isostatic even at relatively low thermal gradients, despite significant variations in ice shell thinning between test cases. Increasing thermal gradient produces basin topography that is slightly closer to isostatic equilibrium (Figs 1d-f), but the magnitude of these differences are minimal relative to the much larger variations in basin profile and ice shell thinning. While in each case these basins exhibit significant uplift of the ice/ocean interface consistent with the presence of a positive mass anomaly produced from impact, the differences in postimpact compensation state of SP will likely result in different long-term pathways of evolution for the basin during viscous relaxation and loading. As such, while postimpact conditions may appear to facilitate mascon formation in scenarios incorporating ocean thicknesses greater than 100 km and a wide range of thermal gradients, further testing must consider the relative role of viscous relaxation of basin topography in diminishing the observed postimpact structure for the various thermal gradients.

Conclusions and Outstanding Questions: Initial analysis of impact simulations for formation of the SP basin indicates that variations in preimpact thermal gradient produce dramatic differences in resulting ice shell thickness and surface topography for the postimpact basin. As such, as we continue to refine ocean thickness estimates the thermal gradient of the ice shell must be considered a primary control on ocean survivability in addition to ocean thickness itself. We find that uplift of a subsurface ocean may occur at a range of potential thermal gradients, provided that the ocean thickness exceeds 100 km. In testing much lower ice shell thermal gradients than previously considered (~0.6-0.8 K/km), we find that colder preimpact thermal structures also produce substantial uplift of the ice-ocean interface; such a scenario could occur in association with an insulating clathrate layer to mitigate viscous relaxation above and ocean freezing below [6]. Future work will incorporate the final basin structures from these runs as the starting point for full finite element modeling following [14-15], which will incorporate the postimpact relaxation of the basin and its response to N_2 loading to assess the resulting mass and gravity anomalies produced by the basin.

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