THE 3-KM HIGH SUBJOVIAN MEGADOME ON GANYMEDE: SIMULATION OF STABILITY VIA PRATT ISOSTASY. J. P. Kay[1], P.M. Schenk[1], A. J. Dombard[2], W.B. McKinnon[3] [1]Lunar and Planetary Institute, USRA, Houston TX 77058, [2]Dept. of Earth and Environmental Sciences, University of Illinois at Chicago, 845 W. Taylor St. (MC-186), Chicago, IL, 60607 [3]Washington University in St. Louis, St. Louis, MO (kay@lpi.usra.edu)

Introduction: Voyager Stereo Digital Elevation Models (DEMs)-and a limb profile-revealed an anomalous megadome on Ganymede ~600 km in diameter and 3 km tall (Fig. 1), 3 times larger than any known topographic feature on Ganymede. Its origin is unknown, and there does not appear to be any geological feature correlated with the megadome. It is centered at the subjovian point (0° N, 0° E), a location consistent with thickening at the cold pole with subsequent True Polar Wander (TPW) [1], and may be consistent with the leading-trailing hemisphere crater asymmetry [2]. Based on the presence of undisturbed bright terrain within the region, it is unlikely that the megadome predates the bright terrain [3]. Topography of this scale needs to be supported. There are several possible methods of support for the megadome: Lithospheric strength, or Isostastic (Airy or Pratt). Here, we explore all three methods of support for the megadome.

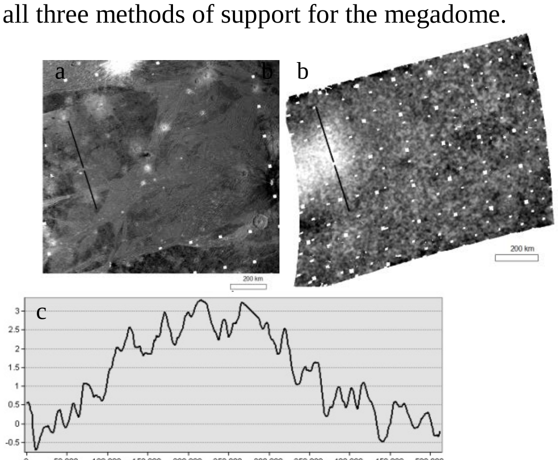

Figure 1: a) Galileo Image of the region. Black line indicates the location of the megadome that is not visible. b) Voyager DEM that shows the megadome black line is cross section shown in c. c) Topographic profile of the megadome.

Methods: We use the commercially available MSC.Marc finite element package, incorporating a viscoelastic rheology. The software is well suited to the investigation of geodynamic problems [4-7]. We use material, thermal, and rheological parameters for water ice that have been measured in the laboratory [see 8-10].

The lithospheric model uses an icy half space, with a megadome that is 3 km high and ~600 km wide. The surface temperature was 120 K, uses centimeter grain sizes, and has a subchondritic heat flow of 1 mW m^{-2}.

The Airy isostasy models simulate a megadome on an ice layer ostensibly 150 km deep, roughly the pressure depth of ice's minimum melting point on Ganymede, and we include initial compensating topography on the base of the ice shell. The surface temperature is 120 K, and the base of the shell is fixed at 250 K, resulting in a heat flow of ~3 mW m^{-2}. The underlying ocean is simulated as additional viscoelastic elements under the ice layer with a very low viscosity and a density of 1000 kg m^{-3}.

For the Pratt model, we have created an icy half space with two different meshes, one with a 120 km thick crust and another with a 200 km crust. Both of these crusts sit on top of an incompressible layer with a very low viscosity (effectively a fluid, thus simulating Ganymede's ocean). Each mesh is 1400 km wide and 1400 km deep. Surface temperature is 90 K, and we have tested for two different heat flows 5 and 20 mW m^{-2}. For the 120 km thick crust, we have tested four different densities for the variable density column: 875, 900, 926, and 950 kg m^{-3}. For the 200 km thick crust, we have tested 920, 930, 940 and 950 kg m^{-3}. The background density of the ice is 950 kg m^{-3}.

Results: In searching for the method of support for the megadome, we test each of the three models discussed above. We look for which of our results have the smallest variation in the final topography as compared to the original topography.

When testing the lithospheric support models, we find that the strength of Ganymede's lithosphere is insufficient to support this megadome, even under a subchondritic, low heat flow at present. After 10 kyr, the megadome losses nearly a kilometer of elevation, and within a million years, it has lost 50% of its elevation. Similarly, we find that Airy isostasy arising from topography on the base of Ganymede's Ice Ih shell cannot support the megadome. It losses 95% of its elevation within 100 Myr.

For Pratt isostasy, we place constraints on the density anomalies that would need to exist with Ganymede's lithosphere in order to support the topography of this megadome. All of our simulations have run for at least 1 Myr to narrow down the parameter space for subsequent modeling for the long term stability of the megadome. Our initial results demonstrate that for the two crust thicknesses that we have chosen, low heat flows are required to support the megadome. A density between 875 and 900 kg m^{-3} is required to preserve the megadome for the 120 km thick crust for 5 mW m^{-2}

during the first million years of the simulation. Of the densities tested, there does not exist one that is capable of supporting the bulge for 20 mW m^{-2}. For the 200 km thick crust, the density that shows the least amount of relaxation is the 930 kg m^{-3} for the 5 mW m^{-2} heat flow. This compares to the analytical value (for 100% initial compensation) of 935 kg m^{-3}. Once again, there is no simulated density contrast that works for the 20 mW m^{-2} example in the 200 km thick crust.

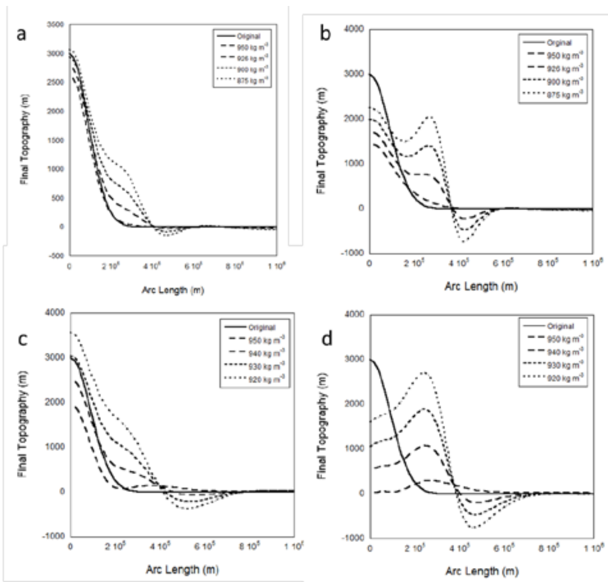

Figure 2: For each curve, we plot the surface topography on the y axis and the location on the surface on the x-axis after 1 million years. The *original line* in each plot is the same and represents the initial topography. a) 120 km and 5 mW m^{-2} b) 120 km and 20 mW m^{-2} c) 200 km and 5 mW m^{-2} d) 200 km and 20 mW m^{-2}.

Discussion and Conclusions: We have found that lithospheric support of the megadome is not feasible even at the low heat flows. The current heat flow expected out of Ganymede at present is 3-4 mW m^{-2}, assuming heat comes solely from chondritic levels of long-lived radionuclides. Thus, the 1 mW m^{-2} represents a significantly subchondritic Ganymede. Even here, the ice lithosphere is too weak to support any large scale topography.

The megadome also does not appear to be supported by Airy isostasy. This result is not surprising. The ice at the base of the ice shell is, by definition, ice that is approaching its melting point and is therefore viscously weak. Consequently, the ice in the lower shell cannot transfer the buoyancy forces from the compensating topography to the surface. This mechanical decoupling effectively turns the Airy case into a purely lithosphere support case, where the lithosphere is too weak (even weaker than above because of the higher heat flow) to support the megadome. We have further tested this notion by matching the ocean density to the ice, thereby eliminating any possibility for buoyant support. The final surface deformations are nigh indistinguishable, further demonstrating the Airy isostasy will not be an effective mode of support in ice shells over oceans [cf. 11].

It does appear to be possible to support and preserve this megadome feature via Pratt isostasy with a density anomaly and low heat flows for at least relatively short timescales (1 million years). It will be necessary to explore the formation of these features of much longer timescales given the temporal relationship between the megadome and the surrounding tectonics. Subsequent work will further refine the relationship between long term preservation, heat flow, and the density for a given crustal thickness. It is also possible that the megadome started off as a much larger feature and subsequently relaxed to its present day shape; this will be explored by starting the simulations with larger initial topographies and simulating the amount of relaxation over longer time scales (0.1-1 Gyr).

A question we have not yet explored is how it is possible to generate a large scale density anomaly in the first place. Clearly, Ganymede has much to reveal.

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