**OH GIVE ME A HOME WITH A RESURGENT DOME: LOKI PATERA, IO** Tracy K.P. Gregg, Dept. of Geology, 126 Cooke Hall, University at Buffalo, Buffalo NY 14260-3050 (tgregg@buffalo.edu).

**Introduction:** Loki Patera, Io (13°N, 309°W) is the largest volcano on Io, both in terms of size and power output [1] (Fig. 1). The patterns of power output and surface temperature changes with time within Loki Patera have been interpreted to be caused by the repeated overturning of a lava lake [1, 2], lava intrusions [3] or pahoehoe-style surficial lava flows [4]. Loki Patera contains an island of material that is both cooler and brighter than the surrounding patera floor. Throughout the changes observed on the patera floor over the past almost 4 decades, there have been no changes in the island's planform shape. Similarly, the patera floor is sprinkled with bright spots termed "bergs" [4] that also remain in the same location over time.

Loki Patera's island has been interpreted to be either a "raft" of solidified crust on the surface of an active lava lake [5] or a resurgent dome [6, 7]. The constancy of the island's outline throughout repeated thermal events on the patera floor is not consistent with a "raft" of solidified crust. Similarly, the constancy in locations of individual "bergs" [4] argues against the patera floor being an actively orverturning lava lake. The unchanging shape and location of Loki Patera's island and "bergs" are more consistent with the theory of the island being a resurgent dome rather than a raft of solidified crust.

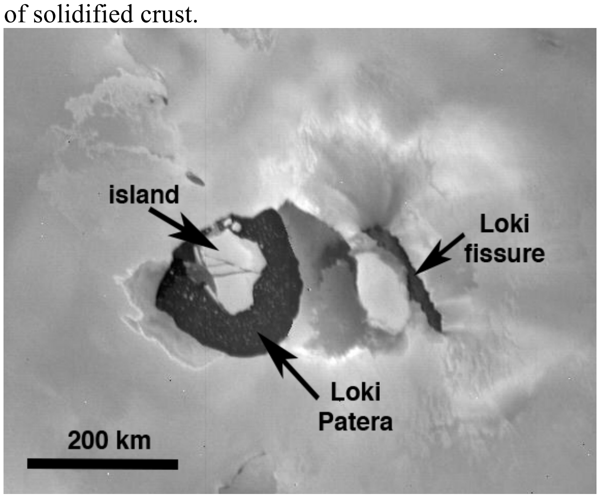


Figure 1. Loki Patera, Io (13°N, 309°W) is the dark, horseshoe-shaped feature containing a bright island. Dark lineations cross-cutting the island are here interpreted to be extensional features (graben) on a resurgent dome [cf. 8]. Voyager 1 ISS image, courtesy of NASA/JPL; NASA Photojournal image PIA00375.

Here, I explore the implications of Loki Patera's island being a resurgent dome.

**Observations, Inferrences and Constraints:** The Loki Patera island is approximatley 100 km in its longest dimension. If the island is a resurgent dome, then the dark lineations cross-cutting the island are interpreted to be extensional graben [cf. 8]. Assuming that the bright island is the entire resurgent dome (that is, none of the resurgent dome is hidden from view), the dark lineations represent a extensional strain of 5 – 7%. No doming is visible in either Voyager or Galileo images, nor is there any topographic signature of doming in Loki Patera's island [9]; shadow measurements suggest that the patera walls are <2 km high [10], and the island shows less topographic relief than the walls. If Loki Patera's island is a resurgent dome, the vertical uplift is likely <2 km. Assuming spherical geometry for the proposed resugent dome, a maximum uplift of 2 km corresponds to a horizontal strain over 100 km of <<1%.

Although the bright surface of the Loki Patera island is consistent with sulfur [11], the temperatures of the dark patera floor are more consistent with a mafic (probably basaltic) lava [12]. I therefore assume basaltic composition for Loki Patera's magma and solidified lava.

**Methods:** If Loki Patera is a collapse caldera with a resurgent dome, then resurgence is essentially caused by either: 1) increasing the volume of material contained beneath the dome (i.e., in a magma chamber); or 2) decreasing the volume of the geologic container that holds the magma beneath the dome [13]. Simple models relate the pressure increase inside a putative magma chamber to the amount of strain observed on the surface [13].

A standard model for maximum uplift in the center of doming over a magmatic intrusion [14] is given by:

$$h_{max} = \frac{(p - \rho g d)L^4}{384D} \quad (1)$$

in which p is the upward pressure (Pa) exerted by the magma chamber; ρ magma density (kg/m$^3$); g is gravitational acceleration (1.8 m/s$^2$); d is the thickness of the deforming patera floor (m); L is the diameter of the resurgence (m); D is the flexural rigidity of the deforming patera floor (Pa m$^3$). Given that $h_{max}$ <2 km, and using the dimensions of Loki Patera's island, the maximum pressure can be constrained.

Marsh's [13] model for magma chamber pressurization due to vesiculation, caused by cooling and crystallization, is given by:

$$p = \frac{0.54RTX}{\Delta V_r + \Delta V_m(1 - X)} \quad (2)$$

in which p is the pressure generated by vesiculation (Pa); R is the ideal gas constant (J/mol K); T is magma temperature (K); X is mole fraction of the gas (for Io, likely $SO_2$ [4]; $\Delta V_r$ is the change in volume of the magma chamber (and here is assumed to be 0) and $\Delta V_m$ is change in volume from melting (J/Pa). The major difference between vesiculation on Io and Earth is the composition of the gas, which would not have a significant effect; thus, the values obtained for Earth and Io by this process should be similar.

The numerical values used are shown in Table 1.

**Results**: The amount of pressure in a constant-sized magma chamber generated from vesiculation of a maximum of 0.5 wt.% $SO_2$ [7] is on the order of $10^5$ to $10^6$ Pa (eqn. 2), which is sufficient to cause uplift of ~100 m. To achieve a maximum uplift of 2 km, a magmatic pressure on the order of $10^{16}$ Pa (eqn. 1).

An uplift of 100 m would result in a horizontal strain of the Loki Patera island of <<1%, assuming that the dome profile is the arc of a sphere. To achieve the observed strain (5 – 7%), again assuming a dome profile in the shape of the arc of a sphere, a maximum uplift of 4.5 – 6.3 km is required; this is not observed.

**Table 1.** Values used in calculations.

| Symbol | Units | Value | Reference |
|---|---|---|---|
| $h_{max}$ | m | 1 – 2000 | 9, 10 |
| p | Pa | -- | -- |
| ρ | $kg/m^3$ | 2000 – 3000 | 2, 7, 11, 12 |
| g | $m/s^2$ | 1.8 | 10 |
| d | m | 10 – 1000 | -- |
| L | m | 100,000 | -- |
| D | Pa $m^3$ | | 14 |
| R | J/mol K | 8.3 | 13 |
| T | K | 1000 - 1800 | 1, 7 |
| X | -- | 0.001 – 0.005 | 7 |
| $\Delta V_m$ | J/Pa | $0.9/10^5$ | 13 |

**Discussion**: Although the morphology of Loki Patera's island, and its unchanging nature, are both consistent with the island being a resurgent dome, model results for a resurgent dome are inconsistent with observations. If the dark lineations that cross-cut Loki Patera's islands represent graben formed during uplift of the patera floor, the measured strain (5 – 7%) is at least an order of magnitude higher than what can reasonably be generated by magmatic pressures.

However, it is possible that the best available image resolution of Loki Patera (~1 km/pixel) is insufficient to allow precise strain measurements, and that the actual strain is lower than measured here. Additionally, I assumed that the entire Loki Patera island represents the whole resurgent dome. However, portions of this proposed resurgent dome might be buried beneath the dark moat material, making the resurgent dome larger than can be measured with visible wavelengths. In that case, the calculated strain would decrease, and the amount of pressure required for uplift would therefore decrease. However, a larger dome requires greater pressures to create the same amount of vertical uplift as is observed in a smaller dome.

**Summary and Future Work:** With the results obtained with these simplified and assumption-filled models, I cannot unequivocally disprove the hypothesis that the Loki Patera island is a resurgent dome. However, the preliminary results suggest that the amount of strain indicated by the dark lineations on the Loki Patera island is inconsistent with the amount of strain produced by an uplift of <2 km. Future work will include investigating more detailed models.

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