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Tectonic resurfacing on Ariel, a Uranian satellite

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Abstract

The surface of Ariel, the second major moon in the Uranian system, displays evidence for resurfacing in the lack of large (>10 km) craters. Portions of Ariel's surface contain large (> 10 km wide) canyons, or chasmata. Using a two-layer physical analogue model and stress modeling software (SatStressGUI), we set constraints on the tectonic formation of Ariel's chasmata.

1. Introduction

Voyager 2 encountered the Uranian system in 1986 and returned images of all of the major moons in the system. Ariel, the second major moon from Uranus, was imaged at ~3 km/pixel. The lack of large (>10 km diameter) identifiable craters on Ariel's surface implies that the satellite has resurfaced (Fig. 1) [1]. This resurfacing is also evidenced by the chasmata, or large (>5 km wide) canyons, that extend for 10s of kilometers (Fig. 2) and are located near the equator of the moon (in the limited images obtained by Voyager) [2]. Previous work on the chasmata hypothesizes that they are cryovolcanic features and evidenced by the smooth material that fills these canyons [e.g., 3]. In this work, we examine whether the chasmata could form through tectonic processes by investigating extension in a two-layer physical analogue model and modelling the diurnal stresses.

2. Analogue Model

In order to simulate chasmata formation, we develop a two-layer physical analogue experiment, previously developed for ridged plains formation on Europa [4], to simulate an extensional environment on Ariel. We then compare the resulting morphology of the graben produced to observations of the chasmata.

The analogue model consists of a ductile, lower viscosity layer underlying a Coulomb-material brittle layer. We use therapeutic putty with a measured viscosity of about 10^4 Pa s for our ductile layer and fine-grained sand for the brittle layer. We choose these materials for our experiments because they scale up reasonably well to conditions on Ariel. For example, if we scale with the cohesive strength of our experimental sand (~60 Pa) and use approximate values for Ariel [1, 3], we obtain a spatial scaling factor of $1:10^{-6}$, which means that 1 cm thick sand in our model represents a 10 km thick ice layer on Ariel [5].

To set up an experiment, we first layer the putty into a 90 cm by 90 cm box and let it relax to a flat surface over the course of a few days before adding the desired amount of sand. We also add coffee grounds on top of the sand to act as strain markers. For experiments where we simulate extensional processes, we move one wall outward with a step motor.

When we increase the brittle layer thickness in the model, the spacing of resulting normal faults also increases. The resulting horst and graben system in the experiments have similar morphology to the chasmata on Ariel (Fig. 3) including: (1) flat-topped ridges, (2) broad troughs, and (3) slight bowing-up of the material within the troughs [3].

3. Stress Models with SatStressGUI

To determine if the driving stresses to create the observed features are tidally controlled, we use SatStressGUI [6] to calculate the magnitude and orientation of the resultant stresses. We perform a range of simulations that vary the ice shell and ocean thicknesses, and eccentricities to determine the magnitude and orientation of potential stresses. We then compare the resultant stresses to mapped features on the surface to determine if there is a correlation. This modelling serves to constrain the brittle and ductile thicknesses used in the analogue modelling aspect of this work. Additionally, the modelling can be used determine if Ariel had a larger eccentricity in the past that could have resulted in larger stresses.

4. Figures

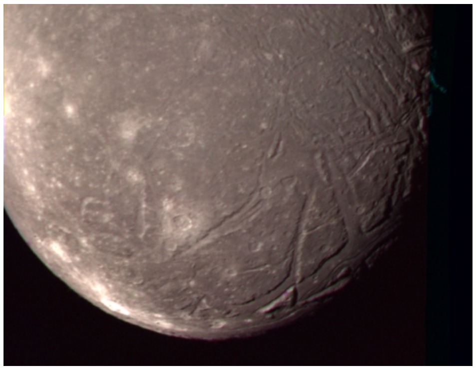

Figure 1: Ariel colour image from Voyager 2 (PIA00041) illuminating the south polar region.

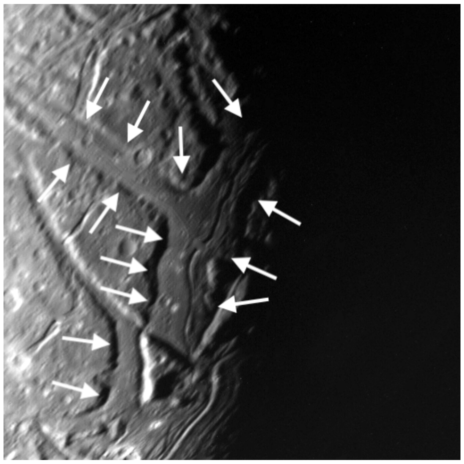

Figure 2: Chasmata (indicated by white arrows) on Ariel's surface (PIA01356, resolution ~ 2.4 km/px).

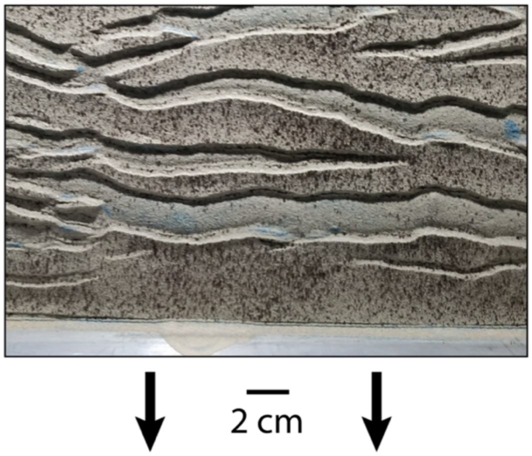

Figure 3: Extension experiment from two-layer analogue model. The resulting horst and graben formations resemble the chasmata on Ariel.

5. Summary

In this work we explore the possibility for a tectonic origin of the chasmata on Ariel’s surface. We compare analogue and numerical models to features on the surface of the moon to constrain the origin of the observed features. Our results have consequences for the depth to a potential liquid layer and orbital history of the satellite.

Acknowledgements

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