EPSC Abstracts
Vol. 7 EPSC2012-834 2012
European Planetary Science Congress 2012

Isostasy on Iapetus

L. Czechowski, J. Leliwa-Kopystynski
Institute of Geophysics, Department of Physics, University of Warsaw, Warszawa, Poland (lczecho@op.pl, Fax: +48-22-5546882)

Abstract

Iapetus is a medium-sized icy satellite (MIS) of Saturn with two spectacular features. They are: geologically old equatorial ridge (ER) rising above the equatorial bulge (EB) and abnormally large flattening. The origin of both features still remains an enigma. Here we show, building on the principle of isostasy, that EB could be a result of low density matter (roots) underlying the lithosphere below the equator. The partial gravitational differentiation had formed low density layer inside the satellite. After an overturn the low density material forms ER and EB. So, we explain both EB and ER in the frame of one hypothesis.

1. Introduction

Two spectacular features are observed on Iapetus: equatorial ridge (ER) rising above the equatorial bulge (EB) – Fig. 1. The existence of EB means that the satellite has abnormally large flattening. Iapetus' flattening is equal to 0.046 and it corresponds rotational period 16 hours although the present period is 79.33 days. The origin of both features still remains an enigma; nevertheless a few different hypotheses were presented, e.g. [2]. We present here our hypothesis stating that the EB and ER are formed as results of partial differentiation of the satellite's interior and later global overturn.

2. Isostasy

Let us note that the Cassini data concern the geometric shape only. The comparison of this shape with the shape of equipotential surface, i.e. the geoid, is necessary to prove that the flattening is non-hydrostatic. Most of terrestrial mountains are in isostatic equilibrium, i.e. they are underlain by 'roots' formed from low density matter. The gravity acting on the elevated parts is compensated by buoyancy force acting on the roots. The isostatic equilibrium is a result of the fluid-like properties of properties of the rocks in the Earth's mantle.

The rheology of icy satellites is similar to terrestrial rocks although for different range of temperature and pressure. The uppermost layer ('lithosphere') is elastic for small deformation and brittle for large deformations. It means that mountains on the surface could exist for billions of year. The medium below the lithosphere is also solid but for very slow geologic processes it behaves like a viscous fluid.

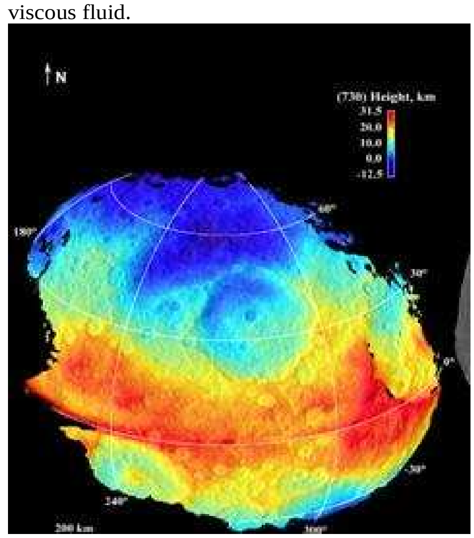

Figure 1. Topography of Iapetus. After [4].

3. Partial differentiation

The heating of satellite interior could lead to melting and consequently to gravitational differentiation of the matter. [3] developed the model of this process based on the finite difference method combined with parameterized model of convection. It includes solid state convection, melting, convection in molten region and differentiation. The heating from the decay of the short-lived and the long-lived radioactive isotopes are included as well as the heat of accretion. The model has 3 basic parameters: (i) t_{ini} time from formation of CAI to beginning of accretion, (ii) t_{acr} duration of accretion, (iii) η_0 viscosity of the satellite's interior at the temperature of melting (but before melting). The full description of the model is given in [3]. Fig. 2 presents a sample result of this model. It indicates that for given parameters the radius of molten region is about 0.65 of radius of the satellite.

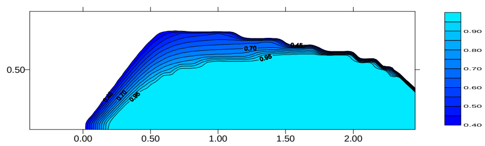

Figure 2. An example of melting history of Iapetus according to our model for t_{ini} = 0.4 My, t_{acr} = 1 My, $\eta_0 = 10^{12}$ Pa s. The vertical axis gives r/R_{sat}, the horizontal axis gives $\log_{10} t$, where t [My] is the time from the beginning of accretion. Figure presents fraction of latent heat supplied to the matter (1 means that matter is molten).

4. Gravitational overturn

After differentiation, the silicates form the central core, while the liquid forms a molten layer around the core. It is an unstable situation, because low density differentiated layer is below the undifferentiated matter of higher density. It results in an global overturn. The system of equations describing the process is introduced by [1]. The buoyancy resulting from the difference of density $\Delta\rho$ is the main driving force. The result of the overturn is presented in Fig. 3. The low density matter forms roots below the equatorial region.

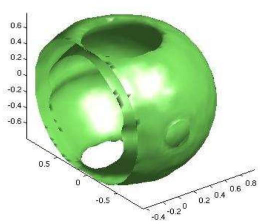

Figure 3. The distribution of low density matter as a result of gravitational overturn according to our hypothesis. The low density matter forms a layer between two given surfaces. Note deep roots below equatorial region.

4. Conclusions

We explain existence of both: ER and EB in the frame of one hypothesis. It does not require any specific rheological properties of the satellite.

We hope that Cassini mission will provide data about gravity of Iapetus necessary to discriminate between hypotheses of hydrostatic and non-hydrostatic flattening.

Acknowledgements

This work was partially supported by the Polish Ministry of Education and Science (grant 4036/B/H03/2010/39) and National Science Centre (grant 2011/01/B/ST10/06653). Computer resources of Interdisciplinary Centre for Mathematical and Computational Modeling (ICM) of Warsaw University are also used in the research.

References

[1] Czechowski, L., 1984. The numerical model of the Earth's mantle convection with gravitational differentiation, Acta Geophysica Pol., XXIX, 3, 207-215.

[2] Czechowski, L., Leliwa-Kopystyński, J., 2008. The Iapetus's ridge: Possible explanations of its origin. Adv. Space Res., 42, 61-69.

[3] Czechowski, L., 2012. Thermal history and differentiation of Rhea. Accepted in Acta Geophysica.

[4] Thomas, P.C., 2010. Sizes, shapes, and derived properties of the Saturnian satellites after the Cassini nominal mission. Icarus 208, 395–401.