EPSC Abstracts
Vol. 13, EPSC-DPS2019-293-2, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Tidal dissipation in Io's and Europa's silicate mantle: Influence of a partially molten layer

Mathilde Kervazo (1), Gabriel Tobie (1), Gaël Choblet (1), Caroline Dumoulin (1) and Marie Běhounková (2)
(1) Laboratoire de Planétologie et de Géodynamique, Université de Nantes, UMR-CNRS 6112
(2) Charles University, Prague, Czech Republic
(mathilde.kervazo@univ-nantes.fr)

Abstract

Io, the inner most of Jupiter's Galilean satellites, is the most volcanically active, and probably one of the most remarkable body in the outer Solar System [1]. The presence of a subsurface ocean on the second Galilean moon Europa [2], along with the spectacular volcanic activity exhibit by its neighboring satellite Io, raise the possibility of seafloor volcanoes [3], which has major implications for Europa's ocean habitability.

The observational constraints available concerning the heat budget of these satellites is limited to Io. The total power emitted from Io's surface is estimated to about 100 TW at present [4,5], which is several orders of magnitude greater than can be explained by radiogenic heating alone. More recently, re-analysis of the Galileo magnetic data at Io revealed the existence of an induction effect, providing evidence for a near-surface partially molten zone, a so-called astenosphere, with a rock melt fraction of 20 % or more and a thickness of at least 50 km [6]. The existence of such a partially molten layer at the top of Io's silicate mantle appears consistent with the prodigious heat flux emitted from Io (e.g. [7, 8, 9]), but it is still unclear how Io reached such a highly dissipative state.

Unlike Io, the surface heat flux of Europa is unknown. Due to further distance from Jupiter and its smaller size, dissipation in Europa's mantle is expected to be much smaller than on Io (e.g. [10]), but still could be comparable to present-day radiogenic heating. Combined radiogenic heating and tidal heating could sustain partial melting in Europa's mantle during billions of years [11], especially during periods of enhanced eccentricity which may lead to melt accumulation in the asthenosphere [12]. Evaluating the coupling between melt generation and heat production is essential to assess the possibility of seafloor volcanism on Europa and to understand the mechanism at the origin of the tidally-induced volcanism on Io.

In the present study, we model the viscoelastic deformation of Io's and Europa's mantle using an Andrade rheology. We test the influence of a molten layer, assuming different rheological laws for the influence of partial melt on anelastic properties of rocks. A simplified parameterization for melt production and extraction [13] will be used to determine for each tested astenosphere configuration whether an equilibrium between heat generation and extraction can be reached or not. For Io, we determine the rheological structure of the silicate mantle (lithosphere/molten astenosphere) required to explain the present-day heat budget and the heat flux pattern. For Europa, we estimate the maximal heat production that could be generated by considering different molten layer configuration and different eccentricity values.

Acknowledgements

The present work received financial supports from the ANR OASIS project and from CNES (Europa Clipper/SUDA).

References

[1] Lopes, R. M., and Williams, D. A., Io after Galileo. Reports on Progress in Physics, 68(2), 303 (2005).

[2] Khurana, KK., et al., Nature, Vol. 395, pp. 777 (1998).

[3] Thomsom, R. and Delaney, J., JGR: Planets, Vol. 106, pp. 12355-12365 (2001).

[4] Veeder, G. et al., JGR: Planets, Vol. 99, pp. 17095-17162 (1994).

[5] Spencer, J. et al., Eos Trans AGU, Vol. 81, pp. 19 (2000).

[6] Khurana, K. et al., Science, Vol. 332, pp. 1186-1189 (2011).

[7] Segatz, M. et al., Icarus, Vol. 75, pp 187-206 (1988).

[8] Bierson, CJ. and Nimmo, F., JGR: Planets, Vol. 121, pp 2211-2224 (2016).

[9] Renaud, J. and Henning, W., The Astrophysical Journal, Vol. 857, pp. 98 (2018).

[10] Tobie, G. et al., Icarus, Vol. 177, pp. 534-549 (2005).

[11] Běhounková, M. et al., Sustainability of the melting in the silicate mantle of Europa, EPSC (2019).

[12] Moore, W. et al., Thermal evolution of Europa's silicate mantle, Europa (2009).

[13] Moore, W., JGR: Planets, Vol. 108 (2003).