EPSC Abstracts
Vol. 13, EPSC-DPS2019-1632-2, 2019
EPSC-DPS Joint Meeting 2019

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

A study on the onset of the thermal convection in Ceres' crust

M. Formisano (1,*), C. Federico (1), J. Castillo-Rogez (2), M.C. De Sanctis (1) and G. Magni (1)
(1) INAF-IAPS, via Fosso del Cavaliere 100, 0133 Rome, Italy; (2) Jet Propulsion Laboratory, California Institute of Techology, Pasadena, Ca, USA

* michelangelo.formisano@inaf.it

Abstract

Ceres is the largest body of the Main Belt characterized by a large amount of water in its interior as suggested by several geological and geochemical evidences [1,2,3,4,5,6]. The presence of water ice has been also detected on the surface, in some specific craters [7,8,9]. In this work we have investigated how the composition of the crust as well as the temperature gradient across the crust can affect the onset of thermal convection. We also tested if the thermal stress induced by the convection can produce domes like Ahuna Mons.

1. Numerical Model

We applied a 2-D finite difference element method (FEM) to solve the Navier-Stokes equation, in the Boussinesq approximation, and the heat equation. We also considered the fluid as incompressible and the absence of sink or source of new material [10]. A 2-D cartesian geometry is used, in which the surface temperature is fixed (we use the radiation equilibrium temperature), while at the bottom of the crust we use two different values: 215 K and 275 K [11]. No slip conditions on the sides are imposed. We adopted three different composition, made of water ice, clathrate hydrate, rock (antigorite) and salt (hydrohalite). First configuration is similar to that adopted in [11], while the others are compatible with the physical constraints imposed in the most recent works on Ceres (e.g. [12]).

2. Results

We report the results (see Fig.1) of our numerical simulation adopting the composition similar to [11], which consists in 30 vol.% ice, 40 vol.% clathrate, 20 vol.% salt and 10 vol.% antigorite. This composition is characterized by a mean density that is in agreement with the work of [13]. The results shown in Fig.1 are performed with a temperature at the basis of the crust equal to 275 K, the higher value provided by the work of [14]. Also with this high value, the thermal convection is not vigorous in the crust and it lasts for a period < 100 Myr, affecting about the 80% of the whole crust. For this reason we would expect a negligible contribution as thermal stress on the top of the crust. If we assume as temperature of the bottom of the crust a value < 250 K, no thermal convection starts. A vigorous convection is obtained considering a crust composition made mainly of clathrate (50 vol. %) and ice (40 vol.%) with salt and rock almost negligible. In this case we observe a weak thermal convection also with a low temperature (215 K) at the basis of the crust.

3. Conclusions

From these numerical results we can conclude that the thermal convection probably does not affect the thermal history of the crust, being possible for a narrow set of thermophysical parameters. These lead to two main considerations: 1) dome formation (like Ahuna Mons [14]) is probably due to the diapirism rather than thermal convection; 2) brine could be preserved until now [11].

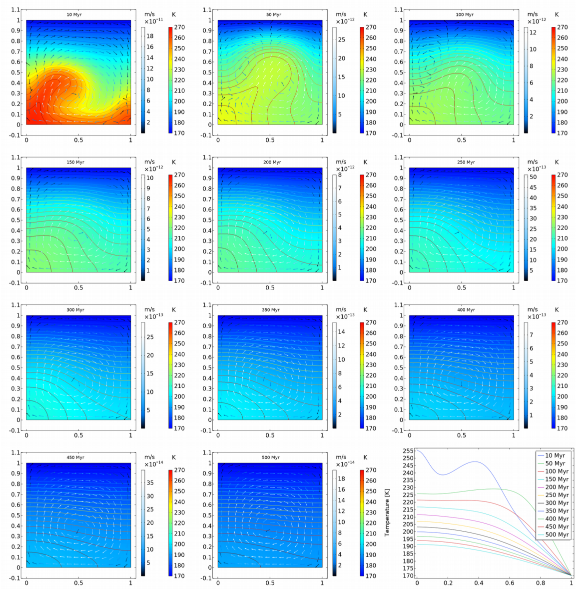

Fig.1 Temperature maps from 10 Myr to 500 Myr, with a time step of 50 Myr (apart from the two first panels). Last panel (bottom right) shows a 1-D temperature profile at the center of the cell, at given times. In the x-axis, 0 represents the bottom of the crust while 1 the surface. Left colour scale refers to the convective velocity (m s^{-1}), right colour scale refers to the temperature [K].

References

[1] De Sanctis, M.C. et al., Nature, 536, 54-57, 2019

[2] Ciarniello, M. et al., A&A, 598, A130, 2017

[3] Carrozzo, F. G. et al., Nature, Science Advance, 4(3), 2018

[4] McSween, H.Y. et al., Meteoritics & Planetary Science, 0(0), 2018

[5] Schmidt, B.E., et al., Nature Geoscience, 10, 338-343, 2017

[6] Prettyman, T.H., et al., Science, 355, 55-59, 2017

[7] Combe, J.-P., et al., Science, 536, aaf3010, 2016

[8] Combe, J.-P, et al.. Icarus, 318, 15, 22-41, 2018

[9] Raponi, A. et al., Science Advance, 4(3), 2018

[10] Formisano, M. et al., GRL (in preparation), 2019

[11] Castillo-Rogez, J. et al., GRL, 46(4), 1963-1972 (2019)

[12] Park, R. et al., GRL, 31(1), 2017

[13] Konopliv, A. et al., Icarus, 299, 411-429, 2018.

[14] Ruesch, O, et al. Science, 353, aaf4286, 2016