Geophysical and thermal histories of asteroids 4 Vesta and 21 Lutetia. M. Formisano[1], M.C. De Sanctis[1], C. Federico[2], D.Turrini[1], F.Capaccioni[1], [1] INAF-IAPS, Via Fosso del Cavaliere 100-000133 Rome (Italy), [2]Dep. Of Earth Science, University of Perugia, 06123 Perugia (Italy)

Introduction: 4 Vesta and 21 Lutetia, two asteroids of the Main Belt, represent two important case study to investigate the primordial stages of the evolution of terrestrial planets and of the Solar System in general.

4 Vesta is one of the large asteroid of Main Belt and probably it is the parent body of HED meteorites [1] : as a consequence we know it was one of the first bodies to have formed and differentiated in the Solar System.

Lutetia is a border-line object: it belong to those objects that survived to the collisional evolution of the Main Belt and possibly differentiated [2] . Moreover it could be used as a case study to investigate the minimal conditions to obtain a differentiated object.

The Model : To study the geophysical histories of these two asteroids we developed a numerical 1D model ([3] , [4]) for the contemporary solution of the heat equation with radiogenic heat source and the advection equation, which controls the percolation of the metals inside the asteroids. The numerical solution is obtained using a finite difference method in radial direction (FTCS scheme).

We investigated the link between the evolution of the internal structure and thermal heating due to ^{26}Al and ^{60}Fe and long-lived radionuclides (e.g. ^{238}U and ^{235}U), taking into account the chemical differentiation of the body and the affinity of ^{26}Al with silicates: our simulation covered a timespan of 5 Ma starting from the condensation of CAIs.

We considered primordial Vesta and Lutetia as spherical bodies with fixed radius (270 km and 50 km, respectively) and composed of a homogenous mixture of two components, the first one generically referred to as metals and the second generically referred to as silicates. This composition is similar to those of the H and L classes of he ordinary chondrites. We explored several thermal and structural scenarios differing in the available strength of energy due to the radiogenic heating and in the post-sintering macroporosity.

In the case of Vesta, by comparing them with the data supplied by the HEDs, we used our results to constrain the accretion and differentiation time as well as the physical properties of the core, while in the case of Lutetia this comparison is not possible since we do not possess “ rock samples” and the available data are quite limited. Nevertheless, we could constrain its formation time in case the asteroid partially differentiated.

Results: Differentiation takes place in all scenarios in which Vesta completes its accretion in <1.4 Ma after the injection of ^{26}Al into the solar nebula. In all those scenarios where Vesta completes its formation in <1 Ma from the injection of ^{26}Al, the degree of silicate melting reaches 100 vol% throughout the whole asteroid. If Vesta completed its formation between 1 and 1.4 Ma after ^{26}Al injection, the degree of silicate melting exceeds 50 vol% over the whole asteroid, but reaches 100 vol% only in the hottest, outermost part of the mantle in all scenarios where the porosity is lower than 5 vol%. If the formation of Vesta occurred later than 1.5 Ma after the injection of ^{26} Al, the degree of silicate melting is always lower than 50 vol% and is limited only to a small region of the asteroid. The radiation at the surface dominates the evolution of the crust, which ranges in thickness from 8 to about 30 km after 5 Ma: a layer about 3–20 km thick is composed of primitive unmelted chondritic material, while a layer of about 5–10 km is eucritic.

We observe that Lutetia differentiate completely in no scenario. We observe that in the scenarios characterized by a global porosity of 30 vol.% proto-core (a structure enriched in metals) formation is possible for accretion time less about 0.35 Ma: the size ranges from 4 to 8 km and its formation time ranges between 0.35 Ma and 0.54 Ma. The maximum value for the size of the core is reached in the scenario with a porosity of 10 vol.% and instantaneous accretion: in this case the formation of the core occurs at about 0.18 Ma.

References:

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