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Onset of differentiation and internal evolution: the case of 21 Lutetia

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Abstract

Asteroid 21 Lutetia is one of the large main-belt asteroids and has been visited by the Rosetta spacecraft. It could have preserved a mostly intact record of any early metamorphic and melting processes (Weiss, B.P. et al 2011). Several scenarios of accretion and internal evolution are here presented, by varying the time-delay parameter, which controls the strength of radiogenic sources, and the internal composition.

1. Introduction

As suggested by Weiss et al. (2011), 21 Lutetia could be partially differentiated as inferred by the new constraints on its density, composition and morphology from Rosetta spacecraft. This indicates Lutetia experienced a partial differentiation, forming a metallic core overlain by a primitive chondritic crust. We apply the thermal code developed to constrain the formation time, the size and other physical properties of the (possible) core of Lutetia by varying the time-delay in the injection of ^{26}Al and the initial composition.

2. Numerical Procedure: Geophysical model of Lutetia

We use the thermal code we developed for the study of the internal and structural evolution of Vesta (Formisano et al. 2012). We consider primordial Lutetia as a homogeneous sphere with radius fixed to 50 km and initial temperature (that is also the surface temperature) to 200 K. When the melting temperature of Fe-FeS is reached, the percolation of iron into the silicate matrix and the formation of the proto-core take place. Since our model does not take into account heat removal mechanisms other than conduction and irradiation at the surface, our results supply a reliable picture of the thermal history of Vesta up until the onset of the differentiation. We vary the initial composition, in particular the global porosity ϕ and the time-delay parameter, determining different evolutional scenarios we summarize in Tab.1.

	Core Size $[km]$	**Core Time Formation** $[Ma]$	**Density** $[Kg\ m^{-3}]$
Scenario 0: $\Delta t_d = 0 t_{1/2}{}^{26}Al$			
$\phi = 0.10$	24.5	0.184	4829
$\phi = 0.20$	16.3	0.241	5124
$\phi = 0.30$	8.0	0.345	5482
Scenario 1: $\Delta t_d = 0.5 t_{1/2}{}^{26}Al$			
$\phi = 0.10$	19.4	0.270	4845
$\phi = 0.20$	10.2	0.360	5171
$\phi = 0.30$	4.0	0.538	4491
Scenario 2: $\Delta t_d = 1 t_{1/2}{}^{26}Al$			
$\phi = 0.10$	12.5	0.403	4808
$\phi = 0.20$	4.0	0.557	4768
$\phi = 0.30$	NO	NO	NO

Table 1: Summary of scenarios developed with constraints on size, time formation and density of the core, after 2 Ma. NO stands for temperature not high enough to melt the metallic component.

3. Summary and Conclusions

We observe that in those scenarios characterized by a global porosity of 30%, accretion is possible in < 1Ma and the size of the core ranges in 4-8 km with a time of formation < 0.538 Ma from CAIs). The maximum value for the size of the core is reached in the scenario with a porosity of 10% and instantaneous accretion: in this case the formation of the core is very fast (about 0.184 Ma from CAIs).

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