THE ROLE OF PHASE TRANSITIONS IN THE MARTIAN MANTLE. N. Michel[1] and O. Forni[1], [1]Université de Toulouse, UPS, CESR, 9 avenue du Colonel Roche, F-31028 Toulouse Cedex 9, France (nathalie.michel@cesr.fr).

Introduction: The presence of phase transitions in the Martian mantle, the two exothermic phases, olivine to β-spinel and β- and γ-spinel transitions, and in particular the endothermic spinel to perovskite transition, have been recognized to play an important role in the style of mantle convection [1], and the dynamo of the planet [2]. The exothermic phase transitions tend to accelerate the mantle flow and influence the volcanic evolution. On the contrary, the endothermic spinel to perovskite phase transition tends to inhibit the convection [3] and induces layered convection [4].

As the spinel to perovskite phase transition occurs at extreme depth, due to high pressure, its presence in the mantle involves that Mars has a very small core. Actually, we cannot be certain about the core size as we do not know exactly the composition of the core. Harder and Christensen (1996) [5] and Breuer et al. (1998) suggest a range of possibilities for the size of the Martian core between 1400 km and 1800km, depending of sulfur content in that core [6].

Decreasing in depth with the core cooling, the spinel to perovskite phase can disappear involving a sudden increase of the heat flow out of the core. If the increase of the heat flow exceeds a critical value where a dynamo can be sustain, a core reactivation is conceivable, after the disappearance of the primitive global magnetic field [7].

In the present work, we want to improve the study of phase transitions, adding the core cooling, the decay of radioactive elements, and a temperature and depth dependant viscosity to the numerical model, with two different sizes of the Martian core.

Numerical Simulation: We have employed the axisymmetric spherical shell code CITCOM2D [8, 9], using finite-element resolution method. The temperature at the top of the model is 220 K and temperature at the bottom is decreasing with time as we modified the code to take into account the core cooling. The initial bottom temperature is 2500 K. Isothermal and free-slip boundary conditions are applied at the top and the bottom of the model. We consider three different models: A first one (model SC) with a small core (a radius equal to 1360 km) allowing the presence of the endothermic spinel to perovskite phase transition close to the core-mantle boundary (CMB), and an exothermic phase transition olivine to γ-spinel at 780 km from the CMB. The second model (model LC2) considers a large core of 1700 km of radius, with two exothermic phase transitions, olivine to β-spinel (at a radius of 2380 km) and β- and γ-spinel transition (at a radius of 2040 km). Finally, as the Martian mantle is supposed to have an higher iron content than the Earth's mantle, the third model (model LC1), includes only one exothermic phase transition, with a thickness of 170 km, instead of 35km as in both previous models, according the isothermal phase relations in the binary system Mg_2SiO_4–Fe_2SiO_4 from Bertka and Fei (1997) [10]. These three models are illustrated in figure 1. In each one, we added to the model the decay of radioactive elements from an initial heat production of 8.3 10^{-8} W/m^3 [11] and a viscosity contrast between the bottom and the top of the model $\Delta\eta = 10^7$.

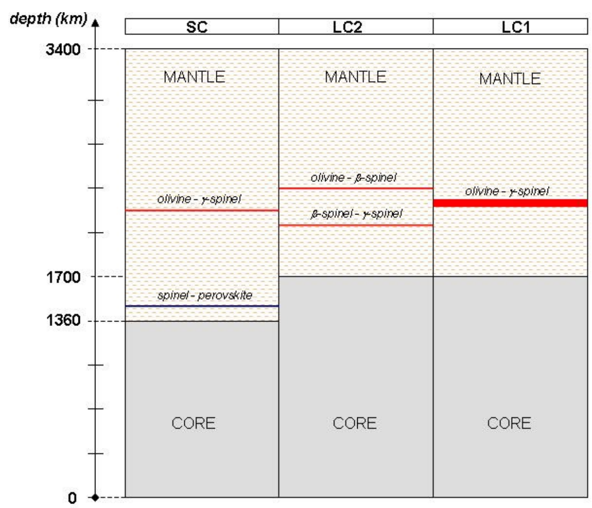

Fig.1. Internal structure of Mars with phase transitions and for two different core radii of 1360 km (SC) and 1700 km (LC). For the case with a large core, the model LC2 includes two exothermic phase transitions with a thickness of 35 km each, and the model LC1 includes only the olivine to γ-spinel phase transition with a thickness of 170 km.

Results: First we will examine the effects of phase transition in the model with a small core and in particular the effects of the presence of the spinel to perovskite phase transition on the mantle convection. Then we will compare effects of phase transitions in the two large core cases:

Small core (SC). With a spinel to perovskite phase transition at 100 km above the CMB, the endothermic phase do not decrease in depth enough to disappear and is still present at 4.5 Ga. As a perovskite layer is supposed to be present only in the early Martian evolution, the previous case is not coherent. With a perovskite layer of 50 km thickness, the endothermic phase disappears after about one billion year. That disappearance involves an increase of the heat flow out of the core but that increase is not significant to explain a core reactivation [7, 12]. At the same time, one billion years, melt is produced in one plume, calculated by the difference between mantle temperature and the solidus temperature of a dry peridotite [13], (figure 2). The endothermic phase inhibited the heat flow out of the core until it disappeared, involving a release of heat and the generation of a hot melting plume.

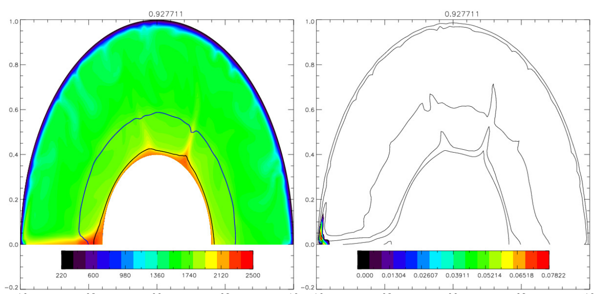

Fig.2. (a) Temperature profile in the Martian mantle and phases transitions at 0.9 billions years for model SC. (b) Excess temperature above the solidus of anhydrous peridotite in colors, and in black solids lines some levels of the temperature, for the same model. Temperatures are in Kelvin degrees.

Convection in the Martian mantle is not dominated by a single large upwelling as expected with the presence of an endothermic phase close to the core mantle boundary [5]. The core cooling seems to prevent the predominance of a single-plume pattern. In figure 3, stream function is represented at 0.9 billions years and 4.5 billions years.

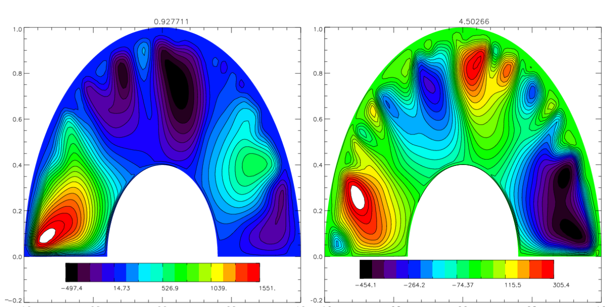

Fig.3. Stream function at 0.9 billions years and 4.5 billions years for model SC. Values are dimensionless.

Large core (LC1 and LC2). With a large core, the presence of one or two exothermic phases in the mantle accelerates the heat flow but no particular differences are observed between the two cases. The core is cooling very fast, involving the cessation of the core dynamo and the disappearance of the magnetic field, and no reactivation is conceivable. Mantle temperatures are not high enough to exceed the solidus temperature, and no melt zones are observed.

Conclusion: The presented results demonstrate that it is difficult to rejuvenate a dynamo, even when an early perovskite layer occurs in a small core. The melt production regions observed in case of a small core suggest a volcanic history on Mars with only one period of melt generation but early in the Martian history. It is also difficult to obtain degree one convection [5] with the endothermic phase due to the effects of the core cooling.

The study of the two models (LC1 and LC2) reveals no particular differences in the style of the convection depending on the iron content taken in the Martian mantle.

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