WHAT DO RADIOGENIC ISOTOPES IN SHERGOTTITES AND NAKHLITES TELL US ABOUT THE MARTIAN MANTLE? V. Debaille[1] and A. D. Brandon[2], [1]Laboratoire G-Time, Université Libre de Bruxelles, Av. F.D. Roosevelt, CP160/02, 1050 Brussels, Belgium (vinciane.debaille@ulb.ac.be), [2]Department of Earth and Atmospheric Sciences, University of Houston, Houston TX 77204, USA for second author (abrandon@uh.edu).

Introduction: The SNC suite (shergottites, nakhlites and chassignites) provides the only samples we can directly analyze for understanding the martian interior. Unfortunately, they are differentiated lavas and do not directly reflect the composition of the martian mantle. On the other hand, radiogenic isotope ratios are not fractionated during magmatic processes and can decipher not only the composition but also the time-integrated evolution of the source of these martian samples. In order to understand the evolution of the martian mantle, $^{142}Nd/^{144}Nd$, $^{143}Nd/^{144}Nd$ and $^{176}Hf/^{177}Hf$ isotope ratios have been measured in several nakhlites and shergottites, then providing a consistent story for the evolution of Mars.

Martian mantle mineralogy: The shergottites have Lu/Hf and Sm/Nd ratios that define a well correlated trend [1]. This relationship has been interpreted as mixing between a depleted and an enriched reservoir [2-7]. The depleted reservoir has been directly related to depleted shergottites [1, 2]. It is postulated to have a Sm/Nd ratio that is lower compared to the lavas themselves, and using a Monte-Carlo simulation, the mineralogy of the source of depleted shergottites has been modeled by 60% olivine, 21% clinopyroxene, 9% orthopyroxene and 10% garnet [1]. Such a mineralogical assemblage corresponds to the upper martian mantle at a depth of 250-400 km [8]. The origin of the enriched reservoir has often been related to the martian crust. However, the Re-Os systematics in shergottites preclude this hypothesis [4, 9]. In contrast, it has been proposed that this enriched reservoir is located at the top of the martian mantle and is broadly similar to the lunar KREEP source, where it is composed of quenched residual melts resulting from 98-99% of the crystallization of a magma ocean [1, 10].

Crystallization of the martian magma ocean and its fate: Crystallization of a magma ocean is a bottom-up process that is expected to form refractory Mg-rich cumulates first, and Fe-rich cumulates at the end of the process, at the top of the mantle [11]. It has been shown that depleted shergottite mantle source crystallized ~22 million years (Myr) after solar system formation (assf) (using the recently revised decay constant of ^{146}Sm [12]) with the same mineralogical assemblage as above [1]. The enriched source crystallized later, around ~83 Myr assf [7]. At the end of the crystallization of the magma ocean, one can expect to observe a density gradient that can be re-equilibrated via a mantle overturn [11]. It has thus been proposed that nakhlites provide the first geochemical evidence of the occurrence of a mantle overturn, because of the decoupling between their $\varepsilon^{142}Nd$ and $\varepsilon^{182}W$ systematics [13]. Both nakhlites and depleted shergottites show recent sources (~1.3 Gyr ago for nakhlites, ~450 Myr ago for depleted shergottites) in the martian mantle that are directly inherited from the crystallization of the martian magma ocean and its subsequent overturn. This observation is even more critical when considering ALH84001 that is 4.09 Gyr old and that has geochemical affinities to more recent shergottites [10]. This implies that the martian mantle preserved ancient geochemical signatures related to early differentiation.

Preserving an unmixed martian mantle over Mars history?: A major paradox of the martian mantle is thus how to preserve the chemical heterogeneity observed in SNCs despite a martian mantle expected to be convective at the present time [14]. Mantle convection should rapidly homogenize chemical heterogeneities. As such, some have proposed that the martian mantle has stopped convecting a long time ago [15]. A numerical model recently developed [16] shows that a convective mantle can still be poorly-mixed in the case of stagnant-lid tectonic regime. This is the case of Mars, showing a stagnant lid for at least the last 4 Gyr [17].

Conclusions: The isotopic signatures of shergottites and nakhlites provide a consistent picture of the martian mantle, from the formation of Mars and the crystallization of a magma ocean, followed by mantle overturn, to the more recent times when their mantle sources melted to produce these igneous rocks. A convective but still poorly-mixed mantle can be explained by the martian plate tectonics, characterized by stagnant-lid regime.

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