NEW EXPERIMENTAL CONSTRAINTS ON THE ORIGIN OF SHERGOTTITES: SUPER-CHONDRITIC CA/AL IN MELTS FROM A GARNET-FREE MARTIAN MANTLE. M. Collinet[1], B. Charlier[2], E. Médard[3], J. Vander Auwera[1] and T. L. Grove[4]. [1]Université de Liège–F.R.S.-FNRS, B20 Département de géologie, 4000 Liège, Belgium, mcollinet@ulg.ac.be. [2]Institut für Mineralogie, Leibniz Universität, 30167 Hannover, Germany. [3]Laboratoire Magmas et Volcans, Université Blaise Pascal–CNRS–IRD, 63038 Clermont-Ferrand, France. [4]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA.

Introduction: Shergottites, the most abundant group of Martian meteorites, are basalts and gabbros that show two major discrepancies with the remotely sensed Martian crust. First, they are characterized by much younger crystallization ages [e.g. 1]. Second, they present a depletion in Al relative to the rocks analyzed by the Mars Exploration Rover (except Bounce rock [2]) and the Mars Science Laboratory missions. This Al-depletion is expressed by high CaO/Al_2O_3 ratios (1.1-1.2) [e.g. 3, 4] compared to the chondritic value of the primitive Martian mantle (0.8) [5]. The new paired meteorites Northwest Africa (NWA) 7034 [6] and 7533 [7] present old crystallization ages and chondritic CaO/Al2O3 ratios in agreement with surface analysis. Thus, shergottites which seem to have a common origin were probably ejected from a recent igneous province not representative of the average Martian crust.

The origin of the Al-depletion of shergottites is still poorly constrained. Early melting experiments in the spinel stability field [8] suggested that liquids with high CaO/Al_2O_3 ratio cannot be produced by melting a primitive Martian mantle [5] and that, instead, shergottites derive from a source already depleted in Al. Later experiments performed in the stability field of garnet on a similar mantle composition produced liquids with high CaO/Al_2O_3 ratios [9]. However, these high pressure liquids contain low SiO_2 and high FeO and cannot represent shergottite parental melts. Garnet is also expected to trap Heavy Rare Earth Elements (HREE) in the residue. Yet, no depletion in HREE has been reported in shergottites.

Here, we present new melting experiments performed on the same Primitive Martian mantle [5] at the transition between the spinel and garnet stability fields. Despite the absence of garnet, we have obtained liquid composition with super-chondritic CaO/Al_2O_3 ratios. We compare the composition of shergottites with liquids from our experiments to discuss the origin of shergottite parental melts.

Methods: Experiments were performed from a synthetic primitive Martian mantle [5], the same starting mix as used for our experiments at lower pressure [10]. For each experiment, about 10 mg of the starting material are packed in a Pt-Graphite double capsule. After 12h at 400 °C, the capsule is welded shut and loaded in an end-loaded piston-cylinder apparatus. Experiments were conducted at 2.4 and 2.65 GPa (210-240 km in depths) and temperature between 1350 and 1430 °C. The design of the graphite capsule is optimized to induce micro-cracks in the lid which extract the liquid while limiting iron loss into the Pt outer capsule.

Run products were analyzed with a JEOL JXA-8200 Superprobe at the Massachusetts Institute of Technology. Beam conditions were set to 15 kV and 10 nA and glasses where analyzed with a 5 µm defocused beam when possible. The degree of melting and the proportion of crystalline phases were estimated by mass balance calculations.

High CaO/Al_2O_3 ratios: The liquids produced for 10 to 15 % of melting exhibit super-chondritic (1.1-1.2) CaO/Al_2O_3 ratios identical to those of olivine-phyric shergottites (Fig. 1). The ratio decreases with further melting and reaches the chondritic value after 20-25% of melting.

The high CaO/Al_2O_3 ratios of liquids in our experiments result from two combined pressure effects. First, with increasing pressure, the pigeonite coefficient of the peritectic reaction (pig + sp + ol = liq + opx) increases continuously. With pressure, melts are thus preferentially enriched in CaO increasing up to 10-11 % around 2.5 GPa. Second, the compatibility of Al in orthopyroxene greatly increase with pressure. The partition coefficient of Al between orthopyroxene and melt is increases by a factor of four from 0.5 to 2.6 GPa (Fig. 2.).

Major element compositions: Our experimental liquids have the same CaO/Al_2O_3 ratio as shergottites. However, their compositions still present considerable differences. In particular, they are enriched in both CaO (9.5-11%) and Al_2O_3 (8.5-9%) compared to shergottites. Our liquids are also much richer in alkali elements (~3 wt%) compared to both depleted (~0.5 %) and enriched (~1.4 %) shergottites. Finally, experimental melts are poorer in SiO_2 (~42%) relative to shergottites (~48%) and have slightly lower Mg# (~0.56).

Implications: The important differences in composition between our experimental liquids and shergottites indicate that shergottites cannot derive directly from the primitive Martian mantle. When the degree of melting is increased, the alkalis, Al and Ca decrease in the liquid but, at the same time, the super-chondritic signature is lost.

We suggest that shergottite parental melts were produced by melting a refractory mantle distinct from the composition used for our experiments [5]. This refractory mantle could present the super-chondritic CaO/Al_2O_3 ratio of shergottites but, as shown by our new experimental results, it is not necessary. The reduction of the stability field of pigeonite and the increased compatibility of Al in orthopyroxene with increasing pressure has the same effect on the composition of liquids produced from a more refractory mantle. Thus, the mantle source could have a CaO/Al_2O_3 ratio intermediate between chondritic and shergottitic values (e.g. 0.9-1.0) and the final 1.2 ratio of shergottites would result from melting at fairly high pressures (>2.0 GPa), but still in the absence of garnet.

As the mantle cools, the thickness of lithosphere progressively increases and melting is expected to occur at greater depths [11]. Thus, we note that the young ages of shergottites are consistent with melting at higher pressure due to the thermal evolution of the planet. For exemple, the Tharsis province is a good candidate environment where melting of a refractory mantle at high pressure could have produced shergottite-like melts. It is characterized by a magmatic activity persistent in Mars history that built a crust close to 100 km thick [12].

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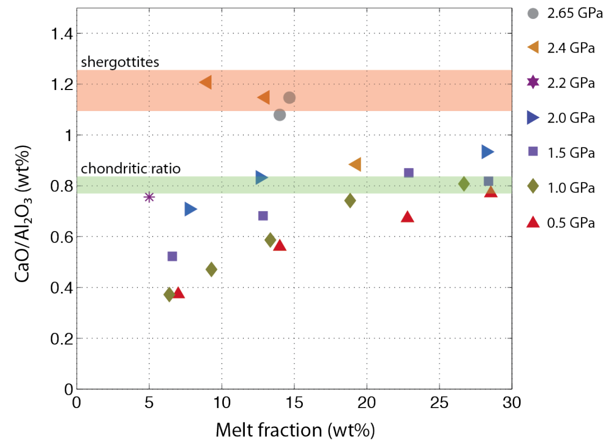

Fig. 1. CaO/Al_2O_3 ratio in experimental melts as a function of the degree of melting. Data from 0.5 to 2.2 GPa are from [10]

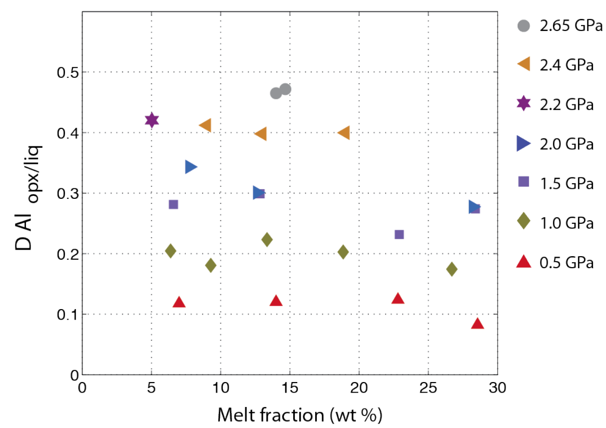

Fig. 2. Partition coefficient of Al between orthopyroxene and the melt in experiments as a fonction of the degree of melting. Data from 0.5 to 2.2 GPa are from [10].