U-Th-Pb EVOLUTION REQUIRES VERY OLD AGE FOR NEWLY FOUND DEPLETED SHERGOTTITES. A. Bouvier[1], J. Blichert-Toft[2], F. Albarède[2], A. El Goresy[3], C. B. Agee[4], and P. Gillet[5]. [1]University of Minnesota, Minneapolis, USA (abouvier@umn.edu), [2]Ecole Normale Supérieure de Lyon, France, [3]Bayerisches Geoinstitut, Bayreuth, Germany, [4]University of New Mexico, Albuquerque, USA, [5]Ecole Polytechnique Fédérale de Lausanne, Switzerland.

Introduction: Martian meteorites (~110 indentified) remain the only rock specimens available for isotopic and chronological investigations of the evolution of Mars' interior. Deciphering the chronology of crystallization and secondary processes in Martian meteorites provides constraints on the differentiation, alteration and shock processes observed in these rocks and by extension on Mars. Among the different petrological groups of SNC meteorites, shergottites, nakhlites and chassignites, the chronology of shergottite formation is not agreed upon (e.g., [1, 2]). The Pb isotopic compositions of mineral separate and whole-rock residues of 13 individual shergottites analyzed so far define two distinct Pb-Pb mineral isochrons corresponding to ages of 4.1 Ga (enriched and intermediate shergottites; E and I) and 4.3 Ga (depleted shergottites; D) ([1] and refs. therein). These Noachian Pb-Pb ages for shergottites contrast with results obtained from long-lived parent-daughter-based chronometers (U-Pb, K-Ar, Rb-Sr, Sm-Nd, Lu-Hf), which systematically yield younger 0.1-0.6 Ga ages (e.g., [2-4]). However, concordant ages using different chronometers including Pb-Pb are found for nakhlites and Chassigny at ~1.3 Ga [1], and at ~4.1 Ga for the ungrouped orthopyroxenite ALH 84001 [1, 5]. Additionally, two newly identified martian basaltic breccia meteorites, NWA 7034 with a Rb-Sr age of ~2.1 Ga [6], and the probably paired stone NWA 7533 [7], are found to not be genetically related to SNCs. Interestingly, NWA 7034 is the only martian meteorite chemically very similar to orbital and lander analyses of martian terranes [6]. To shed new light on the relationship and crystallization histories of martian meteorites, we here present the results of our continued Pb-Pb investigations of five new martian meteorites.

Samples and methods: We analyzed the Pb isotopic compositions of three D shergottites, the NWA 1950 and NWA 6162 finds, as well as the witnessed fall meteorite Tissint, one E shergottite, NWA 4468, and the enriched basaltic breccia, NWA 7034. About 0.5 to 0.8g chips taken from 1.5 to 2g samples of each meteorite were grinded to whole-rock (WR) powders using an agate mortar. For Tissint, abundant dark glass was hand-picked prior to powdering. The remaining material was processed for mineral separation by gravimetry for the shergottites and by hand-magnet for NWA 7034 [1, 6]. About 0.1 to 0.3g of the WR powders and mineral fractions were further processed for leaching, dissolution and Pb extraction as previously described in [1]. Specifically for acid-washing procedures, NWA 6162, Tissint and NWA 7034 WR were leached over 3 steps (30mn @100°C 1.5M HBr, 2h @120°C 1M HF, and 1h @120°C 6M HCl), while NWA 1950 and NWA 4468 WR and minerals were leached over 4 steps with an additional intermediate step in 3M HNO_3 for 1h @100°C. The Pb isotopic analysis of Tl-doped samples were carried out by MC-ICP-MS at 200V/ppm on a Nu Plasma HR and at 1000V/ppm on a NeptunePlus both equipped with 100µl/mn nebulizers at ENS-Lyon.

Results: In a $^{208}Pb/^{206}Pb$ vs. $^{204}Pb/^{206}Pb$ diagram, we find that all SNC meteorites, including our new data and NWA 7034, fall onto a common regression line with radiogenic $^{208}Pb^*/^{206}Pb^*$ of ~1 (Fig. 1), consistent with an evolution based on the initial Solar System composition [8]. Only ALH84001 mineral and WR residues [1] have fractionated Pb isotopic systematics with lower $^{208}Pb/^{206}Pb$.

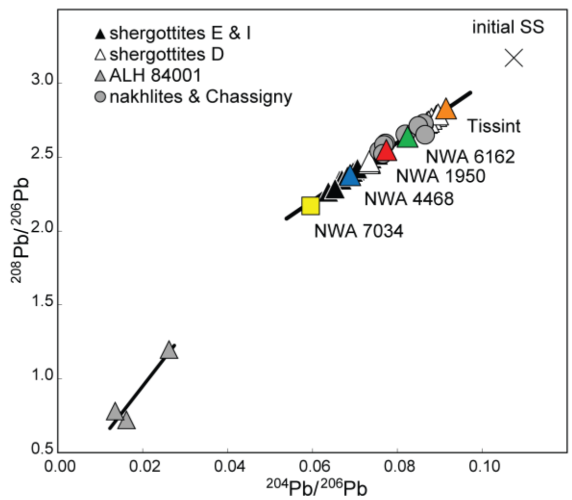

Figure 1: $^{208}Pb/^{206}Pb$ vs. $^{204}Pb/^{206}Pb$ of whole-rock (WR) residues of enriched (E), intermediate (I), and depleted (D) shergottites, and WR and mineral residues of ALH 84001, and nakhlites and Chassigny in grey scale symbols from the literature ([1] and refs. therein), shown together with new Martian WR meteorite data for NWA 1950 (D), NWA 4468 (E), NWA 6162 (D), Tissint (D), and NWA 7034 (bas. breccia). Also shown is the initial composition of the Solar System [8].

In $^{207}Pb/^{206}Pb$ vs. $^{204}Pb/^{206}Pb$ space, NWA 4468 mineral and WR residues are consistent with other E and I shergottites analyzed previously [1], and fall on a

~4.1 Ga isochron (Fig. 2). The Pb isotopic compositions of NWA 1950, 6162, and Tissint are in agreement with previous data on QUE 94201 [4] and NWA 1195 [1] D shergottites. Taken together, Tissint and NWA 6162 WR residues and leachates L2 and L3 indicate a Pb-Pb age of 4.33±0.18 Ga. The composition of NWA 7034 WR residue and last 2 leachates fall near the BSE composition (Fig. 2), but are not consitent with the E and I shergottite isochron. Instead NWA 7034 WR residue and leachates together define an imprecise ~0.9 Ga Pb-Pb errorchron. Mineral Pb isotope analyses are under way to obtain an internal Pb-Pb isochron age for NWA 7034.

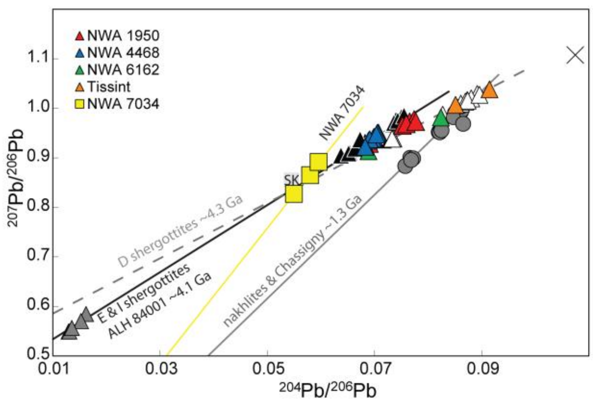

Figure 2: $^{207}Pb/^{206}Pb$ vs. $^{204}Pb/^{206}Pb$ for literature data from WR and maskelynite residues of E, I and DS, N&C, and ALH 84001 (see Fig. 1 for symbols and refs.), as well as new data (residues and last leachates of WR and mineral separates) for NWA 1950, 4468, 6162, 7034, and Tissint. Also shown is the Pb isotopic composition of the modern terrestrial average SK [10], and the initial Solar System [8]. Solid and dashed lines represent the best regression lines through each petrological group of Martian meteorites and their corresponding Pb-Pb ages.

Differentiation and crystallization histories of Martian meteorites: The $^{208}Pb/^{206}Pb$ evolution of SNCs, ALH 84001 and NWA 7034 provides constraints on the long-term Th/U evolution and differentiation history of Mars. The initial $^{208}Pb^*/^{206}Pb^*$ of E and I shergottites is 0.99±0.07. The Pb isotopic compositions of freshly recovered Martian meteorites, such as Tissint, are in agreement with results for NWA 1950 and 6162, as well as with other DS analyzed previously [1,4]. For DS, the initial is $^{208}Pb^*/^{206}Pb^*$ =0.96±0.05. The nakhlites and Chassigny have a slightly higher but less precise $^{208}Pb^*/^{206}Pb^*$ =1.2±0.2 [1]. The lower value of $^{208}Pb^*/^{206}Pb^*$ =0.2±0.2 for ALH 84001 relative to SNCs and the Pb-Pb age of 4.1 Ga identical to E and I shergottites [1] are consistent with significant Th/U fractionation during orthopyroxene/melt fractionation from an enriched shergottitic parent magma and crystallization at 4.1 Ga [1, 9]. The $^{208}Pb/^{206}Pb$ systematics of NWA 7034 WR are consistent with martian Pb isotopic evolution. All SNC meteorites, the two E plus I and D shergottite groups at 4.1 and 4.3 Ga, respectively, and nakhlites and Chassigny at 1.3 Ga, indicate a U-Th-Pb evolution at constant Th/U (~3.9, see Fig. 5 in [1]) for Mars, which is similar to the Th/U deduced for iron meteorites [8], chondrites [11], and Earth [10]. Young shergottites would indicate an anomalous and variable Th/U (~3.2) for Mars' interior, which would be at odds with any other known planet from the Solar System. In terms of U-Pb systematics, the Tissint WR residue has the least radiogenic and most pristine Pb isotopic composition measured so far for a martian sample, with $^{206}Pb/^{204}Pb \approx 10.93$. In addition, we deduce an integrated $^{238}U/^{204}Pb$ (μ_1 [1]) of ~1.5 at 4.568 Ga. If the crystallization age of Tissint was instead 0.6 Ga [12], this composition would correspondond to a nearly chondritic U/Pb evolution for the source of Tissint's parental magma. NWA 7034's ^{207}Pb-^{206}Pb systematics indicate a distinct and younger evolution than shergottites.

There is overwhelming evidence from petrological observations that shergottites are by far the most intensely shocked rocks of the SNC suite [13]. Shock-induced pervasive melting in at least 23 vol.% of the shergottites consisting of maskelynite and pyrrhotite, partial melting of pyroxene, titanomagnetite, and ilmenite, and observations of several high-pressure polymorphs and pressure-induced dissociation reactions [13] must have dramatically affected the isotopic systematics of parent-daughter-dependent chronometers. Under such conditions, the interpretation of the young parent-daughter-based radiometric ages of shergottites as being crystallization ages is precarious, especially when considering their coincidence with a well-indentified late major impact event. The Pb-Pb chronometer has the strong advantage of being unaffected in old silicate minerals by recent events [1, 8].

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