LU-HF AND SM-ND AGES AND SOURCE COMPOSITIONS FOR DEPLETED SHERGOTTITE TISSINT. T. E. Grosshans[1], T. J. Lapen[1], R. Andreasen[1], and A. J. Irving[2], [1]Dept. of Earth and Atmospheric Sciences, University of Houston, TX, USA (thera.grosshans@gmail.com), [2]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA.

Introduction: Tissint is the fifth witnessed Martian meteorite fall and was collected in Morocco in 2011. The quick recovery of this meteorite limits the possibility of weathering or contamination by terrestrial components. Early studies determined Tissint to be a depleted olivine-phyric shergottite similar in bulk composition to Dar al Gani 476 and EETA79001A. It has a porphyritic texture with primary mineral phases of olivine, plagioclase (maskelynite), and pyroxene (augite and pigeonite). Other phases include oxides (chromite, ilmenite, magnetite) and phosphate [1,2].

A previously published ^{143}Nd-^{144}Nd age of 596 ± 23 Ma indicates Tissint to be one of the oldest known shergottites [3]. Tissint's ejection age of 1.05 ±0.15 Ma is similar to those for other depleted olivine-phyric shergottites, and suggests that a single impact event ejected several depleted shergottites together [4].

Here we present trace element abundances for the major constituent phases of Tissint, Lu-Hf and Sm-Nd ages, and initial isotope data. Lu-Hf and Sm-Nd source compositions are calculated from internal isochrons and compared with previously published data for Tissint and other shergottites and ALH 84001.

Methods: Two samples of Tissint were analyzed for this study. A thick section was analyzed by laser ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS) at the University of Houston to measure trace element abundances of the major constituent phases. The abundances of Hf and Nd were also used to estimate the amount of spike to add to the samples.

The other sample consisted of a 1 g interior piece of Tissint that was crushed using a boron carbide mortar and pestle and sieved. Mineral fractions were separated using heavy liquids separation. To ensure the purest mineral grains are analyzed, the mineral aliquots were picked using tweezers and a binocular microscope. Approximately 30 mg of the powder collected after sieving was used for the 'whole rock' fraction. Mixed ^{176}Lu-^{178}Hf and ^{149}Sm-^{150}Nd spikes were added to each mineral and bulk fractions prior to sample digestion. After digestion, the fractions were run through a chemical separation process to isolate Lu, Hf, Sm and Nd. These elements for each aliquot were analyzed on the Nu Plasma II MC-ICP-MS at the University of Houston to measure isotope ratios for isochron calculations.

Results: *REE Concentrations*: The average chondrite-normalized REE concentrations of the primary phases are represented in Figure 1. Concentrations of most REE in olivine are under the detection limits of the LA-ICP-MS and, therefore, are not plotted in the diagram. Based on the low REE concentrations in olivine, it was not analyzed for isotopic compositions for the Lu-Hf and Sm-Nd isochrons.

Preliminary *in situ* trace element analyses of plagioclase and pyroxene show similar REE patterns to bulk Tissint and other depleted shergottites. The bulk rock and mineral compositions show depletion in LREE with an increasing slope from LREE to middle REE and a moderately flat pattern from the middle to HREE elements. A high positive Eu anomaly is observed in plagioclase whereas pyroxene exhibits a low to moderate negative Eu anomaly. The steep slope for LREE of plagioclase may indicate mixed phase analyses.

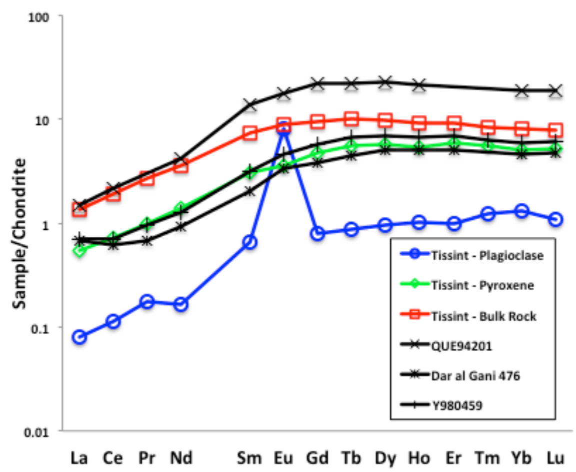

Figure 1. Chondrite-normalized REE abundances for Tissint phases (this study), bulk Tissint and other depleted shergottites. Chondrite and bulk rock abundance data from [1, 2, 5-8].

Lu-Hf Isotope Systematics: A preliminary Lu-Hf age of 583 ± 86 Ma was determined from the plagioclase and pyroxene fractions. The calculated initial ^{176}Hf/^{177}Hf isotope ratio is 0.284057 ± 0.000046. The initial ε^{176}Hf of Tissint is +58.0, nearly 10 epsilon units higher than that of QUE 94201 (+49.5) [9] and DaG 476 (+50.4) [10]. The initial ^{176}Hf/^{177}Hf ratio and ε^{176}Hf indicate Tissint was derived from one of the most depleted Martian mantle sources yet measured.

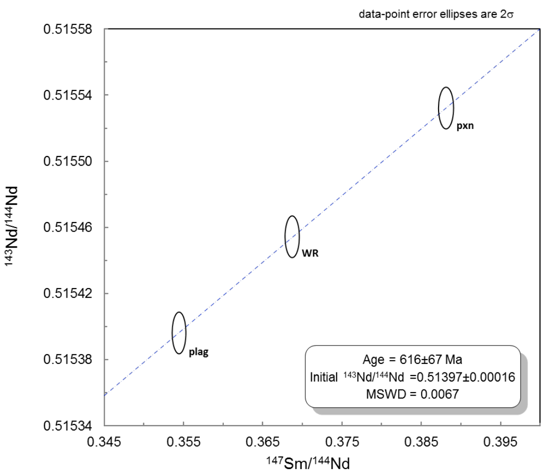

Figure 2. Sm-Nd internal isochron diagram derived from plagioclase, pyroxene, and whole rock fractions using Isoplot (v. 4.13).

Sm-Nd Isotope Systematics: The Sm-Nd age of Tissint determined from the plagioclase, pyroxene, and whole rock fractions is 616 ± 67 Ma (2σ; MSWD = 0.0067; Figure 2). The initial $^{143}Nd/^{144}Nd$ isotope ratio is 0.51397 ± 0.00016. The initial εNd is 41.6, close to values for DaG 476 (+38.9) and SaU 008 (+39.1) [10], and lower than for QUE 94201 (+47.6) [11]. The Sm and Nd concentrations in the oxide fraction were too low to measure and were not used for the Sm-Nd isochrons.

Source Compositions: The source $^{176}Lu/^{177}Hf$ and $^{147}Sm/^{144}Nd$ isotope ratios of Tissint and other shergottites are calculated assuming a differentiation age of 4.513 Ga and CHUR parameters of Bouvier et al. [12]. The decay constants used for ^{176}Lu and ^{147}Sm are 1.865 x 10^{-11} a^{-1} and 6.54 x 10^{-12} a^{-1}, respectively.

The calculated source $^{176}Lu/^{177}Hf$ isotope ratio of Tissint is 0.0555, similar to those for other depleted shergottites DaG 476 (0.0520) and SaU 008 (0.0511) [calculated from 10]. The calculated source $^{147}Sm/^{144}Nd$ isotope ratio of Tissint is 0.279, identical to the ratio presented in Brennecka et al. [3], and similar to ratios for QUE 94201 (0.284), DaG 476 (0.271), and SaU 008 (0.271) [calculated from 10,11].

Discussion: The internal isochron Lu-Hf and Sm-Nd ages of 583 ± 86 Ma and 616 ± 67 Ma are within error of the previously published $^{143}Nd/^{144}Nd$ age of 596 ± 23 Ma [3]. These ages establish Tissint as the oldest known shergottite (except possibly Dhofar 019). Initial $\varepsilon^{176}Hf$ and $\varepsilon^{143}Nd$ values of +58.0 and +41.6 indicate Tissint was derived from a highly depleted source like those for other depleted shergottites.

Calculated source $^{176}Lu/^{177}Hf$ and $^{147}Sm/^{144}Nd$ compositions of 0.0555 and 0.279, respectively, are plotted on a binary mixing array defined by enriched,

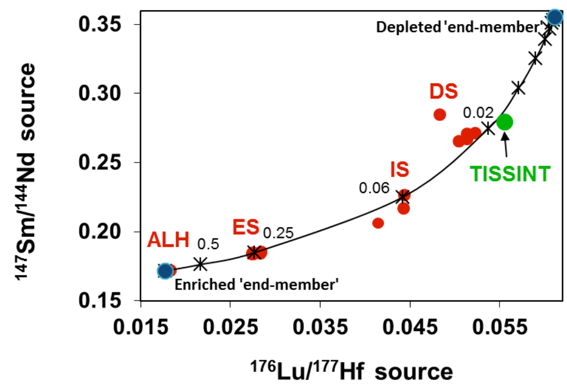

Figure 3. Mixing diagram for shergottites and ALH 84001 $^{147}Sm/^{144}Nd$ and $^{176}Lu/^{177}Hf$ source compositions. Red dots are shergottites; DS = depleted shergottites; IS = intermediate shergottites; ES = enriched shergottites; ALH = ALH 84001. The black binary mixing line is based on source compositions of cumulates (enriched end-member) in the upper mantle assemblage (UM1) of [10] produced in a 2000 – 1350 km deep magma ocean. Isotope data used for the source calculations of shergottites come from [9-10, 12-17]. Labeled mixing proportions (black symbols) are based on the fractions of residual trapped liquid.

intermediate, and depleted shergottites (Figure 3). Tissint plots as a depleted end-member and close to the mixing curve. Calculated source compositions indicate Tissint derived from a source that is the most depleted in trace elements, and has the largest fraction of cumulates to residual trapped liquids [13] compared to other shergottites. The location of Tissint on this mixing array improves the definition of the depleted end-member on this mixing curve.

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