

## Sm-Nd AND Rb-Sr ISOTOPIC SYSTEMATICS OF A HEAVILY SHOCKED MARTIAN METEORITE TISSINT AND PETROGENESIS OF DEPLETED SHERGOTTITES.

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**Introduction:** Tissint is a very fresh Martian meteorite that fell near the town of Tissint in Morocco on July 18, 2011. It contains abundant olivine megacrysts (~23%) in a fine-grained matrix of pyroxene (~55%), maskelynitized plagioclase (~15%), opaques (~4%) and melt pockets (~3%) and is petrographically similar to lithologies A and C of picritic shergottite EETA 79001 [1,2]. The presence of 2 types of shock-induced glasses and all 7 high-pressure mineral phases that were ever found in melt pockets of Martian meteorites suggests it underwent an intensive shock metamorphism of ~25 GPa and ~2000°C localized in melt pockets [2]. Mineral textures suggest that olivines, pyroxenes and plagioclases probably did not experience such high-temperature. Earlier determinations of its age yielded 596±23 Ma [3] and 616±67 Ma [4], respectively, for the Sm-Nd system and 583±86 Ma for the Lu-Hf system [4], in agreement with the 575±18 Ma age of the oldest olivine-phyric depleted shergottite Dho019 [5]. However, the exposure ages of Tissint (~1 Ma [1, 6, 7]) and Dho 019 (~20 Ma [8]) are very different requiring two separate ejection events. These previously determined Sm-Nd and Lu-Hf ages are older than the Ar-Ar maskelynite plateau age of 524±15 Ma [9], reversing the pattern usually observed for Martian meteorites. In order to clarify these age issues and place models for Tissint's petrogenesis on a firm basis, we present new Rb-Sr and Sm-Nd isotopic results for Tissint, and discuss (a) the shock effects on them and the Ar-Ar chronometer, (b) correlation of the determined ages with those of other depleted shergottites, and (c) the petrogenesis of depleted shergottites. Since the meteorite is a recent fall, terrestrial contamination is expected to be minimal, but, the strong shock metamorphism might be expected to compromise the equilibrium of the isotopic systems.

**Samples and Analytical Procedures:** Many small interior fragments of Tissint and one chunk with fusion crust, weighing a total of ~2.5 g was allocated for this study. After chipping off fusion crust fragments, the sample was crushed gently to pass a nylon sieve of opening size <149 µm. About 400 mg was taken as the bulk rock sample (WR). The rest of the sample was sieved into 74-149 µm and 44-74 µm size fractions. Mineral samples were separated from the 74-149 µm size fraction. The non-magnetic plagioclase (Plag) and the most magnetic opaques (MM) were separated by a Franz magnetic separator at a current of 0.8 A. Two more plagioclase samples, 3 pyroxene samples (Px) and 1 olivine sample (Ol) were further separated using combinations of magnetic susceptibilities and densities. In addition, the bulk rock (WR) and all mineral samples except MM were washed with HCl (1N for Plag and Ol and 2N for WR and Px) in an ultrasonic bath for 10 minutes to eliminate possible post-crystallization, extra-terrestrial, or terrestrial, contamination. Residues(r) of acid-washed bulk rock and mineral samples, WR leaches (l) and the combined acid washes from all minerals (Leach) were analyzed.

**Sm-Nd isotopic results:** Fig. 1 shows <sup>147</sup>Sm/<sup>144</sup>Nd and <sup>143</sup>Nd/<sup>144</sup>Nd data for fifteen Tissint samples (red circles). All fifteen data points define a linear array (blue line) corresponding to a Sm-Nd age of 472±36 Ma for  $\lambda(^{147}\text{Sm})=0.00654 \text{ Ga}^{-1}$  and an initial  $\epsilon_{\text{Nd}}=+44.4\pm 1.0$  using the Isoplot regression routines [10]. The data deviate from the isochron by <1.5  $\epsilon$ -unit (see inset). The deviations probably are caused by the heavy shock metamorphism that the meteorite experienced [2]. This age agrees with those of DaG476/Y980459 (470±12 Ma [11,12]) and SaU 094/005 (445±18 Ma [13]), but is significantly younger than the earlier ages reported by [3,4] for Tissint and by [5] for Dho 019. This younger age is also in marginal agreement with the Ar-Ar plateau age (524±15 Ma) for maskelynite grains [9] and the Rb-Sr isochron age (next section) and represents the crystallization age of Tissint. The proposed old ~4.3 Ga Pb-Pb model age for depleted shergottites and Tissint [14], does not agree with our Sm-Nd isotopic data. Simply put, the initial  $\epsilon_{\text{Nd}}$  values calculated for Tissint at the presumed old age are unreasonably low, e.g., -40 for Leach (phosphates) to -190 for pyroxenes (most resistant mineral). Concordant Sm-Nd, Ar-Ar and Rb-Sr ages for a less shocked Martian shergottite, NWA 1460, also were previously interpreted as a crystallization age (346±17 Ma) [15]. Initial  $\epsilon_{\text{Nd}}$  and ages for seven depleted shergottites studied so far are summarized in Fig. 2. The figure clearly shows that at least four igneous events related to the formation of depleted shergottites are identified from five or six isotopically distinct sources of superchondritic <sup>147</sup>Sm/<sup>144</sup>Nd (0.264-0.283, blue dotted lines, red line for Tissint). The magmatic activities spanned ~250 Ma. Variable exposure ages for these meteorites suggest that they came from at least four impact-ejection events. Tissint, along with DaG476, SaU005/094, and Y980459 could be derived from a basaltic complex of ~472 Ma old terrane on Mars by a single ejection event ~1 Ma ago.

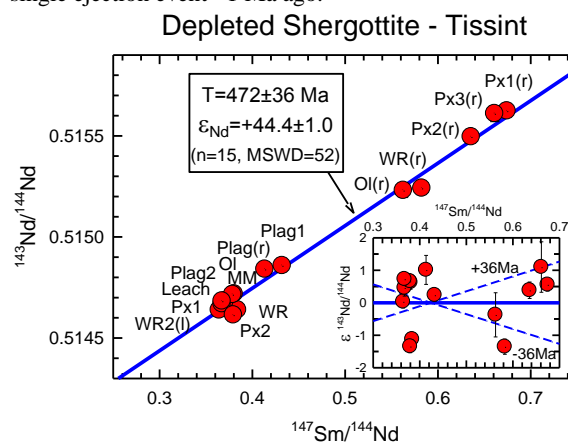


Figure 1. Sm-Nd isochron of Tissint.

