THE TISSINT DEPLETED PERMAFIC OLIVINE-PHYRIC SHERGOTTITE: PETROLOGIC, ELEMENTAL AND ISOTOPIC CHARACTERIZATION OF A RECENT MARTIAN FALL IN MOROCCO.

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Fall History: At about 2 am local time on July 18, 2011 a bright fireball was observed by several different people in the region of the Oued Drâa valley, east of Tata, Morocco. Observers reported that it was at first yellow in color, and then turned green before it appeared to split into two parts. One portion appeared to fall in the valley, while another portion was seen to strike a prominent mountain (Laglab). In October 2011 nomads began to find very fresh, fusion-crusted stones in a remote area of the Oued Drâa intermittent watershed, south of Tanzrou and southwest of Tissint; broken crusted stones were also found on Laglab mountain. A total of over 7 kilograms of stones was collected by local people.

Physical Characteristics: Some stones (both larger and smaller) are almost completely coated by glistening black fusion crust, characterized by thicker layers on exterior ridges as well as much glossier regions (above interior olivine macrocrysts) – see Figure 1. Some stones have thinner secondary fusion crust on one or more surfaces (see Figure 1a). The crust on many stones has been broken in places (presumably upon striking the ground) to reveal the interior, which appears overall pale gray in color with larger, very pale yellow olivine macrocrysts, and sporadic small pockets and some very thin veinlets of black glass. No terrestrial weathering is evident.

Petrography: The rock is porphyritic, with olivine macrocrysts (up to 1.5 mm) and microphenocrysts (up to 0.4 mm) set in a finer groundmass of patchily zoned pyroxene, plagioclase (maskelynite; $An_{61.1-64.3}Or_{0.5-0.4}$), Ti-poor chromite, ilmenite, pyrrhotite and minor merrillite. Both the larger olivine macrocrysts (cores $Fa_{19.4-20.2}$, FeO/MnO = 42-44) and smaller olivine microphenocrysts ($Fa_{29.1-30.2}$; FeO/MnO = 45-46) exhibit thin ferroan rims ($Fa_{43.2-60.4}$, FeO/MnO = 50-55) against the groundmass, and contain tiny chromite inclusions. Narrow ferroan zones also occur within the interior of some olivine macrocrysts, suggesting that they may be agglomerated early-formed crystals that had previously reacted with melt. Pyroxenes contain orthopyroxene cores ($Fs_{24.0-24.4}Wo_{4.1-4.6}$, FeO/MnO = 30-32), pigeonite ($Fs_{26.1-51.6}Wo_{11.9-16.9}$, FeO/MnO = 31-35) and subcalcic augite ($Fs_{21.7-23.3}Wo_{25.0-24.2}$, FeO/MnO = 26-28).

Figure 1. **a.** (top) *987 gram stone with both primary and secondary fusion crusts. Photo © A. Aaronson.* **b.** (middle) *147 gram fusion-crusted stone. Photo © S. Ralew.* **c.** (bottom) *297 gram broken stone. Black glossy objects are olivine macrocrysts visible through the primary fusion crust. Photo © R. Chaoui.*

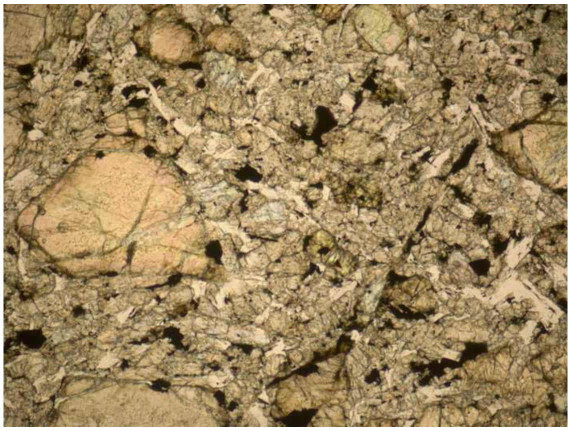

Figure 2. *Plane light optical thin section image. Olivine (pinkish), pyroxene (pale gray), maskelynite (white), opaques and shock melt veinlet (black). Width of field = 2.37 mm.*

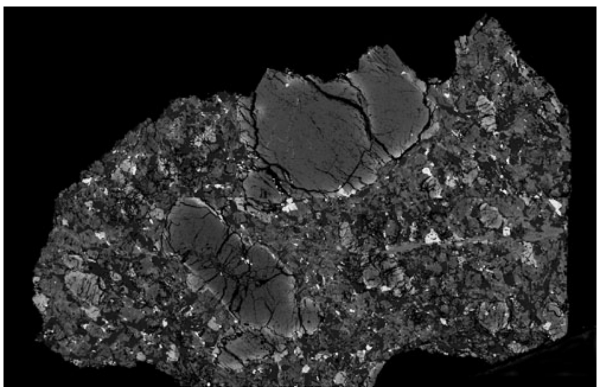

Figure 3. *Back-scattered electron image (width = 5.5 mm) showing two olivine macrocrysts with ferroan reaction rims. Brightest grains are chromite and pyrrhotite; darkest grains are plagioclase. A shock melt veinlet is visible at center right.*

Oxygen Isotopes: Analyses of two acid-washed whole rock subsamples by laser fluorination gave, respectively: $\delta^{18}O$ = 4.844, 4.943; $\delta^{17}O$ = 2.849, 2.892; $\Delta^{17}O$ = 0.299, 0.290 per mil. These results plot in the upper part of the range for many other shergottites [1].

Bulk Elemental Composition: Powder prepared by grinding 1.25 grams of interior material in an agate mortar was analyzed by ICP-MS. The REE pattern in Figure 4 is probably not representative of the bulk specimen, since the prepared powder likely undersampled the macrocrysts. Preliminary abundances (all in ppm) are as follows:

La	0.29	Eu	0.44	Er	1.42	Rb	0.36
Ce	1.07	Gd	1.77	Tm	0.19	Sr	31.9
Pr	0.22	Tb	0.35	Yb	1.23	Ni	186
Nd	1.47	Dy	2.29	Lu	0.18	Co	45
Sm	0.95	Ho	0.49	Hf	0.96	Pb	0.25

A representative bulk major element composition would be difficult to obtain because of the irregular distribution and size of olivine macrocrysts, but by analogy with Northwest Africa 6162 [2] Tissint is almost certainly permafic (or even ultramafic).

Sr-Nd-Hf Isotopic Compositions: Radiogenic isotopic compositions and other elemental abundances are being determined for presentation.

Discussion: Tissint is a fairly primitive Martian magmatic rock, but as with most other such olivine-phyric shergottites the olivine macrocrysts likely have been accumulated into a more evolved liquid. Nevertheless, it seems clear that Tissint has affinities to the depleted mantle source on Mars, and is related to (and possibly launch-paired with) SaU 005, NWA 1195, NWA 2046, NWA 2626, NWA 4925, NWA 5789, NWA 6162, DaG 476 and Yamato 980459.

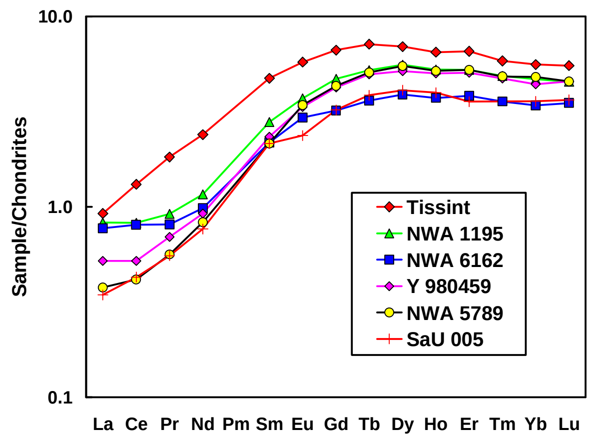

Figure 4. *Chondrite-normalized bulk REE abundances for Tissint and other depleted olivine-phyric shergottites [2, 3, 4, 5 – Eu data for NWA 1195 reported in [5] was corrected for Ba interference].*

Significance: Tissint represents the fifth witnessed fall of a Martian meteorite (the last one being Zagami 49 years earlier) and the first such olivine-phyric shergottite example. The extreme freshness of this material will permit important studies to reassess the effects of desert weathering and organic contamination in meteorites of similar type. Measurements of short-lived cosmogenic nuclides should allow independent confirmation of the timing of this special fall.

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Website: http://www.imca.cc/mars/martian-meteorites.htm