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# Carbonaceous particles in rock of the Tissint martian meteorite

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## Abstract

Carbon-rich globules and plates sized 10-50µm in the Tissint martian meteorite lie within the fragile rock, made up of loosely consolidated micro-fragments. It is interpreted as wind-blown martian dust with rather few carbonaceous spheroids that became buried in the regolith until the impact ejection event.

## 1. Introduction

The Tissint meteorite is one of the few meteorites observed on arrival in July 2011 and pieces were picked up after 3 months in the Moroccan desert [0]. Most of the 60 or so martian meteorites have been picked up in bio-active sites, or after years stored in museum collections, or in Antarctica millennia after falling, and potentially have significant terrestrial contamination. Tissint was likely to have little contamination, as is found in our specimen. Tissint belongs to the olivine-phyric subgroup of shergottites and is a depleted permafic variation [2]; our sample is very friable.

The preliminary electron-microscopy of the cm-sized fragment under study in Cardiff found carbon concentrated in globule and plate structures, within jumbled micron-sized mineral grains [3]. The latter include olivine microcrysts, which are interpreted as indicating an aqueous phase on Mars [2]. The Shergotty meteorite of 1865 [1] indicates an aqueous environment for several centuries and a volcanic origin 165-300 Myr ago [4]. While Tissint may have been ejected from Mars by the same impact event, it could still be geologically different being ejected perhaps 100km away from Shergotty itself.

Carbon in the celebrated Alan Hills martian meteorite (ALH84001) has been intensively studied, both in reduced (PAH hydrocarbon) and carbonate forms, and in 'biomorphs' taken as indicators of potential fossil microbes [5]. Dendritic carbon was found in the Nakhla meteorite, filling fractures and containing complex carbonaceous compounds (found by laser-Raman spectrometry) [6], but there are arguments for it being terrestrial contamination. Other work on 11 meteorites including Tissint has found reduced carbon in the form of complex hydrocarbons that might have been formed by volcanic processes [7].

## 2. Present Study

Our sample of Tissint showed no fusion crust [2] from atmospheric friction, implying it was an interior fragment. We broke it up (clean handling in laminar flow cabinet) to find fresh interior surfaces for study.

We found several 10-50µm globules and plates in SEM images, embedded in the porous rocky matrix to various extents, which EDAX spectra showed to be carbon/oxygen-rich. The 10µm egg-shaped globule in Fig. A was reported earlier [3] and is here shown in the very rough substrate of scale 1-10µm with a diagonal crack that shows bulk coherence. The 20µm 'potato' in Fig. B in similarly rough aggregate has moved slightly and retains small fragments attached to its upper surface. Its surface structure is pock-marked, maybe by previously-adjacent angular fragments.

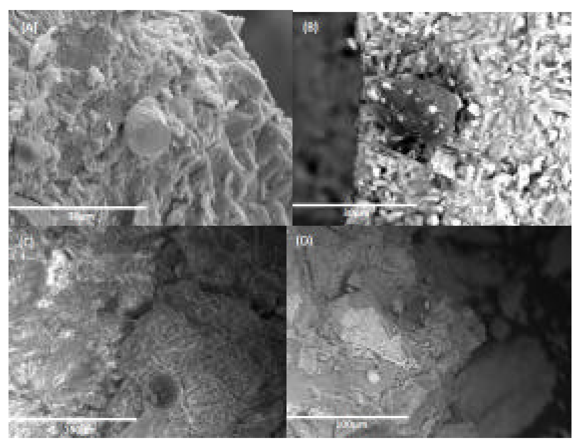

**Figure 1 : (A) cracking of the coating on the 'egg' (gold-coating used for the electron microscopy), due to expansion under heating by the electron beam. Note the diagonal crack in the substrate, lower left to upper right under the top of the 'egg'. (B) is without gold coating, showing more clearly the angular rock dust. The gaps above and right of the 'potato' indicates it broke loose from the substrate during the fracturing. (C) the large 'dinner plate' is in more processed rock – note the 20µm cracked crystal below it and the large scale crack to its left continuing above it to the right, both appearing to be original. (D) the 100µm area below and left of the deformed plate is also continuous, but with cracks that might have arisen in the meteorite's ejection and landing phases.**

The 50µm circular plate in Fig. C is similar to a 30µm plate shown previously [3], but with biofilm and stick attached – in this case only rock fragments are on the plate, plus slight pock-markings and 2-3µm damage-sites. The 25µm deformed plate in Fig.D shows similar rock fragments and damage.

## 3. Discussion

The working presumption is that these carbonaceous particles were accumulated among largely mineral dust by martian winds, that form into an aggregate rock under largely dry conditions typical of martian equatorial and mid-latitudes. A few mm-sized olivine grains are reported in other samples of Tissint, but ours appears to have only very fine micron-sized grains, accompanying the larger carbonaceous particles. This corresponds to size-sifting in light winds, that selects larger particles only with low density. Figs. (A) and (B) show loosely aggregated µm-sized grains with angular points unabraded. (C) and (D) show coherent areas of rock; these could arise, we hypothesise, through the daily frosting and sublimation of water on a surface that remained exposed over months or years. Also, irradiation from solar UV and cosmic rays play a part in weathering.

Subsequently fresh dust arrived to cover it and the whole became buried under metres (1-10m) of dust overburden. Burial could even be to 100s metres, as evidenced by the North Polar cap layered terrain, and still remain in the dry regolith, higher than any deep internal permafrost or frozen ocean. The deposit consolidates under pressure into the loose rock. Consolidation was sufficient to ensure ejection as a coherent rock by the impact that ejected Tissint and associated shergottites into space. There are significant differences over crustal rocks over the 100km scale of an impact crater to produce the observed variety of olivine-phyric shergottites.

The carbonaceous particles suffered little mineralisation during the frosting period and once buried were safe from bio-degradation in the sterile environment. But it underwent physical and possibly some chemical degradation over the aeons of burial. The pressure was inadequate to collapse some hollow objects (10-15µm A,B) but sufficient to collapse others (25-50µm C,D).

## 4. Summary and Conclusions

The carbon globules and discs are quite unlike the reduced carbon sealed within rocks that could be bio-carbon or generated in volcanic processes [8]. They are unlike the disc-like carbonates reported in ALH84001 [9], of 100µm scale and consistent with remnants of biological structures, thus supporting claims [5] of other biomarkers in two other Mars meteorites.

Only bio-processes are known to concentrate carbon on a 10µm scale, supporting the hypothesis that our objects could be remnants of polysaccharide shells from algal type cells [3]. Laser Raman spectroscopy is underway to look for signatures of reduced (PAH) carbon. Additional detailed study of the C-isotopic signatures could distinguish between indigenous C components (bio and carbonate) and look for evidence of bio-fractionation, as Gibson et al. [4].

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