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Macromolecular carbon as a biomarker in the Martian meteorite 'Tissint'

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Abstract

The Tissint martian meteorite of 2011 is a loosely bound rock aggregate some 300Myr old, ejected from Mars by large impact a Myr ago. It appears to show hydrothermal alteration of the near-surface regolith. It contains crack-filling carbonaceous material as in some earlier martian meteorites, but also a few loosely integrated carbonaceous particles and plates.

1. Introduction

The Tissint meteorite is important for the low terrestrial contamination, being collected after 3 months in the arid Moroccan desert. Recovered fragments of Tissint reveal a fine-grained (pale grey) patchily-zoned matrix of pyroxene, enclosing pale yellow olivine inclusions and small pockets of thin veinlets of black glass. There is particular interest in the carbonaceous material which was in domains of macromolecular form in earlier martian meteorites. Fracture-filling dendritic carbon was studied in Nakhla [1]. Macromolecular carbon (MMC) zones a few microns in size were found in several S martian meteorites, including Tissint [2]. In Tissint it is also crack-filling and – for the first time in our sample – in some carbonaceous spheroids and plates sized 10-50μm within the mineral matrix [3,4] Crack-filling veins and association with pyrite imply hydrothermal precipitation, not the igneous origin previously proposed [2,5]. NanoSIMS separation of carbon isotopes has been found [6] to favour a biogenic origin of the crack-filling material, whose Mars-like high deuterium proves it to be indigenous.

2. Raman spectroscopy results

Raman spectroscopy has been used [1,6] to show the carbonaceous material is of complex kerogenous composition. Our Micro-Raman study of Tissint's carbonaceous coatings in the D-band (Γ_D) imply a complex precursor carbon inventory, comparable to materials of bio-origin (plants, algae, fungi, prokaryotes) that have undergone low-T diagenesis. The Raman D-band (Γ_D) parameters are plotted in Fig.1 against peak metamorphic temperatures; this indicates the processing temperature has not exceeded ~250°C, consistent with hydrothermal precipitation.

3. Discussion

Figure 2 plots I_D / I_G against Γ_D for fossils extracted from a variety of comparative sources. Samples with complex precursor carbonaceous inventories divide into three clusters, with Tissint clustering with the Rhyne chert, Gunflint chert and Murchison CM2 carbonaceous chondrite.

Electron spectroscopy with EDAX shows our carbonaceous material to be rich in O as well as C, demonstrating incomplete diagenesis, which is consistent with an intermediate stage in transition to macromolecular carbon domains [2] integrated in the rock matrix.

4. Summary and Conclusions

Martian surface geology is thought to be dominated by asteroidal impacts, shown by complex shock crystal patterns. Tissint would be an aggregate of impact-dust fragments, which has undergone limited hydrothermal alteration. Hardy prokaryote spores that aggregated with dust-fragments of pulverised rock have retained their circular shape through burial and compression. At higher degrees of diagenesis and compression, they could turn into the MMC (macromolecular carbon) phases studied by Steele et al.(2012) in other martian meteorites. The carbon particles could have been blown from a distant and much different martian environment, but would be an indicator of biology in a recent epoch (~300Myr).

5. Figures

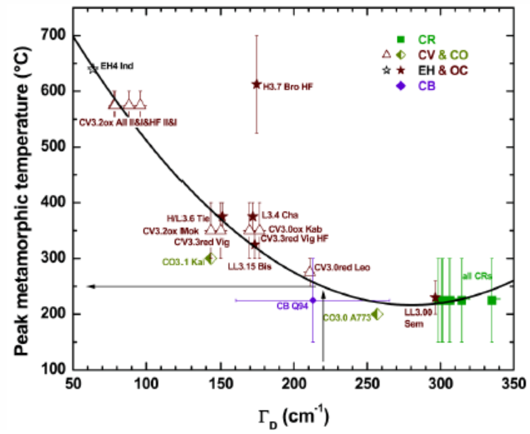

Figure 1: Shows peak metamorphic temperatures as provided by [7] against, Raman D-band (Γ_D) parameter. The fitting curve is a second order polynomial PMT (°C) = 931-5.10 × Γ_D × cm^1 + 0.0091 × Γ_D^2 × cm^2. Also shown is the Γ_D = 220 value determined for the carbonaceous material sampled in the globules observed in Tissint from which it can be inferred that the organic material was subjected to a peak temperature of ~250 °C. Figure adapted from [8].

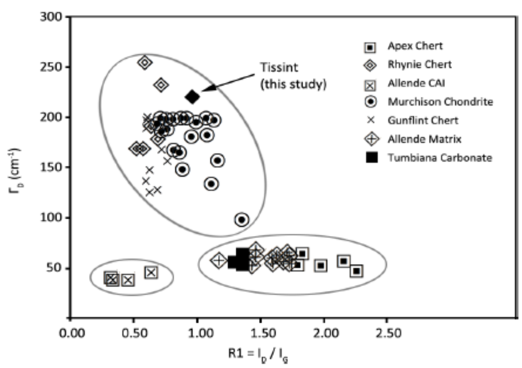

Figure 2. Comparison of I_D / I_D against Γ_D for fossils extracted from a variety of comparative sources. Samples with complex precursor carbonaceous inventories can be seen to cluster - Rhyne chert, Gunflint chert and Murchison CM2 carbonaceous chondrite, T ~ 27-150°C. Similar clustering can be seen in fossils analysed in the Apex Chert and the Tumbiana Formation, T ~ 300-1000°C. Purely graphitic carbon in the Allende CAI , T > 1000°C is also shown. Data and figure adapted from [9].

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