

DIAGENETIC ALTERATION OF CARBON: STAC FADA AS A MARTIAN ANALOGUE

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Introduction: The Stac Fada Member is a Mesoproterozoic (1177±5 Ma) single-layer ejecta impactite exposed in NW Scotland [1, 2]. Its deposition history is potentially analogous to that of impact ejecta on Mars [3]. The Stac Fada lithology is composed ca. 20-35% by volume of devitrified and altered vesicular glass. By using micro-Raman spectroscopy, we ascertain whether these altered impact glasses preserve organic carbon compounds and whether these are of astrobiological significance – i.e. can be classified as biosignatures. Indeed, glass buffers peak exposure temperatures and creates an anoxic environment which can preserve and avoid the degradation of organics over geological time [4].

Methods: Samples were collected of the Stac Fada Member at the Stoer and Second Coast outcrops, as well as from the underlying Clachtoll and Bay of Stoer formations. At the University of Manchester, a Leica DM750 optical microscope was used to locate targets in thin sections. For micro-Raman spectroscopy, we used a Horiba Xplora Plus instrument to collect hyperspectral maps with a typical pixel size of 1.5 µm. A 10 mW laser beam at 5 s exposure was used to avoid altering organics. All spectra were background corrected, cosmic ray reduced, and calibrated against ASTM E 1840 polystyrene [5].

Findings: Raman spectroscopy identifies carbon compounds within the Stac Fada altered glasses that has a characteristic three-peak spectrum: a D-peak at 1325 cm⁻¹, a G-peak at 1580 cm⁻¹, and a third peak at ca. 1440 cm⁻¹ which is likely produced by amorphous, diamond-like carbon. The consistent spectra for nearly all organic matter found within Stac Fada suggests a common origin for organics, likely diamond-like carbon formed at high pressure during the impact event. This amorphous diamond-like carbon has later degraded into graphite and other products. Within melt-rich impact breccia samples, disseminated apatite grains ca. 10 µm in size are preferentially found inside altered impact glass. The original glassy melt has been mostly altered to clays (including illite and chlorite) that host diagenetic minerals such as hydroxyapatite and anatase. Raman spectroscopy identifies shorter-chained polyynes with a characteristic spectral peak at ca. 2150 cm⁻¹ in association with a Ti-O rich mineral, likely titanite. Longer chained polyynes, with a characteristic spectral peak at ca. 2090 cm⁻¹, are associated with apatite, characterised by a peak at ca. 963 cm⁻¹ that likely corresponds to hydroxyapatite.

Implications: Characterisation of the organic inventory of Stac Fada impact melt-bearing impactites suggests that post-depositional alteration of carbon within impactites may create organic carbon species. Similar to the distribution seen in the Ries crater, Germany [6], impact diamonds are ubiquitous within the melt-rich ejecta deposit. A co-association of apatite and titanite with polyynes, as identified by Raman spectroscopy, suggests that diagenetic alteration of carbon into complex organics may be catalysed by these minerals. Given the likely prevalence of impact-bearing lithologies on the surface of Mars, this has important implications in future searches for martian biosignatures. Surface weathering involving fluids are seen in the Black Beauty family of martian meteorites via the precipitation of Mn-oxides [7], and evidence for post-impact hydrothermal alteration is preserved within apatite [8]. Alteration processes seen in the Stac Fada ejecta may be similar to those at the martian surface.

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