Organic matter in Itokawa particles

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The first Hayabusa mission returned samples from the near-Earth S-type asteroid 25143 Itokawa to Earth in 2010 [1]. Although Itokawa has a lithology related to ordinary chondrites (OCs) that typically have low organic contents, several Itokawa particles were found to contain organic matter (OM) [2-5]. However, there was not an explicit conclusion to the origin of the observed OM in these early studies. We have extended our search for OM into other Itokawa grains. Here, we report extraterrestrial OM (macromolecular carbon and amino acids) observed in six Itokawa particles (including a category 1 particle: RA-QD02-0162 [#62; also nicknamed "Amazon"], and five category 3 carbon-rich particles: RA-QD02-0012 [#12], RA-QD02-0078 [#78], RB-CV-0029 [#29], RB-CV-0080 [#80] and RB-QD04-0052 [#52]).

All allocated Itokawa samples were initially analysed by spot and point-by-point mapping Raman spectroscopic analysis at the Open University, UK. Amazon was then transferred and mounted into indium on an aluminium stub, which was studied with a NanoSIMS 50L ion microprobe for its H,C,N isotopic compositions. The rest of the samples were mounted in sterile gold foils, and the amino acid contents of their acid hydrolysed hot water extracts were obtained with a liquid chromatography with tandem fluorescence and accurate mass detection at NASA Goddard Space Flight Center, USA.

Based on the observation of the Raman parameters (e.g. the peak locations and widths of the defect (D) and graphite (G) bands) [6], a significant variety of carbonaceous materials has been observed in Amazon. The carbonaceous materials include primitive and unaltered OM that shares similarity with the IOM in primitive (CI,CM,CR) carbonaceous chondrites, as well as OM that has been heavily graphitised. The organic structure of the heated material is best represented by nanocrystalline graphite, comparable to that observed for metamorphosed meteorites (e.g., L3–6 Inman, Tieschitz and New Concord, CV3 Allende, and EH4 Indarch), suggesting peak metamorphic temperatures (PMT) of >~600°C. The thermal history recorded in the graphitic OM agrees with PMT estimates for returned Itokawa regolith grains (600–800°C) [7].

We have obtained the H,C,N isotopic compositions for the primitive OM in Amazon, which exhibits unambiguously extraterrestrial isotopic signatures ($\delta D = +4868 \pm 2288‰$; $\delta^{13}C = -24 \pm 5‰$; $\delta^{15}N = +344 \pm 20‰$), contrasting to the typically negative isotopic values obtained for terrestrial organic matter [8]. The δD and $\delta^{13}C$ values of the organic material in Amazon are comparable to OCs, however, the $\delta^{15}N$ value is higher than that typically observed for OCs ($\delta^{15}N = -47$ to $+36‰$), and is similar to that of CRs ($\delta^{15}N = +153$ to $+309‰$) [9]. Our data suggest a genetic link between the primitive organic material observed in Itokawa to CRs and IDPs for they share similar D, ^{13}C and ^{15}N enrichments [10].

The high carbon contents of the five category 3 Itokawa particles suggest potentially higher OM abundances, hence we extracted and analysed amino acids in these samples. Although terrestrial contamination was observed primarily as L-protein amino acids, several terrestrially uncommon non-protein amino acids were also observed at low abundances, such as β-aminoisobutyric acid (β-AIB), β-amino-*n*-butyric acid (β-ABA), and β-alanine. Itokawa amino acid content observed here was dissimilar to thermally altered OCs, but preliminarily analogous to more aqueously altered CR2s.

Continued evolution of Itokawa is evident by the infall of primitive organic material derived from CRs/IDPs, accounting for a complex interplay between the remnant Itokawa silicates with exogenous organics. The results reported here are the first evidence of extraterrestrial OM in asteroid material from a sample-return mission, showcasing a working protocol for analysing samples returned by the Hayabusa2 and OSIRIS-REx missions.

References

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