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Organic-inorganic spatial relationships in carbonaceous chondrites

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ORGANIC-INORGANIC SPATIAL RELATIONSHIPS IN CARBONACEOUS CHONDRITES. V. K. Pearson¹, A. T. Kearsley², M. A. Sephton¹ and I. Gilmour¹. ¹Planetary and Space Sciences Research Institute, The Open University, Milton Keynes, MK7 6AA, United Kingdom. ²School of Biological & Molecular Sciences, Oxford Brookes University, Headington, Oxford, OX3 0BP. (v.k.pearson@open.ac.uk)

Introduction: The relationship between organic matter and aqueous alteration in carbonaceous chondrites is well-documented [1,2]. There is a positive correlation between the abundance of organic material and the degree to which carbonaceous chondrites have been aqueously altered [1]. Previous studies have suggested that there is a relationship between organic matter content and the presence of aqueously produced minerals such as phyllosilicates and magnetite [1] that are common matrix constituents. However, this association is poorly characterised and little is known about the spatial relationships between the two. In terrestrial systems, organic material is also found in association with hydrous phases, particularly phyllosilicate minerals [3].

Using a novel organic labelling technique, the location of organic material in carbonaceous chondrites has been investigated. Whole rock samples of Murchison (CM2), Ivuna (CI1) and Orgueil (CI1) were exposed to OsO₄ vapour. Reactions between the organic matter and OsO₄ vapour results in the precipitation of fine-grained osmium metal in regions containing organic compounds. The Os can then be detected using analytical scanning electron microscopy to determine the location of organic matter in relation to other phases within the samples.

Results: *Terrestrial analogues:* To determine whether the Os vapour might also react with inorganic phases within the samples, terrestrial analogues of meteoritic minerals were exposed to OsO₄ vapour under the same conditions as the meteorite samples. X-ray mapping of organic matter-free samples of terrestrial olivine, pyroxenes, carbonates, gypsum, iron oxides, feldspars, serpentines, montmorillonite and saponite showed no evidence of the incorporation of Os.

Murchison: The incorporation of Os within the samples was studied using the Os-M and Os-L X-ray lines. In Murchison an enrichment in Os was observed in the fine-grained alteration rims surrounding anhydrous chondrules and olivine aggregates. These rims are composed of minerals rich in Fe, Si, Ni and Mg, a composition typical of phyllosilicate-type materials. No evidence of Os incorporation was observed in the interior of chondrules or olivine aggregates. In addition, no Os-enrichment was detected surrounding other hydrous minerals such as sulphides or carbonates. No magnetite was observed in the sample of Murchison under investigation.

Ivuna and Orgueil: X-ray mapping of the Os-impregnated surfaces of Ivuna and Orgueil also indicated the preferential incorporation of Os within matrix material. Fig. 1 shows an X-ray spectrum taken from Ivuna. It demonstrates that Os has a distinct association with Mg, Fe, Si and a light element rich mineralogy (phyllosilicate-type material). Conversely, no Os was found in spectra taken from magnetite grains (Fe and O-bearing mineralogy) although several magnetite grains were observed in Orgueil that were apparently coated with phyllosilicate minerals emphasising the need for care in selecting regions for study.

Discussion: X-ray mapping of the three analysed chondrites indicates that Os is preferentially incorporated within matrix material predominantly composed of Fe, Mg, Si and Ni. We consider the matrix material in these regions to be composed mainly of phyllosilicate minerals, consistent with the elemental mapping. Fine-grained examples of these minerals are found within the alteration rims surrounding anhydrous chondrules and aggregates in Murchison. These alteration rims, and the fine-grained matrix surrounding them, are the result of aqueous alteration on the meteorite parent body. Other hydrous phases were also identified including magnetite and sulphides, although magnetite is scarce within Murchison.

These results support our previous suggestion of a genetic link between aqueous mineral phases and the abundance of organic matter in the carbonaceous chondrites [4]. This was based on a strong correlation between organic matter content and the abundance of paramagnetic Fe-bearing minerals from phyllosilicates, while no such correlation was observed with magnetically ordered magnetite. This study reinforces this conclusion by revealing a strong spatial relationship, as indicated by the preferential incorporation of Os by organic matter, between the distribution of phyllosilicate minerals and organic material in the carbonaceous chondrites. It also supports our previous conclusion that organic matter is not closely associated with aqueously produced magnetite.

A further feature observed in Murchison, is an apparent decrease in the abundance of organic material from the outer edges of chondrule rims towards their unaltered cores. Previous studies have made similar observations and concluded this is consistent with an accumulation process involving aqueous alteration and generation of phyllosilicate layers [2].

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The same organic-inorganic relationship has long been accepted within terrestrial systems and has been attributed to the ability for the clay mineral surface to adsorb organic material and trap it within clay layers [3]. This is believed to promote the condensation and development of more complex species such as macromolecular material [5,6] protecting it between the clay layers and enhancing preservation. Processes such as these may be analogous with events that took place on the early earth, providing an important mechanism for the development of primitive life.

Conclusions: Analytical SEM of Os impregnated samples was employed to determine the location of organic matter within the Murchison, Ivuna and Orgueil carbonaceous chondrites. This demonstrated that organic material is intimately linked to the hydrous phyllosilicate mineral phases found within the matrix

material and in the altered rims of chondrules and anhydrous mineral grains. No such association could be made with magnetite. This supports the hypothesis that the phyllosilicate minerals in carbonaceous chondrites may have adsorbed and trapped organic molecules, resulting in their condensation and the formation of more complex species.

References:

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Figure 1. X-ray spectra from a region of the Ivuna carbonaceous chondrite reacted with osmium tetroxide vapour. Solid peaks show the matrix (phyllosilicate) composition (Mg, Fe, Si, Ni and O) along with Os peaks, representative of organic material. Overlain is the X-ray spectra taken from a magnetite grain (Fe, O) indicating no presence of Os staining or, therefore, organic material.

