

Locating organic material in carbonaceous chondrites.

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Identifying the association between organic material and mineral phases is vital for establishing the chemical evolution that took place on asteroidal parent bodies. We present further results of a study in which we have utilised a novel labelling technique to locate organic material within the inorganic matrices of carbonaceous chondrites.

The technique involves subjecting whole rock samples to OsO₄ vapour impregnation, within a sealed canister, for approximately one week. Reactions between the vapour and organic material results in the incorporation of Os into the organic network. This Os can then be detected using scanning electron microscopy (JEOL JSM-840 SEM fitted with an Oxford Instrument's e-XL energy dispersive (EDS) X-ray microanalyser). In this study we have impregnated a whole rock sample of the Tagish Lake carbonaceous chondrite.

The Tagish Lake carbonaceous chondrite is dominated by a fine-grained matrix. Framboidal clusters and interspersed, rounded grains of magnetite are present within the matrix, along with carbonate grains (<10µm), Mg-silicates and Cr-rich grains. The majority of the fine-grained matrix is composed of Fe, Mg and Si-rich material with some S. These observations are consistent with previous studies of the mineralogy of Tagish Lake. Elemental mapping indicates that Os-labelled organic material is located within the matrix but depleted around the other distinct mineral grains. X-ray spectra taken of all mineral phases confirm this. Spectral information and the known mineralogy of this sample have indicated that this organic-accommodating matrix is composed of phyllosilicate minerals.

Osmium tetroxide vapour impregnation provides a valid method of labelling organic material within the carbonaceous chondrite matrix. Identifying organic matter and phyllosilicate minerals in association within Tagish supports our previous proposal that they may be genetically linked.

Phyllosilicates are the products of aqueous alteration of the asteroidal parent body, which contributes to the development of many mineral phases. However, only aqueously generated phyllosilicate minerals appear to contribute to organic evolution. This is significant since minerals may protect organic material from subsequent processing prior to delivery to planetary surfaces.

These results are consistent with a parallel study we have carried out using OsO₄ vapour impregnation on the Murchison, Ivuna and Orgueil carbonaceous chondrites.

The boron isotope approach to paleo-pCO₂ estimation

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The boron isotopic composition ($\delta^8\text{B}$) of calcite is controlled largely by pH (Hemming and Hansen 1992), hence it is possible to reconstruct the paleo-pH of seawater from marine shells. Most useful are planktonic foraminifera, which are abundant in well-dated deep-sea cores and respond to pH in culture (e.g. Sanyal et al., 2001). Because planktonic foraminifera are distributed through the upper water column it is possible to reconstruct pH-depth curves using multiple species.

An example is presented for an equatorial Pacific box core spanning the last de-glaciation. Between-species variations in $\delta^{11}\text{B}$ are consistent with their depth habitats and down-hole variations are interpreted in terms of changes in atmospheric CO₂ and productivity.

On longer timescales it is necessary to consider possible changes in the $\delta^{11}\text{B}$ of seawater (Palmer et al., 1998) and, as in the above example, alkalinity. The approach of pH-depth profiling loosely constrains seawater $\delta^{11}\text{B}$ and the history of changes in the depth of the lysocline may help constrain the alkalinity. Our ability to reconstruct a consistent pH-depth curve in the Eocene (Pearson and Palmer 1999) confirms that a large original $\delta^{11}\text{B}$ signal can be extracted from material of that age.

We have estimated pCO₂ values that are variable and often in excess of 1000ppm in the Paleogene greenhouse, falling to values much closer to pre-industrial for the entire Neogene (Pearson and Palmer 2000). The Paleogene values greatly exceed some recent stomatal-index estimates (Royer et al., 2001), possibly because over evolutionary timescales plant stomata do not respond to high CO₂ in the same way as they do over ecological timescales.

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