

The insoluble organic matter in carbonaceous meteorites

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Carbonaceous meteorites are the most primitive objects of the solar system. They exhibit significant carbon contents mostly occurring as insoluble organic matter (IOM). IOM might be the first OM available on early Earth for life and should provide information on solar system history. It is therefore essential to decipher the chemical structure of IOM.

IOM was isolated from the Murchison meteorite using successive water and solvent extractions and acid treatments (HCl, HF). Its chemical structure was investigated through a combination of various spectroscopic methods (Fourier transform infra-red, solid-state ¹³C and ¹⁵N NMR, electron paramagnetic resonance, X-ray absorption near-edge spectroscopy), chemical (RuO₄ oxidation) and thermal (pyrolysis) degradations and high resolution transmission electron microscopy. The use of these complementary analytical tools yielded key information on the IOM structure at a molecular level and led to 11 quantitative parameters. A statistical model was therefore proposed for this molecular structure, fitting with these 11 parameters.

Moreover, deuterium isotope abundance was determined in individual compounds released through RuO₄ oxidation and pyrolysis pointing to 3 types of H (aromatic, benzylic and aliphatic) with different D enrichment related to the C-H bond strength. This was further confirmed by laboratory experiments. We therefore propose that the IOM formed in a D-poor environment and was then transported and further enriched through exchange in a D-rich medium. EPR studies also revealed that free radicals were the hosts of extreme D enrichments revealed through nanoSIMS.

These results are difficult to reconcile with the usual interpretation according to which high D/H ratios represent survivals of interstellar grains. More likely, the deuterium-enrichment process took place after the formation of organic grains characterized by low D/H ratios, through an isotopic exchange-reaction with D-rich gaseous molecules, such as H₂D⁺ or HD₂⁺. This exchange reaction most likely took place in the diffuse outer regions of the protoplanetary disk around the young Sun.

Element transport and mineral replacement reactions during alkali contact metamorphism

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To study element transport in crustal rocks, high concentration gradients are favorable, as they are present along the margins of peralkaline rocks intruded into common crustal rocks. The 1.16 Ga peralkaline Ilímaussaq intrusion in SW-Greenland is characterized by its high alkali as well as high LILE, HFSE and volatile content. It intruded at the contact between the granitic Julianehåb batholith and a volcano-sedimentary succession [1].

We took 19 samples along a 1 km long profile from the contact of the Ilímaussaq intrusion into the adjacent granite. Accounting for the exponential character of diffusive processes, we chose a close spacing between samples near the contact with increasing distances further away from the intrusion.

Significant contact alteration, accompanied by growth of new minerals (aegirine, arfvedsonite) has been previously reported [2] and can be observed in the field up to a distance of 40 m away from the contact. This is confirmed by stable isotopic data of Li and B [3, 4], supporting diffusive alteration of the contact rocks.

Our whole rock analyses reveal an influence of the alkaline fluids released by the Ilímaussaq complex on the host granite up to ca. 200 m by elevated contents of e.g. Na, Ca and P as well as depletion in Si and K. In addition, batches of eutectic quartz-feldspar intergrowths in the granite up to ca. 10 m from the contact imply partial melting of the granite.

Among the mineral replacement reactions the growth of amphibole and pyroxene at the expense of biotite as well as the replacement of perthitic alkali-feldspar by almost pure albite are most obvious. To get a full insight on replacement reactions and changes in mineral chemistry along the profile, microprobe analyses will be carried out.

[1] Poulsen (1964) *Rapp. Grønl. Geol. Unders.* **2**, 16. [2] Ferguson (1964) *Bull. Grønl. Geol. Unders.* **39**, 82. [3] Marks *et al.* (2007) *Chem. Geol.* **246**, 207–230. [4] Kaliwoda *et al.* (in press) *Lithos*, 14.