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Biomarker Molecules

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Biosynthetic organic compounds are already widely used to obtain information about natural systems, both for the present and for the geological past. Once one knows the precise structure of a compound, its biological origin and, to some extent, its history may be inferred-hence, the term "biomarker". Most studies of biomarkers are based on recognition of their molecular structures and on the determination of their relative abundances. Indeed, quantitation of properly characterized compounds in the geosphere has served the organic geochemical community well. Thus, proxies based on molecular abundance ratios are routinely applied in petroleum exploration, for example in assessing the provenance of petroleums and the maturity of source rocks. Environmental studies of both natural and anthropogenic compounds use the same methodologies to follow their global fate and pathways. Among the molecules used in paleoenvironmental studies, the algal produced C_{37} alkenones are now exploited extensively as a molecular stratigraphic paleo sea surface temperature (SST) proxy (UK37). Comparison of UK37 based SSTs with SSTs derived from other proxies such as foraminiferal counts is revealing new information on past ocean surface hydrology and ecology.

Paralleling the use of compound abundances, rapid progress is being made in the exploitation of the natural abundances of stable isotopes in individual compounds. This compound-specific approach, which extends that of the traditional bulk organic matter, has been made possible by the development of highly sensitive (nanogram range) compound-specific gas chromatography isotope ratio mass spectrometry (GCIRMS), employing continuous flow separation. Carbon isotopes have been the main target to date, for example in carrying out biomarker mapping of N.E. Atlantic sediments, using both the abundances and $\delta^{13}C$ values of specific n-alkanes (e.g. n-C_{29}) synthesized by land plants as components of protective leaf waxes. They serve as terrigenous biomarkers which, when carried far out in the oceans by the wind systems and deposited in the bottom sediments, provide a regional guide to the relative abundances of C_3 vs C_4 plants on the N.W. Africa continent. Correspondingly, down hole molecular stratigraphic records provide us with a view of the past history of N.W. African C_3 vs C_4 vegetation cover, for example through the last glacial and interglacial transition. Compound specific GCIRMS studies of additional stable isotopes, such as those of hydrogen, oxygen and nitrogen, which are also incorporated into biological compounds, are now underway. There are certainly good prospects for highly selective characterization of the biosynthetic and environmental history enshrined in the multi-isotopic composition of specific biomarker molecules.

Challenging opportunities also exist in the many links which may be made between molecular organic geochemistry and molecular biology. For example, we are beginning to discern some of the underlying molecular phenomena involved in the preservation of organic matter in sedimentary environments through studies in an apparently completely separate field- the interspecific comparison of the molecular structures of enzymes. Some extremophile microorganisms are able to operate optimally at temperatures of up to 110°C: just how do they protect their molecular machinery from thermal destruction? Surprisingly, it turns out that rather small changes in structure are all that are needed. We are also learning about these molecular "survival rules" by looking at the intracellular molecular organization utilised by organisms which have special survival capabilities, such as some endospores, nematodes, plants and insects.

DNA residues in archaeological objects, fossils and sediments represent the ultimate challenge for molecular biomarker studies. Preliminary work using selective depolymerization reagents has had some success in improving the recovery of replicable DNA fragments from debris such as fossilized faeces several tens of thousands of years old. Novel ways of getting small fragments of damaged DNA out of fossilized remains should shed light on molecular preservation processes generally and also provide a unique key to the molecular phylogeny of extinct species.

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