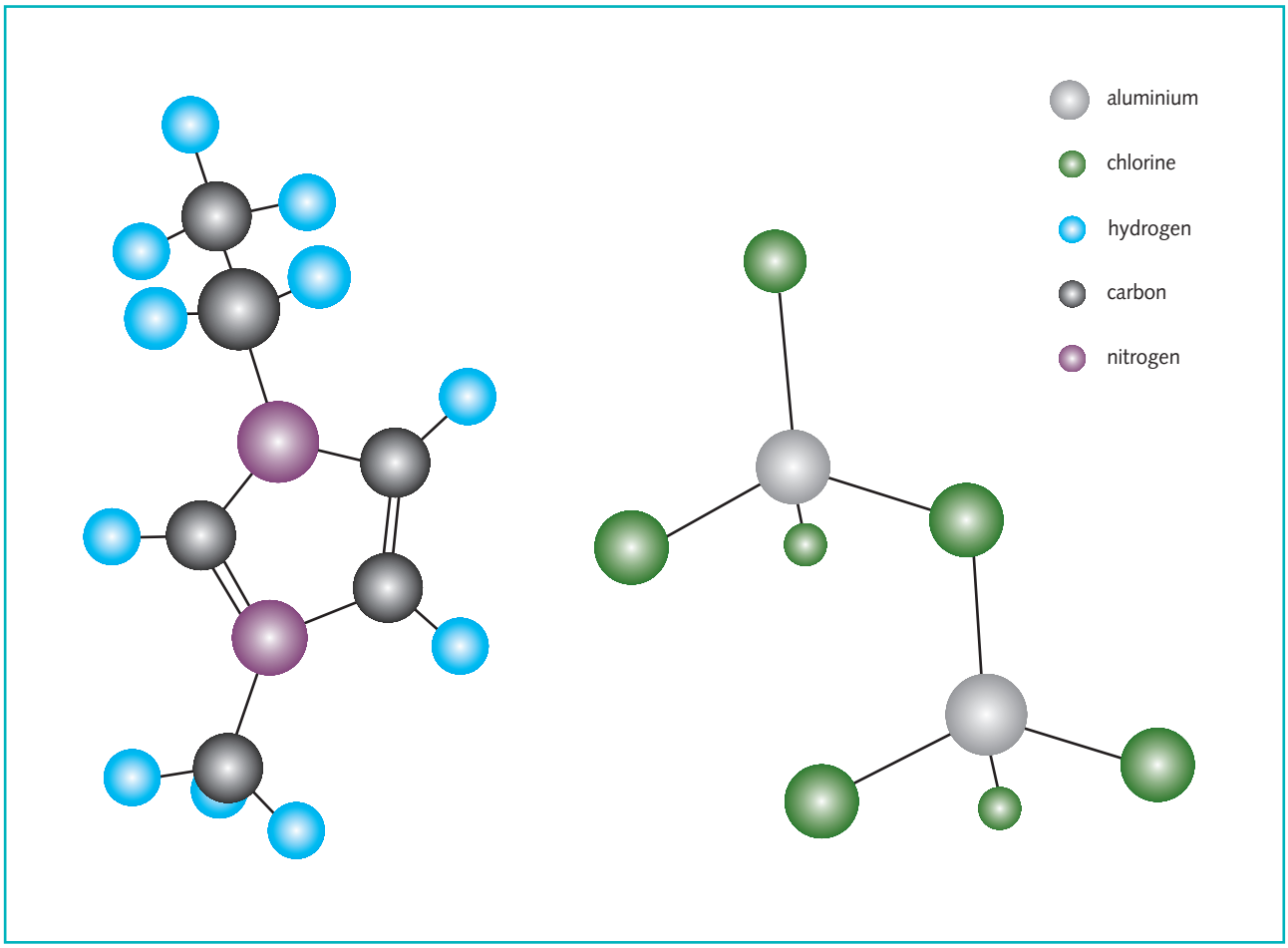
Solving the insoluble?



This ionic liquid (1-ethyl-3-methyl-imidazolium chloride: aluminium (III) chloride) can dissolve previously intractable organic matter, allowing us to find out its chemical structure.

We are using a new method to try to dissolve the normally insoluble material left behind after routine chemical analysis of organic matter in sediments.

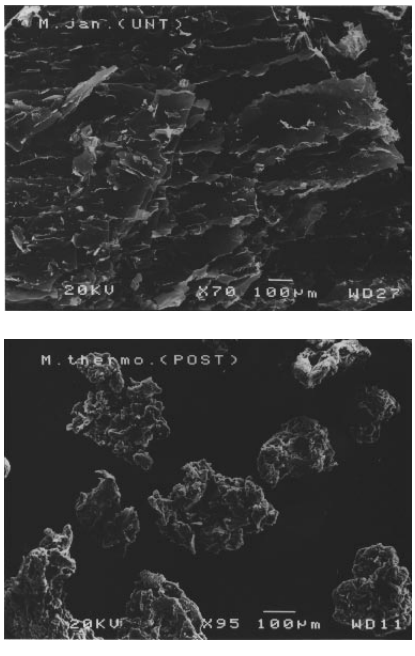
Despite worldwide consumption of 3,000 million tonnes of petroleum a year as fuel and in chemical manufacture, we still do not understand in detail how petroleum is formed! We know that it forms as a result of chemical and physical changes to deposits of dead organisms (eg bacteria and algae) in sediments but there is still much speculation as to how these processes work and which organisms are the main contributors. Greater understanding of how petroleum is formed will assist geochemists in determining the quality of potential oil reserves.

A major problem faced by scientists in this field is that most of the organic matter in sediments is insoluble and not amenable to routine analysis.

We have therefore attempted to dissolve this 'insoluble' material using a novel ionic liquid. Ionic liquids are salts, like table salt, sodium chloride, but are liquids at room temperature (sodium chloride, for example, would be an ionic liquid only above 800°C!).

Our starting materials were samples of lake sediment, bacteria found in sediments and synthetic chemicals known as dendrimers, which we used to monitor the effect of the ionic liquid on the chemical properties of the 'insoluble' matter.

Although the work is still at an early stage, our results suggest that after treatment with ionic liquid we can now dissolve a portion of the previously insoluble material in common solvents, so that it is now amenable to traditional analysis. We hope that this work will explain some of the processes involved in petroleum formation.



Scanning electron micrograph of (top) dead bacteria, and (bottom) insoluble organic matter left behind after the bacteria are treated with conventional solvents.

Molecular Signatures from the Past

The Ancient Biomolecules Initiative is a five-year programme to understand the fate of biological molecules in archaeological and fossil materials, and to explore the applications of this new knowledge. The Initiative is funded by the Natural Environment Research Council.

Natural Environment Research Council

Solving the insoluble: the science in detail

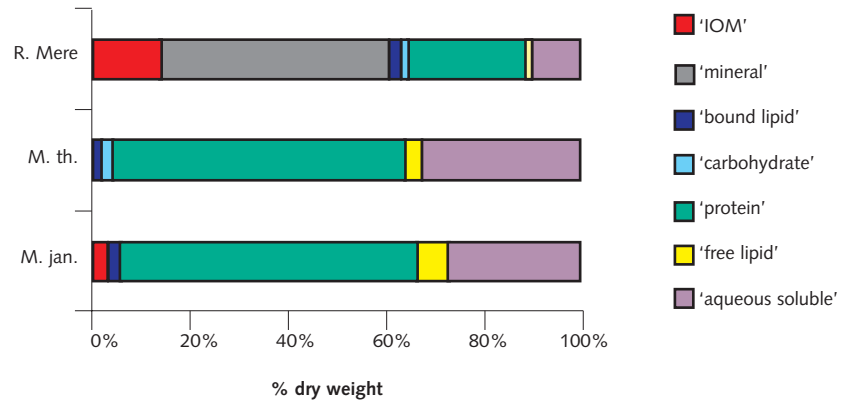
We took samples of lake sediment (Rostherne Mere, Cheshire, UK) and specimens of sedimentary bacteria grown for us in the USA and at the University of Bristol (it is very time consuming to isolate sufficient bacteria from sediments). We removed the readily soluble organic matter (eg proteins and carbohydrates) leaving behind the residue of 'insoluble organic matter' – IOM.

We found that the sediment contained 10-15% dry weight IOM. Two species of methane-producing bacteria comprised 0.1 and 3% dry weight IOM (see diagram on right).

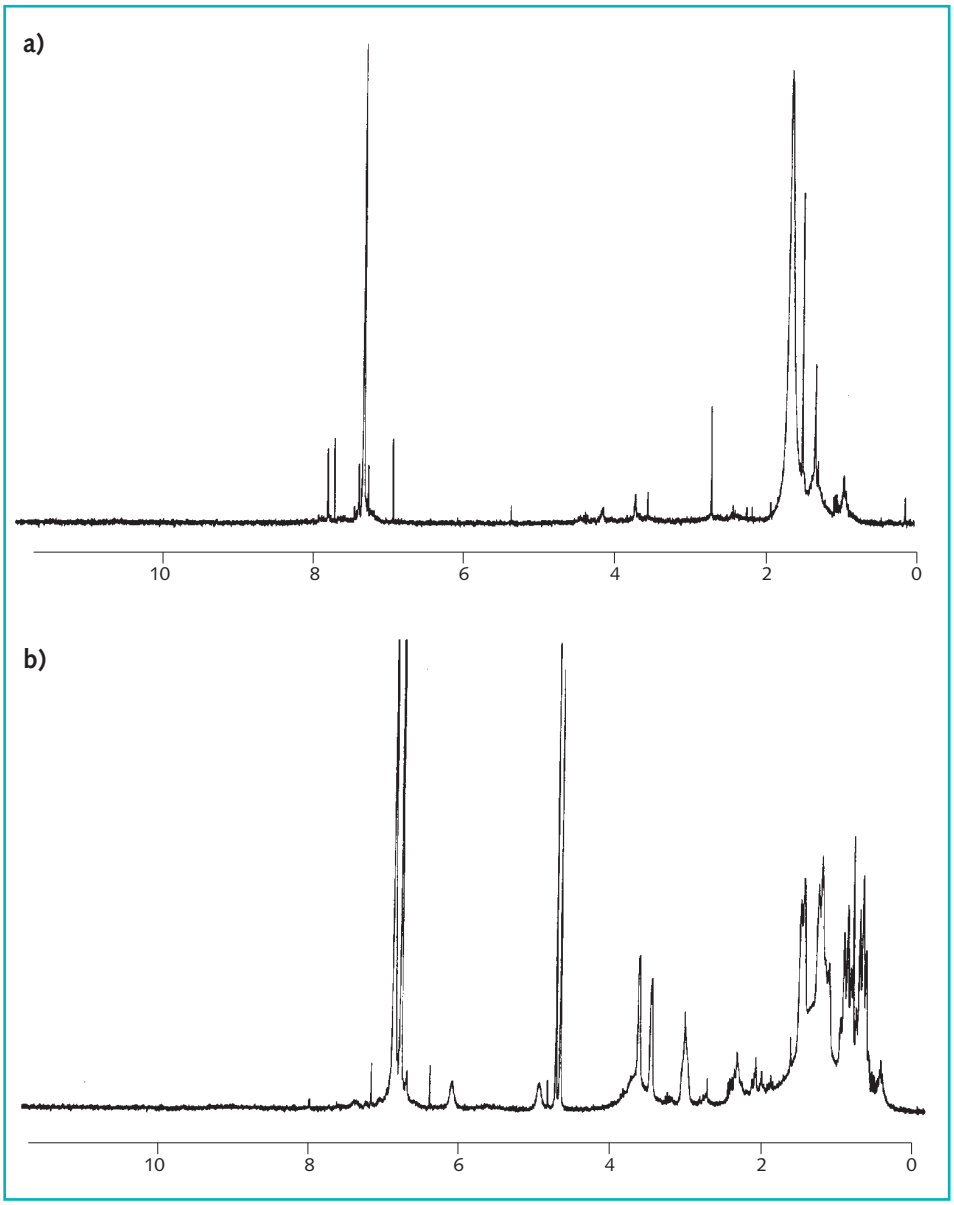
Examination of a particular fraction of bacterial IOM treated with ionic liquid shows that it is substantially different from that of the ionic liquid and that it is mainly aliphatic (see the traces below). We believe that the ionic liquid reacts with the IOM and we are using large dendritic molecules supplied by the University of Warwick to monitor the effects of ionic liquid.

Future Work

We are now planning to examine the effects of ionic liquid on the solubility of other types of IOM from sedimentary bacteria, marine sediments and algae. The discovery of a method by which this intractable material can be dissolved will have a major impact on our understanding of petroleum formation and hence on the future uses of our energy resource.



Proportions of soluble and insoluble organic matter isolated from Rostherne Mere sediment (95-96 cm below lake bed) and bacteria, *Methanobacterium thermoautotrophicum* (M. th.) and *Methanococcus jannaschii* (M. jan.)



Nuclear magnetic resonance spectra of solvent extracts from fitrates of, a) ionic liquid and, b) *M. jannaschii*

Methods

We treated the IOM with the ionic liquid, carefully prepared for us in a nitrogen atmosphere glove-box at Queen's University, Belfast. The (now dissolved) IOM from the sediments and bacteria were hydrolysed with water and filtered. The filtrant and filtrate were both extracted with a common solvent and the extracts analysed using various instrumental techniques (eg nuclear magnetic resonance and infra-red spectroscopy).

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