Simulating petroleum generation

Oil and natural gas take thousands or even millions of years to form from living matter deposited in sinking sedimentary basins. A vital ingredient in the process is heat: the fossilized organic material known as kerogen, formed from polymerized lipids, lignin, protein, and carbohydrates in decaying residues of biological material, needs to be subjected to temperatures above 130°C over a long period.

These conditions are only met at depths thousands of metres below the earth's surface, where heat from the earth's interior 'cracks' the kerogen to produce oil.

In an attempt to speed up the events occurring over millennia into periods of a few minutes, hours, or days, scientists have found it necessary to use even higher temperatures. However, rapid pyrolysis — heating source rocks such as oil shale to very high temperatures — creates by-products such as olefins and carbon monoxide that are not associated with naturally generated hydrocarbons.

Obviously, the reactions occurring during the two vastly different time spans are not identical. Researchers in the past have tried unsuccessfully to produce oil from kerogen without these by-products in the laboratory. These experiments have lasted from a few to several hundred days, and usually the source rock has been subjected to a constant high temperature.

Recently, however, two scientists at the CSIRO Division of Fossil Fuels in Sydney were able to simulate, for the first time, the processes that lead to hydrocarbon generation in a continuously subsiding basin. Dr John Saxby and Mr Ken Riley gradually heated two source rocks to high temperatures over a period of 6 years, to some extent imitating the slow 'molecule-by-molecule' geological decompositions that lead to oil and natural gas. Most importantly, they detected none of the usual by-products of rapid pyrolysis.

The scientists chose two quite different source rocks for the experiment — a torbanite from Glen Davis, in the Blue Mountains west of Sydney, and a brown coal from Loy Yang in Victoria. The latter forms from lignin-rich woody material, whereas torbanite comes from algal deposits.

Torbanite is a black, hard rock and is often associated with Permian coal seams (deposited between 280 and 225 million years ago), such as occur in the Sydney, Bowen, Cooper, and Perth Basins; it contains higher proportions of exinite (the oil-precursor component of kerogen) than coals, making it potentially a good source of oil.

Dr Saxby enclosed a number of small samples of each rock in stainless steel sealed vessels ('bombs') and placed these in an oven at a temperature of

Cooking oil

product	torbanite	brown coal
gas	3·5	21·4
oil	34·5	0·2
asphaltenes	6·9	0·8
solid residue	44·8	66·2
losses (water and light oil)	10·3 (mainly light oil)	11·4 (mainly water)

The products of slow heating from 100 to 300°C over 4 years. The figures show the percentage of the product by weight, relative to the original dry organic matter.

100°C. The temperature was raised by 1°C each week, an increase that takes perhaps 100 years to occur during natural oil formation.

Samples were heated for up to 6 years to a maximum temperature of 400°C.

The most interesting results appeared after 4 years, when the samples had been heated to 300°C. At this point, the torbanite kerogen produced a substance essentially the same as a paraffinic crude oil, while the brown coal generated a mixture of gases (including methane) that resembled 'wet' natural gas — evidence that torbanite can be a source of oil, and brown coal a source of gas condensate.

At the end of the 6-year experiment, the remaining 'bombs' contained gases and residual solids similar to those left behind after complete natural hydrocarbon production.

What are the implications for oil and natural gas exploration in Australia? Although our sedimentary basins are not particularly hydrocarbon-prone, many hundreds of square kilometres of Permian and younger basins in Australia contain substantial deposits of coal and oil shale, including torbanite. As the laboratory work shows, when buried deeply enough so that a substantial temperature rise occurs, such material can produce significant amounts of liquid and gaseous hydrocarbons.

Dr Saxby has been involved in geochemical studies of sedimentary basins around Australia. Together with Mr Rob Martin, he carried out research on the hydrocarbon potential of the Clarence–Moreton Basin. The area appeared to have a low total potential, with most of the organic matter being coaly and therefore gas-prone.

Further, in parts of the basin, lack of porosity limits the effectiveness of potential reservoir rocks to hold the oil. Too much faulting and too much volcanic activity have probably caused any accumulated hydrocarbons formed in the past to escape.

They concluded that the oil prospects within the Clarence–Moreton Basin are probably at best only fair, with the most promising areas being located west of Toowoomba, Qld, for oil and in the Clarence Syncline in north-eastern New South Wales for gas.

In another study of the Simpson–Pedirke Basin in central Australia, Mrs Michelle Smyth and Dr Saxby found that, in some sedimentary layers, oil may have formed or may be forming from cutinite (a type of exinite derived from plant cuticle). However, in other parts of the basin, the lighter volatile components of oil appear to have been lost as the oil migrated up faults and accumulated in reservoirs.

Altogether, some 30 to 40 sedimentary basins in Australia are being investigated by various industrial and governmental groups for their oil and gas potential. By linking the results of laboratory simulation of oil 'diagenesis' with studies of the content and maturity of source materials, and with the temperature gradient through the rock layers, geochemists can conclude with considerable certainty whether or not oil generation has occurred.

And if oil does appear to be 'in them thar hills', only further exploration can reveal whether the black gold is trapped in reservoir rocks or has got away.

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