Spectrum

Oil from coal, using water

Experiments in a CSIRO laboratory have shown promise in making oil from coal using that universal solvent, water.

A scientist at the Division of Applied Organic Chemistry has found that water can be used to turn more than half of a Victorian brown coal sample into synthetic crude oil (syncrude) and gas. Even higher yields can be achieved if the water is made alkaline with sodium hydroxide.

The trick Dr John Kershaw used was to pressure-cook the ground-up coal with water under such extreme conditions that the water behaved as a 'supercritical' fluid. In this state, at about 380°C and 22 MPa, the water greatly enhances the volatility of hydrocarbons in the coal.

Water reaches its 'critical point' at 374°C, and above this temperature water vapour cannot be liquified, no matter what the pressure. It exists as a supercritical fluid, a cross between a liquid and a vapour.

If we were to watch a sealed container of water during heating, the meniscus between the liquid and vapour phases would disappear when the critical temperature was reached. (The pressure would register 218 atmospheres, or 22 MPa, at this temperature.)

Dr Kershaw points to the special attractions of using supercritical water to produce liquid fuel. Apart from the low cost of the solvent, we don't have to pre-dry the coal, which is a significant factor when we consider the high water content of Victorian brown coal (50–70%).

Furthermore, extraction of the product is easy. After an hour's processing, the reactor is cooled and depressurised and most of the wanted liquids, being insoluble in water, simply precipitate out.

For these reasons, Dr Kershaw believes the method may well be more economical than alternative techniques. In particular, it appears to compare favourably with the approach of solvent-refining coal, which is presently being tried out in a pilot plant at Morwell by a Japanese company.

The Morwell process subjects brown coal to high pressure in the presence of solvent and hydrogen. It calls for plentiful hydrogen and dry coal. The mineral matter has to be separated out in a subsequent stage.

Using supercritical water as solvent avoids these drawbacks; and yields of 23–44% syncrude (expressed as a percentage of the dry starting material) have been achieved. Some 10% or more of coal is lost as gas, principally carbon dioxide, but the residue is a dry solid char that can be burnt for its energy.

At least one-third of the liquid product is classed as oil, with the remainder shared between heavier fractions known as asphaltene and pre-asphaltene.

The Yallourn open-cut brown-coal mine.

The ratio of hydrogen to carbon in the products is uniformly high, an attractive feature for refineries. However, because of the high oxygen content of brown coal, the product has a higher oxygen content than that in usual feedstocks, and this is a less favourable aspect.

Of course, the process has already removed a great deal of oxygen in the evolved carbon dioxide, and also some as water. The remaining oxygen can be taken out at a later stage by reaction with hydrogen to form water. (In fact, the Morwell operation removes considerably more of the oxygen this way, at considerable cost of hydrogen.)

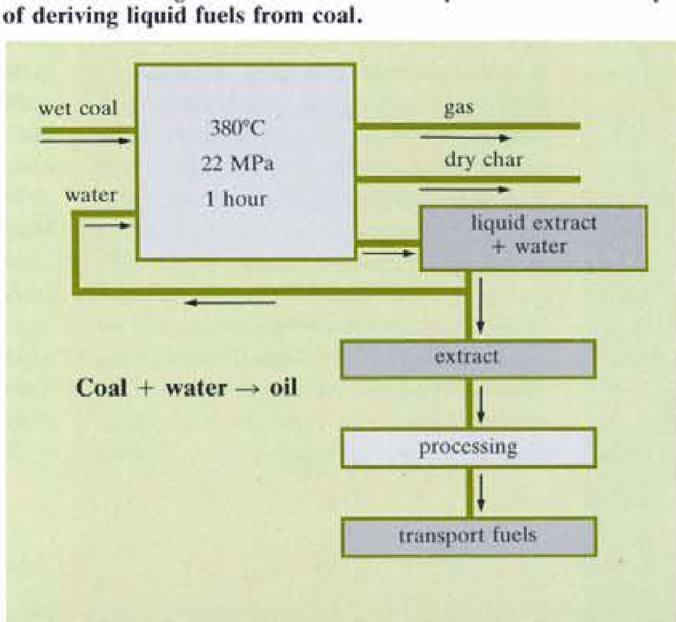
When Dr Kershaw repeated his experiments with black coals, the same high yields could not be duplicated.

Nevertheless, for Victorian brown coal — an abundant resource — Dr Kershaw believes that pressure-cooking it fresh and wet straight from the mine may prove an economical way of deriving liquid fuels.

Andrew Bell

Extraction of Victorian brown coals with supercritical water. J.R. Kershaw. *Fuel Processing Technology*, 1986, **13**, 111–24.

Pressure-cooking Victorian brown coal may be an attractive way of deriving liquid fuels from coal.



Ants and plants — mutualism in action

Well known to biologists is the co-evolution of flowering plants and insects. The two groups of organisms developed during roughly the same period of geological time and together successfully spread over most of the planet's land surface.

During millions of years they have established a sort of partnership, coming to depend on each other. Most obviously, insects use plants for food and shelter, and many plants rely on insects for pollination.

Also, insects living on a plant may act to protect it from larger herbivores, such as mammals. Commonest in this protective role are ants.

In return, of course, they expect food, and the plants involved may provide special sweet secretions, in addition to nectar in flowers. But the ages-old mutual relationship, or mutualism, between ants and flowering plants also extends to seeds.

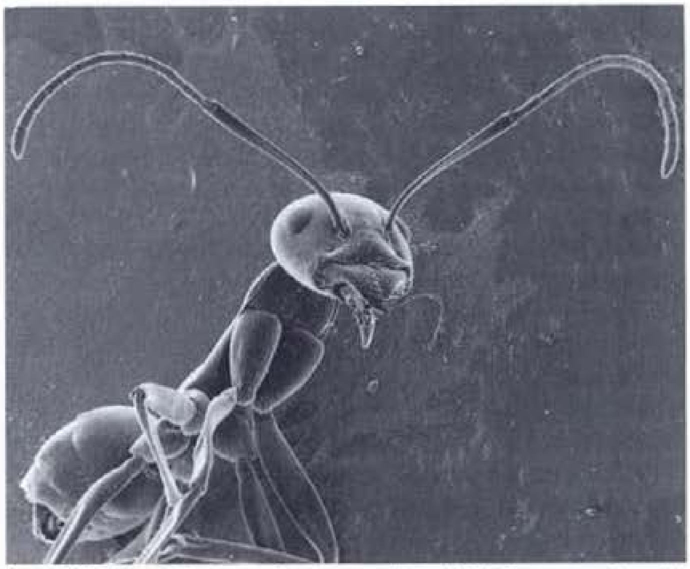
Mr John van Schagen, a post-graduate student at the Curtin University of Technology in Perth, has been studying the effects of ants on plant seeds, and *vice versa*, in a remnant patch of native vegetation in the Western Australian wheat belt. The work formed part of the CSIRO Division of Wildlife and Rangelands Research study of such remnants, and was carried out with the collaboration of the Division's Dr Richard Hobbs, and Dr Jonathan Majer, a senior lecturer at the University.

Mr van Schagen investigated the interactions in three different vegetation areas in Durokoppin Nature Reserve, near Kellerberrin, W.A. Each plot was about 100 sq. m in area, with the dominant plant species differing between the three.

One was a heathland community of small shrubs growing on sandy soil; another, near the centre of the reserve, was dominated by *Casuarina campestris*, a 1- to 2-m-tall shrub; the third lay on the edge of the reserve, next to farmland. This area had been cleared for farming in the past, and so the soil and vegetation had been disturbed. It was dominated by a range of annual plants, with some perennials.

The study continued over the course of a year, allowing the biologists to observe any seasonal variations.

Ants play an important role in dispersing the seeds and fruits of many plants. To help ensure that the ants do the work, the seeds (or fruits) may sometimes bear easily detached nutrient-rich structures termed elaiosomes,



A seed's view of an ant, here a species of *Iridomyrmex* found in the edge and heath plots.

which seem to attract foraging ants.

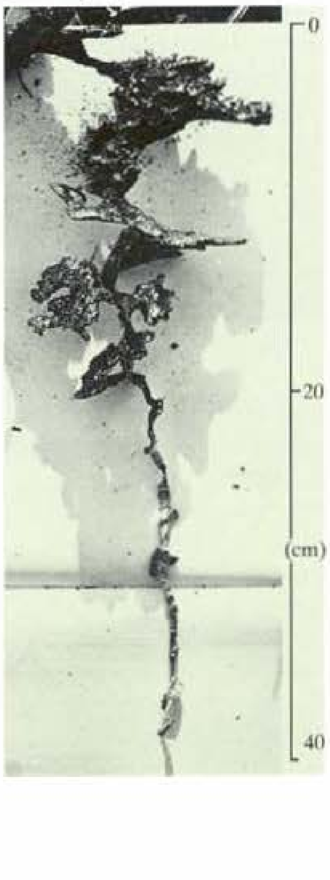
Scientists have recently estimated that about 1500 Australian plant species have seeds with elaiosomes. Certain species of ant will pick up an elaiosome-bearing seed and carry it back to the nest, where the juicy elaiosome is eaten and the seed discarded.

Of course, not all ants just eat the elaiosome; larger ones may eat the entire seed. Other ant species are merely seed collectors. They are not particularly attracted to elaiosomes, but instead collect many types of seed for use in nest-building.

Biologists have come up with several hypotheses about the advantage of all this to the plants involved, especially those producing an energy-rich elaiosome with, apparently, no direct use.

The obvious first idea is dispersal of their seeds — necessary to avoid competition with the parent plants, and with the seedlings of species that don't produce elaiosomes. Secondly, burial in an ants' nest may protect seedlings from burning in hot bushfires. Thirdly, the nest may provide a nutrient-rich environment for the growth of the young seedling. Finally, a nest of aggressive ants would be good protection against seed-eating insects, birds, and mammals.

Have you ever wondered how far into the ground an ants' nest goes? Dr Majer used an ingenious method of finding this out: by pouring molten lead into the nest he obtained a hard cast of it which he could then dig up.



Mr van Schagen wanted to determine the influence of ants on the germination, and hence long-term survival, of the plants in the study area — one of the few areas of native vegetation left in the wheat-belt. To do this he had first to find out about the ants, including their abundance and their level of activity. Then he had to assess the degree of seed consumption or collection they practised.

To collect ants, he used test-tubes containing glycerol and poisonous alcohol, which he inserted in the soil. Wandering, curious ants dropped in and were killed and preserved. In the three study plots — an aggregate of about 300 sq. m — he found a total of 54 different species of ants (by no means all of these are seed-eaters, or even seed-collectors).

As well as being so diverse, ants were also abundant, although the numbers did vary significantly throughout the year, there being more ants around in the warm summer months.

As ants do not maintain a constant internal body temperature, their rate of metabolism, and hence of activity, is closely related to the ambient temperature. When it is warmer more ants forage for a longer time. Also, many of the plants release their largest quantities of seed during the early summer.

Mr van Schagen noticed that the number of ant species varied between the different vegetation plots, although 20 were common to all three. The heath plot held the most species — a total of 42 — but strangely about 90% of all the individual ants caught there came from just one of these! The edge plot came next in terms of abundance of different species, and the *Casuarina* plot was the poorest.

The next question was 'are the ants eating seeds?' To assess seed collection, inventive biologists use plastic Petri dishes containing measured quantities of seed, with covers on to prevent birds stealing the raw material of the experiment. The dishes have small holes in the side to allow ants to come and go.

Mr van Schagen used two types of seed: those of *Casuarina campestris*, and

The three different vegetation types in the study: from top, heath, *Casuarina*, and the edge plot.

those of *Acacia extensa*, the latter bearing elaiosomes. *Casuarina campestris* grows in the area but the *extensa* species of *Acacia* doesn't — although many similar ones do. Its seeds were chosen becuase Mr van Schagen could not accumulate enough local *Acacia* seeds.

The seed depots were inspected at regular intervals over 24-hour periods and the numbers of seeds remaining, and ants seen, were recorded.

The results confirm our beliefs about the strange elaiosome. Ants favoured those seeds with elaiosomes throughout most of the year.

However, in the winter, removal rates of the *Casuarina campestris* seeds rose. This is probably because the ant species attracted to elaiosomes either stop feeding in winter or perhaps switch to a different diet.

Of the plant species present in the plots, Dr Hobbs showed that surprisingly few actually possessed elaiosomes. In part, this may be because many of the plants are herbaceous annuals, whose light seeds are easily dispersed by wind or specially adapted to attach to passing animals. Elaiosomes are restricted to certain families of plants — for example, no eucalypts have them although most acacias do.

Nevertheless, it remains puzzling why, if an elaiosome confers an advantage, more plants have not adopted it. This intriguing structure must have its drawbacks, the cost of producing it presumably being one of them.

To test whether ants' nests protect against destruction of seeds by bushfires, Mr van Schagen took a small stove into the bush and started heating. He maintained a temperature of about 100°C up to 2·5 cm below the surface of a nest for 20 minutes. He also performed a similar feat on soil 2 m from a nest.

As controls, he marked out similar areas of unheated soil — also either over a nest or 2 m from one. He did this in May, and the following October examined the seedlings in each area.

His results showed that certain natives — mainly small annuals such as *Trachymene cyanopetala* and *Helipterum pygmaeum* — and also the non-native broad-leaved annual *Ursinia anthemoides* germinated more readily on ants' nests than on bare soil. Other species indicated by their distribution that they had responded positively to the heat treatment, but were not significantly more common on nest sites.

Many species were adversely affected by the heating, but on the whole the greatest number of seedlings sprouted in the heated nest areas: these plants evidently benefited from the combination of ants and fire. What was it about the nests that gave rise to good seedling development after heating compared with the poor survival rate on heated sites that were away from a nest?

Mr van Schagen suspects — and work by Dr Majer supports this idea — that seeds collected by the ants are concentrated in a nest by burial in a chamber at such a depth that passing bushfires do not destroy them but instead provide the necessary heat shock to start germination. Some plant species had few if any seedlings present on nest sites, indicating either that they were not regularly collected by ants, or that they were eaten rather than being used in nest-building or discarded after their elaiosomes had been taken.

It seems, then, that ants do influence the distribution and germination of certain plant species in the study area, although in this experiment the same effects were not always noticed in each vegetation type. But certainly seeds collected and buried by ants stand a better chance after a fire.

The differences in the abundance and type of ant species found in the three vegetation communities suggest that changing the vegetation will lead to a change in the ant species, which in its turn could prevent certain plant communities from re-establishing in an area — a vicious circle.

The scientists' work so far has provided a valuable species list of ants and plants in the three different communities studied, and shown that the germination of some plants can certainly be influenced by ants. So, in attempting to conserve remnant patches of our original vegetation we should bear this in mind: native plants may rely for their continued health on the tireless ants of the bush, just as they in turn need the plants for food and habitat in order to continue their existence.

Roger Beckmann

Ant-plant interactions in a Western Australian wheatbelt nature reserve. J. van Schagen. Thesis submitted for Graduate Diploma in Natural Resources, 1986, Curtin University of Technology, Perth, Western Australia.

Worth preserving: the amazing diversity of native shrub species, many unique to the area, in a Western Australian sandplain heath.

The introduced pasture species capeweed, here growing in an isolated clump on old rabbit diggings that have provided the necessary soil disturbance and fertiliser.

Preserving nature amid the wheat fields

If you've ever flown over the Western Australian wheat belt you might have seen below a patchwork of regular brown wheat fields interspersed with darker patches of native vegetation. These are all that remain from the days before Europeans cleared much of south-western Australia to create the vast wheat belt.

Despite the low rainfall and the sandy soils, stable plant and animal communities thrived there, well adapted to the hot, dry summers and the few months of winter rainfall.

As the land was cleared and divided into vast paddocks, small, irregularly shaped patches of vegetation remained squeezed between them, often as much by accident as design. Along tracks and roads, trees and shrubs would be left standing in swaths a few metres — sometimes even 50 metres — deep. Now these remnant patches and roadside verges have become vital in the conservation of the beautiful and unique flora and fauna that are struggling to survive in the midst of a monotonous agricultural landscape.

Staff at the Perth laboratories of CSIRO's Division of Wildlife and Rangelands Research have been studying the biology of the remnants and verges, with a view to improving our ability to manage and so conserve them. The scientists are also relating the fauna present to the vegetation characteristics, thereby hoping to identify the type of vegetation most valuable for the conservation

The natural summer understorey vegetation in a woodland of York gums near Kellerberrin, W.A. (top), and (below) a similar area heavily invaded by introduced species; the attractive native flower has disappeared.

The results of one of Dr Hobbs' experiments: the four plots in wandoo woodland are, from top to bottom, control (nothing done), fertiliser added, disturbance and fertiliser, and disturbance only. Introduced annuals have been successful only in the plot that incorporated both soil disturbance and fertiliser.