Coal formation and Australia's drift north

Some of Australia's coal deposits formed much more recently than others. For example, the black coal found near Lake Phillipson, S.A., is 250–70 million years old, while the brown coal around Yallourn, Vic., was laid down only 10–15 million years ago. Queensland's Millmerran deposit is 150–70 million years old.

At the CSIRO Division of Fossil Fuels in Sydney, an important field of study is the environments of coal deposition in times past. An understanding of these helps today's prospectors locate areas where more coal may be discovered.

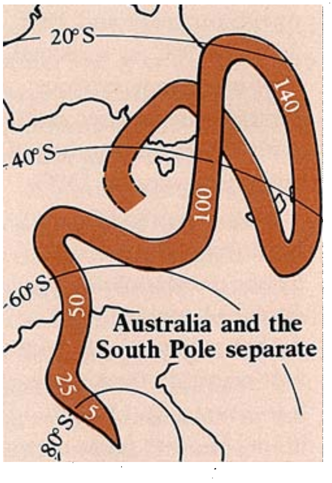
To find out more about the origins of Australia's coals, Dr John Smith and Mr Don Rigby, of the Division, measure the ratios of the stable isotopes of various elements found in them. This work has produced a puzzling finding: the ratio of the two stable isotopes of hydrogen, while varying considerably, seemed to be unrelated to the age, the maturity, or the location of the deposit.

The two isotopes are ordinary hydrogen (H), with just a proton as its nucleus, and the heavy hydrogen isotope deuterium (D), in which a neutron accompanies the proton. A number of reasons why their ratio varies between coals have been suggested.

One possibility is that differences in the types of vegetation that turned into coal deposits provide the key. Normally, about 0·015% of the hydrogen found in water is deuterium. But when plants take up water as they grow they discriminate against deuterium, so the D : H ratio in their tissues is reduced. The extent of this discrimination varies between plant types, making vegetation differences the possible main source of variation in D : H ratio between coals.

Another suggested explanation is the gradual loss of hydrogen from coal over time in the form of methane emissions. The methane generally has a much lower D : H ratio than the coal that it comes from.

Dr Smith and Mr Rigby tested these explanations against their data from Australian coals and found them both wanting. One of their findings was that older coals tend to have a lower D : H ratio than younger ones. This seems surprising, because the loss of methane with its low D : H ratio could be expected to gradually raise the ratio in the hydrogen left behind in the coal.



Where the South Pole has been relative to Australia. The figures on the track show the Pole's position 5, 25, etc. million years ago.

A factor that seemed certain to have some influence was the difference in deuterium content that has been measured between rain falling near the equator and precipitation near the Poles. The water's D : H ratio decreases very gradually as you move away from the equator to about 60° latitude, and then falls more sharply as you approach the Poles. At the Poles only about 0·009% of the hydrogen in rain-water (or snow) is deuterium.

The reason for this variation is that normal water (H_2O) evaporates more readily than heavy water (HDO or D_2O). Atmospheric processes produce evaporation from the oceans in warmer climates and condensation in cooler areas, and thus bring about a gradual reduction in the proportion of heavy water in rainfall with distance from the equator.

As a result, the water that plants growing in the tropics take up is slightly richer in deuterium than the water plants growing in colder climates absorb. So coal, which is essentially the preserved residues of land plants, could be expected to have a higher D : H ratio when formed in the tropics than when deposited nearer the Poles.

But is this the main cause of the isotopic differences found between coals? When the scientists compared the latitudes of Australian coal deposits with their D : H ratio readings they found no correlation.

However, when they related the D : H ratios to the picture of Australia's drift relative to the South Pole built up from recent 'palaeomagnetic' studies done in the CSIRO Division of Mineral Physics (described in *Ecos* 35), a clear picture emerged. The latitudes of coal deposits at the time of their formation correlated well with the D : H readings.

So the scientists conclude that the D : H ratios in coals reflect predominantly the isotopic composition of the available fresh water during growth of the plants that subsequently turned into coal.

Australia used to be much closer to the South Pole than it is now and, according to the continental drift experts, it is still inching northwards, Apparently, some 230 million years ago the Pole was more or less on what is now the Queensland–New South Wales border.

The coal deposit with the lowest D : H ratio measured by the CSIRO team, at Nymboida in northern New South Wales, was south of the present latitude of Macquarie Island when it formed some 180–200 million years ago. The coal near Yallourn, Vic., with one of the highest D : H ratios, was formed much further north — within the latitudes now occupied by Tasmania.

D : H ratios of coals and the palaeolatitude of their deposition. J.W. Smith, D. Rigby, P.W. Schmidt, and D.A. Clark. *Nature*, 1983, **302** (in press).