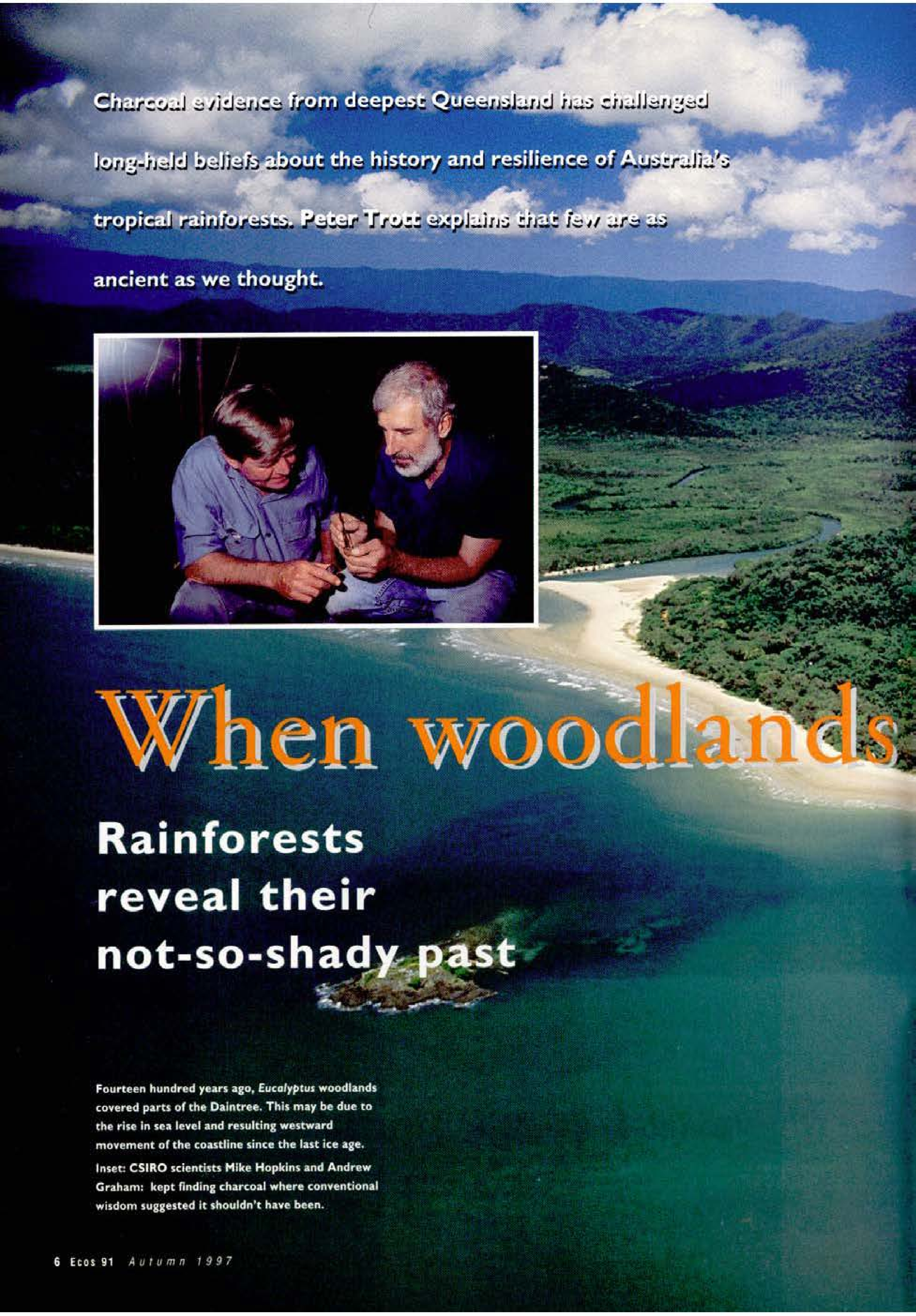
Charcoal evidence from deepest Queensland has challenged long-held beliefs about the history and resilience of Australia's tropical rainforests. Peter Trott explains that few are as ancient as we thought.



When woodlands

Rainforests reveal their not-so-shady past

Fourteen hundred years ago, *Eucalyptus* woodlands covered parts of the Daintree. This may be due to the rise in sea level and resulting westward movement of the coastline since the last ice age. Inset: CSIRO scientists Mike Hopkins and Andrew Graham: kept finding charcoal where conventional wisdom suggested it shouldn't have been.

ruled the Daintree

North Queensland's tropical rainforests are celebrated as living links with Australia's ancient past. Their gnarled, moss-clad trees, and the humus-sweet smell of earth mingling with rotting leaves, are vivid reminders of when Australia was part of the southern supercontinent, Gondwana.

The Australian continent parted from Gondwana some 58 million years ago, carrying northward a cargo of primitive animals and plants. These were the ancestors of today's tropical rainforests, which survive as 11 massifs, each larger than 10 000 hectares, and as many smaller patches between Townsville and Cooktown. They range from coastal and lowland forest to tablelands and mountains.

Until the early 1980s, it was widely accepted rainforest vegetation had been steadfast in these locations, ever since their Gondwanic origin more than 100 million years ago. But according to a new source of data on their history, large tracts of tropical rainforests may not be ancient at all. Ancient types of forest, yes – including descendents of some of the first flowering plants – but re-established during the past few thousand years, after a period of being overrun by *Eucalyptus* woodlands prone to frequent fire.

First to question the permanence of rainforests in Queensland's north-east were CSIRO botanists Dr Len Webb and Geof Tracey. Their biogeographic surveys led them to speculate in 1981 that during the 18 000 years since the last glacial peak, tropical rainforests had undergone cycles of expansion and retreat, perhaps taking refuge in high-rainfall, upland locations. But their evidence was inconclusive, and the true pattern of this 'tug-of-war' between *Eucalyptus* woodlands and rainforest remained a mystery.

Then came a breakthrough. During surveys in the early 1980s, CSIRO scientists Dr Mike Hopkins and

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Peter Lik Photography

Charcoal fragments in soil from beneath rainforest trees.

Andrew Graham kept finding pieces of charcoal in the soil profile beneath what they thought to be continuous rainforest. The discoveries were puzzling, because rainforest is not usually penetrated by fire, the closed canopy preventing the growth of annual grasses as fuel. But here in undisturbed soils, kilometres away from the nearest *Eucalyptus* woodland, there was charcoal.

Hopkins and Graham, who are based at CSIRO's Tropical Forest Research Centre at Atherton, thought the charcoal might shed new light on the process of change in such forests. For example, it might support Webb and Tracey's theory that areas of rainforest periodically yielded to fire-prone *Eucalyptus* woodland. To find out whether these shifts did actually take place – and if so when and where – the charcoal samples had to be dated.

In 1983, Hopkins sought the assistance of Professor Donald Walker at the Australian National University. Walker was not only interested, but introduced Henry Pollach, then head of the university's radio carbon dating laboratory.

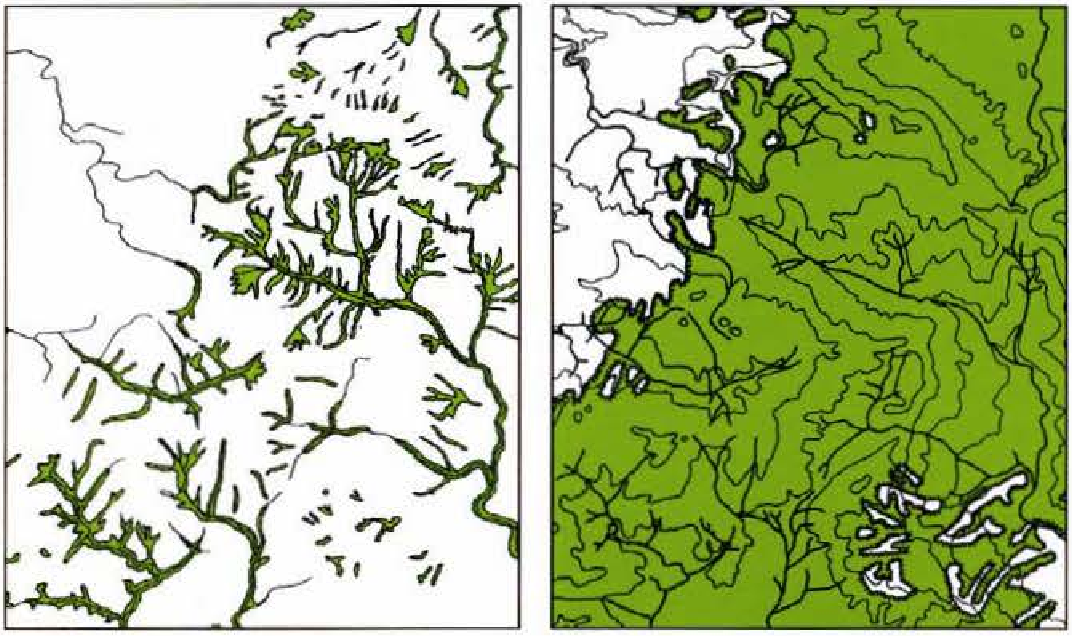
The scientists decided to try dating a few charcoal samples from an undisturbed rainforest area, rich in rare and restricted species, where the charcoal was least likely to have been derived from another site. They chose the Windsor Tableland, 50 kilometres north-west of Port Douglas. A range of samples from there was sent to be radio-carbon dated at the Australian National University's Quaternary Dating Research Centre. (The Quaternary is the geological time period including the Pleistocene and Holocene or Recent time.)

Radio carbon dating relies on a precise measurement of the proportion of an isotope of carbon contained in the cells of plant or animal remains (see story on page 11). It is a useful technique for palaeoecology, because it indicates when the carbon was taken from the atmosphere by photosynthesis (when the tree was living), rather than when the wood was burnt, or when the charcoal was deposited.

Graham vividly remembers receiving a phone message from the centre which said simply: 13 000, 19 000 and 26 000 (years before present). 'That was one of the most incredible moments in my life,' Graham says. 'This confirmed we had found something really exciting: within this extensive and important rainforest area, *Eucalyptus* woodland previously occurred and burnt over at least a 13 000-year period.

Below: Mike Hopkins, Bob Hewett and Andrew Graham hunt for charcoal fragments beneath a several-hundred-year-old blue kauri pine (*Agathis atropurpurea*) on an upland site at Longlands Gap.

Inset: The object of their search. Tell-tale remains of a *Eucalyptus* woodland that dominated the landscape at Longlands Gap some 12 000 years ago.



Where did the rainforests go? Far right: This map shows rainforest distribution on a northern section of the Atherton Tableland at the time of European settlement.

Right: A reconstruction of the probable distribution of rainforest in the same area at the time of maximum incursion by fire-prone *Eucalyptus* woodlands. The network of corridors and narrow strips are the probable former refuges of rainforest vegetation. A knowledge of these areas is important to modern rehabilitation and revegetation programs.

At about the same time, Professor Peter Kershaw of Monash university deduced from pollen analysis of sediments that *Eucalyptus* woodlands had existed in a small area of upland rainforest around the crater lakes of Barrine, Eacham and Lynch's Crater. The distribution of charcoal suggested that, during periods of minimal rainforest cover, they had extended even further, as speculated earlier by Webb and Tracey.

The next step for Hopkins and Graham was to devise a sampling strategy to collect charcoal from a range of locations on high granite areas throughout the heart of the tropical rainforests. This would allow the palaeoecological interpretations to be extended more widely through the humid tropical region. To do this they teamed with John Head from the radio carbon dating laboratory and botanist Julian Ash from ANU's Department of Botany and Zoology. Ash's role would be to determine what kind of trees the charcoal samples once were, using scanning electron microscopy (see story on page 11).

The strategy was designed to eliminate the possibility of including material from camp sites or human activity. This meant collecting samples from remote locations such as above 1400 metres on Mt Bartle Frere and other sites requiring up to one day's hike each way through steeply undulating, vine and leech-infested rainforest.

As the results of the dating and determination flowed back from ANU, a picture emerged of major rainforest contraction, corresponding with the time of cooler and drier conditions which occurred in the tropics towards the end of the last glacial period (30 000 to 10 000 years BP). Analyses of samples from more than 17 locations revealed evidence of a fire-prone landscape dominated by *Eucalyptus* which reached its maximum extent about 10 000 years ago, in some places yielding to rainforest only 3800 years ago. But many ancient and primitive flowering plants still exist today, so the rainforests must have survived in some locations. But where? Hopkins and his colleagues believe it survived primarily in a network of valleys and gorges throughout the region.

Searching high and low

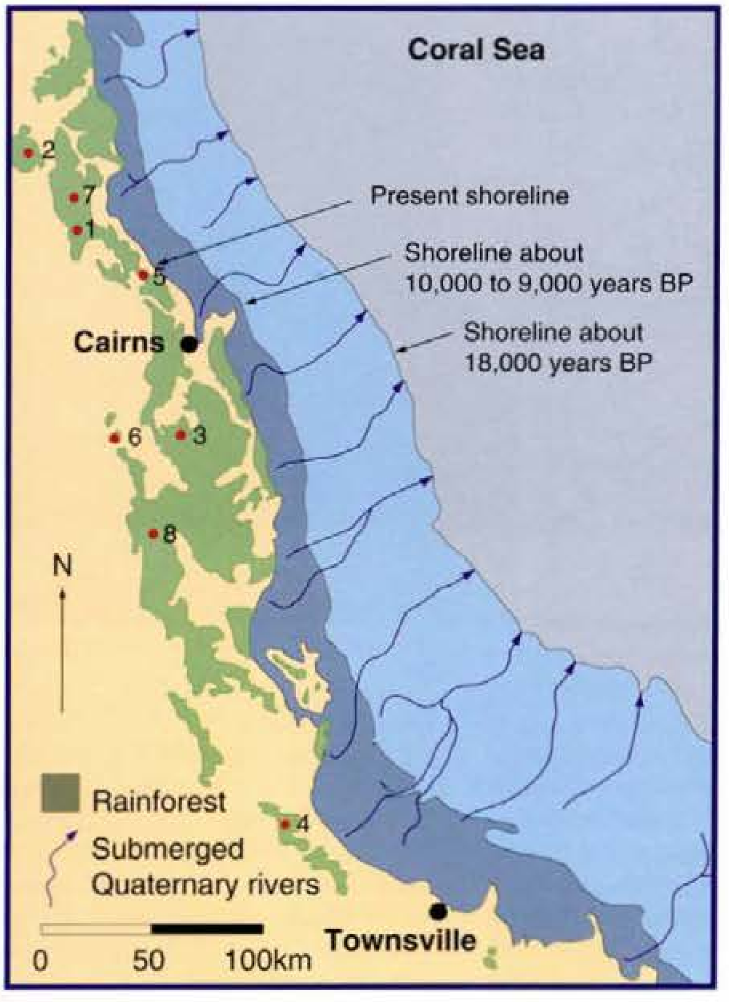
Investigations had so far indicated that the cooler, drier conditions of the last ice age caused *Eucalyptus* woodlands to extend over much of what is now the 92 000 square kilometres of remaining forest between Townsville and Cooktown (protected in the Wet Tropics World Heritage Area). This started to give way to rainforest about 8000 years ago when the climate was much wetter than today, favouring the rapid advance of rainforest. But evidence from high-rainfall upland sites – thought by Webb and Tracey to be rainforest refugia – showed that even many these had succumbed to *Eucalyptus* woodland for a few thousand years.

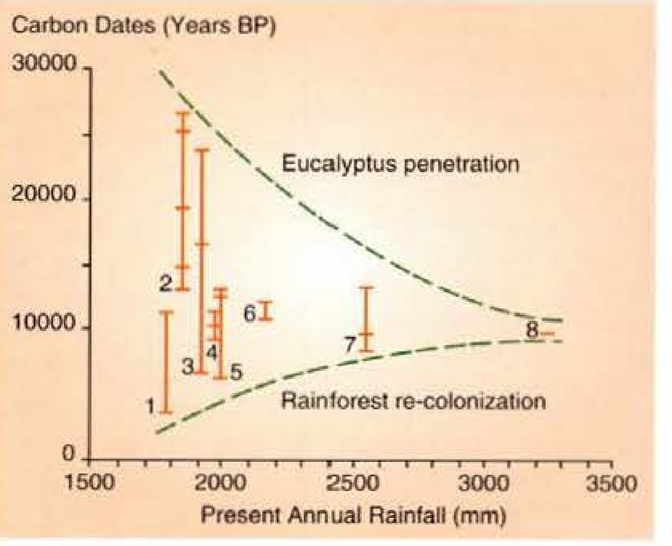
The next stage of research centred on the lowlands around Cape Tribulation. This area supports a particularly high concentration of endemic rainforest plants, many of which are listed as rare or threatened. Further charcoal samples were collected there by the CSIRO team as part of a Cooperative Research Centre for Tropical Ecology and Management.

Analysis of these samples showed a similar pattern of previously widespread eucalyptus woodlands. The new data also indicated that tropical rainforest had

Outcomes at a glance

1. It is vital that refuge areas rich in ancient and rare species be identified and protected in any planning or management activity, particularly with the prospect of climatic change.
2. Rehabilitation and revegetation programs should focus on cleared or damaged areas which have been recognised as former refuges of tropical rainforest.
3. The results give the only picture of the long-term dynamics of tropical rainforests. It has already been shown that tropical rainforest is highly dynamic, establishing more quickly than previously believed when conditions are favourable.
4. The work is basic to understanding the interaction between Aboriginal people and their environment and the development of rainforest culture.





Above: This graph shows the range of radiocarbon dates recorded in eight districts (see map for locations) in relation to present annual rainfall. Rainfall localities with lower present-day rainfalls show earlier penetration by fire-prone Eucalyptus woodlands (before 20 000 BP) and later recolonisation by rainforest (3000-8000 BP), than localities with higher present-day rainfalls.

Left: Changes in shoreline position associated with the most recent sea level rise in the vicinity of north Queensland tropical rainforests. The boundary of the rainforest shown on this map is that which probably existed at the time of European settlement. (Districts: 1: Mt Lewis, 2: Windsor Tableland, 3: Mt Nomico, 4: Mt Spec, 5: Mt Formartine, 6: Longlands Gap, 7: Half Ton Creek Headwaters, 8: Maple Creek Headwaters.)

established much more recently on the lowlands than on the upland areas such as the Atherton Tablelands. In fact, some tropical rainforests between Daintree River and Cape Tribulation are only 1400 years old. Fire-prone *Eucalyptus* woodlands covered parts of what is now the famous Daintree eco-tourism mecca only 1200 years before Captain Cook ran aground on nearby Endeavour Reef. The picture is the same in tropical lowlands elsewhere and areas to the south are going through the same process today (see 'A rare habitat feels the squeeze', *Ecos* 84).

This relatively late spread of rainforest may be explained by the rise in sea level and resulting westward movement of the coastline since the last ice age, Hopkins says. It is estimated that 18 000 years ago, the sea level was 115 m lower and the coastline 50-80 km east of its present position. As the sea level rose, the shoreline moved inland. This this occurred at maximum rates of about 10 to 30 m westward per year, and must have forced the Aboriginal population up between the coast and the steep escarpment which includes Mt Pieter Botte and Thornton Peak. This concentration could have resulted in more aggressive fire regimes which either maintained the *Eucalyptus* woodland, or allowed its re-establishment about 4000 years ago as rainfall declined.

Either way, the evidence of the dynamic nature of tropical rainforests poses a challenge to assumptions about what conservation should protect. Should it focus on keeping landscapes as they are now, as they were at another time, (such as 1770) as some people suggest, or should we allow the natural processes of change to continue unimpeded?

It also suggests that some of the areas where rainforest species survived may not now be available as refuges to carry these species through future periods of climatic change. Many of the river valleys and rich alluvial sites which may have acted as 'Noah's arks' of rainforest plant and animal species in previous glacial peaks have during the past 200 years been cleared, dammed, farmed and otherwise modified.

The scientists are now focussing their research on defining the locations and characteristics of the late Quaternary rainforest refuges. This new information will be particularly valuable for the conservation and management of Australia's tropical rainforests.

More about rainforest dynamics

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What charcoal is that?

THIN cross sections of wood, when viewed under a microscope, can be identified by a characteristic 'fingerprint'. Dr Julian Ash from the Department of Botany and Zoology at the Australian National University in Canberra used an extension of this process to analyse the North Queensland charcoal specimens.

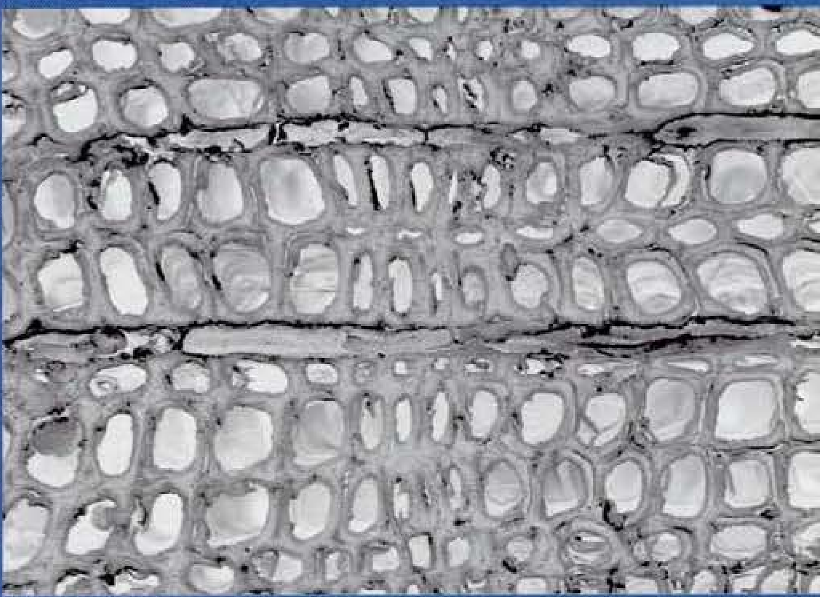
The selected fragments were fractured to reveal transverse, radial and tangential surfaces and these were electroplated with gold and photographed with a scanning electron microscope. The resulting images were identified using the CSIRO Wood Identification Program and checked against microscope slides of wood anatomy of these and related taxa present in north-east Queensland. In all cases where samples were big enough to divide, date and identify, the species were found to be *Eucalyptus*.

How old?

Carbon, the building block of organic matter such as wood and animal tissue, contains a radioactive isotope known as Carbon 14 or ^{14}C. Once fixed in tissue, such as wood, the proportion of ^{14}C diminishes at a known rate. By measuring the proportion of ^{14}C remaining, it is possible to tell how old the material is.

Samples for radio carbon dating are washed in hot hydrochloric acid, rinsed and dried and then the carbon synthesised into benzene and analysed for ^{14}C activity. The resulting ages are expressed as years before the present, plus or minus so many years. This method of dating is useful up to a maximum age of about 40 000 years.

Washed charcoal fragments are electroplated with gold and the tree-type identified with a scanning electron microscope.



Callitris macleayana

These electron microscope photographs are of two species from the boundaries of the eucalypt forest and rainforest in north Queensland. Both species turned up as charcoal at various sites during the study. They illustrate some of the more obvious features which allow identification of charcoal to a generic or species level. (The photos represent a cross-section of wood measuring about 0.40 x 0.56 mm and the centre of the trunk is to the left.)

Above right: Brush cypress (*Callitris macleayana*) is a conifer up to 30 metres tall. The wood is typical of conifers, with many tracheids and narrow rays. Tracheids (seen here in cross section) are elongated, thick-walled, hollow (dead) water-conducting cells. The rays are starch-storing parenchyma cells, seen here forming narrow rows horizontally across the photo. *Callitris* typically produce a 1-2 mm-wide growth ring each year, terminating in a band of radially narrow tracheids during the dry season. These can be seen as a vertical band in the middle of the photo.

Right: Flooded gum (*Eucalyptus grandis*) is a large tree, reaching heights of up to 75 m. The wood has typical dicotyledon tissues, including vessels, fibre-tracheids and both ray and other parenchyma: their size and arrangement are characteristic of the genus and species. The vessels are large, solitary, hollow (dead) cells which give strength to the wood. The starch-storing parenchyma cells form rays and also surround the vessels, forming irregular bands between them. The trees may grow rapidly, laying down 8-12 mm of wood each year, and only forming indistinct growth rings.

Eucalyptus grandis