Cretaceous fossil wood from Collie

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Abstract

A considerable quantity of fossil wood is preserved in coarse gravel at the base of the Nakina Formation in the Western No. 5 Opencut mine at Collie. Experiments are continuing to establish a suitable preservation treatment for the unmineralized wood, which consists almost entirely of lignin. On palynological evidence the age of the wood is Barremian to earliest Aptian. The availability of a large quantity of gymnosperm (podocarp or araucarian) wood and the abundance of gymnosperm pollen in associated sediments attest to the importance of these elements in the coeval, local vegetation. The wood was swept into a shallow, freshwater, Early Cretaceous basin, probably in a single large flooding event that eroded a channel in the underlying Permian Wyvern Seam.

KEYWORDS: Cretaceous, fossil wood, Collie Basin, Nakina Formation, palaeontology.

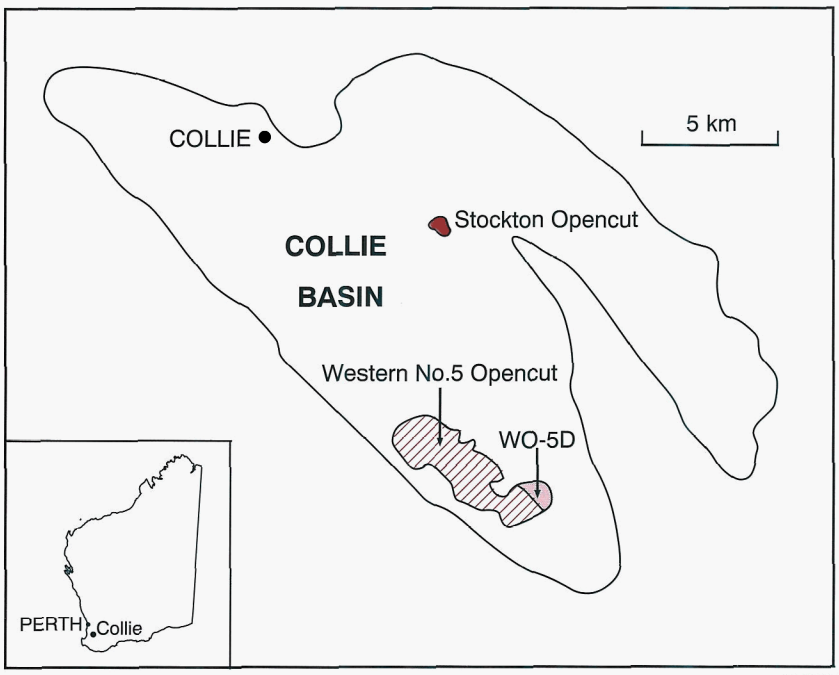

Figure 1. Location of Western No. 5 Opencut mine in the Collie Basin

The Western Collieries No. 5 Opencut mine is located approximately 150 km south of Perth, Western Australia and 15 km southeast of the town of Collie, in the southwestern part of the Collie Basin (Fig. 1). During development drilling at the site of pit 5D (WO-5D), at the southeastern extremity of the mine, a washout was discovered at the base of the Nakina Formation, a unit that forms much of the overburden in this pit. The washout had reduced the thickness of the underlying Wyvern Seam from 4 m to barely 1 m in places. When the mine was opened up, and overburden removed, large pieces of fossil wood could be seen in the pit wall near the base of the Nakina Formation. About 25 pieces of wood and two samples for palynology were collected from the pit by J. Backhouse, and an unsuccessful search was made for other fossil remains.

Earlier work (Backhouse and Wilson, 1989) indicates the age of the Nakina Formation is Early Cretaceous (Barremian to earliest Aptian). Therefore, the Collie wood is broadly similar in age to recently described permineralized wood preserved in the marine Birdrong Sandstone of the Giralia Anticline in the Carnarvon Basin (McLoughlin et al., 1995), and to fossil plant material from the Donnybrook Sandstone and Bullsbrook Formation, units that overlap the Archaean rocks on the eastern margin of the Perth Basin (McLoughlin, in press).

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Geological setting

The Collie Basin is a fault-bounded post-depositional basin containing up to 1200 m of Early to mid-Permian sedimentary rocks (Le Blanc Smith, 1994). Permian strata are unconformably overlain over much of the basin by Early Cretaceous sediments of the Nakina Formation (with a maximum recorded thickness of 20 m). In pit WO-5D, the Nakina Formation directly overlies the Wyvern Seam or Permian sandstone above the Wyvern Seam. The Nakina Formation is removed as part of the overburden before the coal of the Wyvern Seam is extracted.

The Nakina Formation is approximately 15 m thick over most of the area of pit WO-5D (Fig. 2). Over a narrow zone, about 100 m wide, it occupies a channel that has cut down into the Wyvern Seam. In this zone the Wyvern Seam is too thin for economic extraction and consequently the overlying Nakina Formation has not been removed.

In the channel zone, at the base of the Nakina Formation, is a 1 m-thick bed of coarse gravel with rounded quartzite pebbles up to a maximum of 15 cm in diameter. Above this bed lies 3–4 m of gravel and coarse-grained sand that gradually becomes finer up-section.

Above the gravel beds the sediments become finer grained, and about 2 m above the highest wood occurrence is the base of a thick sequence of micaceous claystone and minor siltstone. In this area the claystone extends to the top of the Nakina Formation, which is represented by a weathered zone just below the natural surface.

Wood

Although reworked Permian palynomorphs and clasts of Permian sedimentary rocks are incorporated in the basal Nakina Formation, plant remains in the Permian strata are strongly coalified (sub-bituminous rank). The lignitic character of the Nakina Formation plant axes suggests that they have never experienced deep burial and are Early Cretaceous rather than reworked Permian woods.

Figure 2. View of the Nakina Formation exposed in pit WO-5D, looking south

The woods are gymnospermous and probably belong to podocarp or araucarian conifers, the dominant arborescent elements of Australian Early Cretaceous vegetation (McLoughlin et al., 1995)

Most of the wood fragments are less than 40 cm in length and 20 cm in maximum diameter, but some larger pieces are present. The largest log observed remained embedded in the wall of the pit and had an incomplete length of 130 cm and a diameter of approximately 60 cm. The largest logs, found near the top of the gravel and sand bed, are orientated with their long axes near the horizontal plane, but smaller, more equidimensional pieces appear to have a random orientation. Larger, complete logs are elliptical in transverse section (Fig. 3). It is assumed this is caused by post-depositional compression rather than original growth habit.

In the sediment the wood is completely water saturated and black in colour. Once removed from the enclosing wet sediment it dries out rapidly, becomes greyish in colour and starts to fracture, particularly along the grain. Bark is present on one large log as a layer of soft tissue that easily slides away from the smooth wood beneath. Fractures and hollows in the wood, probably formed by compression, are filled with pyrite. No evidence was seen of borings or other ichnofossils.

Thin section

In thin section the cell structure is intensely crushed. Distinct growth rings are present, which suggests there was some seasonality in the climate, but the nature of that seasonality is not easy to define. Superficially the rings appear to be more regular than those shown by wood from the Birdrong Sandstone of the Carnarvon Basin, but the crushed nature of the wood inhibits accurate measurement or analysis of the growth rings. Nevertheless, the woods show some general features in common with the Birdrong woods in that they have transverse rays of similar height (typically 1–12 cells high) and a relatively large amount of early wood compared to late wood within each ring. The small proportion of late wood reflects a relatively sharp transition between the seasons. This is a common feature of ancient and modern tree growth at high latitudes where seasonal cessation of growth is largely a response to rapid changes in day length rather than extremes of temperature (Parrish and Spicer, 1988).

Wood analysis

The wood was analysed to gain an understanding of the diagenetic history and to ensure that appropriate conservation treatments were applied. The maximum moisture content of the Collie

(a) (b)

Figure 3. *Cretaceous wood. (a) Transverse section showing growth rings. (b) Longitudinal section through a large piece*

wood, determined by drying the sample to constant weight at 105°C and expressed as the weight of water contained as a percentage of the dry weight of wood, was 340%. Waterlogged wood of this type, containing 185–400% moisture, is considered to be moderately degraded (Christensen, 1970). Slow drying at ambient conditions over a period of 29 days produced a cross-sectional shrinkage of 57%.

The results of wet chemical analyses, following the relevant Australian, Technical Association of the Pulp and Paper Industry (TAPPI), and Australian/New Zealand standards, are given below. Elemental analyses were carried out using inductively coupled plasma atomic emission spectroscopy (ICP-AES).

	Percent
Hot water solubles	0.8
Lignin (incorporates ash)	99.2
Ash	1.9

	Parts per million
Iron	2 800
Zinc	210
Aluminium	3 700
Yttrium	20
Vanadium	340
Sulfur	6 700

The ash content is low for waterlogged wood indicating that there has been no significant mineral incorporation into the wood. The quantities of the incorporated elements iron, aluminium, and sulfur in the samples confirm this.

The more easily digested components of the wood structure, the hemi-celluloses and cellulose, have been lost from the Collie wood, leaving only the more resistant lignin (99.2%).

Fourier transform infrared spectroscopy (FTIR) confirmed both the predominance of lignin and the softwood (gymnosperm) origin of the wood.

Conservation

The most widely accepted, and successful, of the many treatments that have been applied to archaeological waterlogged wood is consolidation with polyethylene glycol (PEG) followed by freeze-drying. As successful treatments with PEG rely on the formation of hydrogen bonds between cellulose and PEG, such an approach is less likely to be effective for the cellulose-deficient Collie wood. Despite these reservations this treatment has been included in a suite of experimental procedures that are currently being applied to representative samples of the wood. Other techniques included in the trials are plastination (polymerization in situ using a silicone polymer) and consolidation using acetone/rosin. The results of these trials will be reported elsewhere.

Palynology

Two samples from near the base of the claystone sequence were prepared for palynological analysis. The samples yielded assemblages closely comparable to those reported previously from the Nakina Formation in the Stockton Opencut (Backhouse and Wilson, 1989). By analogy with similar assemblages from the Perth Basin, a Barremian to earliest Aptian age was suggested for the Stockton material. This is also the age favoured for the WO-5D samples.

By comparison with spore-pollen assemblages in the Perth Basin, gymnosperm pollen such as *Araucariacites australis* Cookson, *Corollina torosa* (Reissinger), *Microcachyridites antarcticus* Cookson, and *Falcisporites* spp. are particularly abundant in both the Stockton Opencut and WO-5D assemblages. Whereas spore–pollen abundance is not necessarily an accurate guide to the relative abundance of the parent plant groups, the abundance of gymnosperm pollen implies that the parent plants were at least a significant component of vegetation in the Collie region.

A previously unrecorded form of the acritarch genus *Tetraporina* occurs in both palynomorph assemblages from the WO-5D pit. Acritarchs assigned to *Tetraporina* are probably zygnematacean algal spores (Grenfell, 1995).

Reworked Permian spores and pollen are present as a minor component of Cretaceous palynomorph assemblages from Collie. They are evidence for coeval erosion of unweathered Permian strata from surrounding areas.

Depositional setting

Several lines of evidence suggest that the wood-bearing gravel bed at

the base of the Nakina Formation in WO-5D was deposited in a freshwater fluvial setting, possibly as the result of a single brief period of high runoff. Large, rounded pebbles, derived from the underlying Permian sedimentary rocks and deposited in an erosional channel, are evidence for a high-energy depositional event. A substantial number of large and small pieces of relatively undegraded wood were swept into this channel and buried. Other pieces may have settled into the sediment when they became waterlogged.

A freshwater rather than marine setting is favoured by the presence of spores of zygnematacean algae, although it is possible that these spores were washed into a marine setting. Modern zygnematacean algae inhabit a wide range of freshwater environments (Grenfell, 1995). Further support for a freshwater origin is provided by the absence from the palynological assemblages of marine dino-flagellate cysts and acritarchs of known marine origin, and the absence of marine borings in the wood.

On the western Yilgarn Craton, Early Cretaceous sediments have only been found above Permian intracratonic basins, except for a zone immediately adjacent to the Perth Basin. These small basins may have been eroded to a greater depth than adjacent areas in pre-Cretaceous time and were subject to compaction that did not affect surrounding granitic rocks. By the Early Cretaceous they were shallow depositional basins where sediment accumulated, and where continued compaction and subsidence preserved it from later erosion. The fine-grained nature of most of the Nakina Formation suggests deposition in a sluggish fluvial environment, or more probably in a lacustrine setting. The coarse-grained sediments containing fossil wood represent a high-energy fluvial event, possibly a single heavy flood, flowing into the lake system early in this period of Cretaceous sedimentation.

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