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RADIOCARBON DATES FROM A HOLOCENE DEPOSIT IN SOUTHWESTERN AUSTRALIA

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ABSTRACT. A radiocarbon chronology has been developed using shell, bulk peat, and paired charcoal and pollen preparations from a peat and clay sequence in southwestern Australia. The results indicate the sequence is of Holocene age, and the mid-Holocene was a period of rapid sediment deposition. The earliest record is based on *Bothriembyron* sp. snail shell and there is a strong indication that the deposit had a stratigraphic hiatus between 9600 and 4700 BP. Modern shell of the snail has no ancient reservoir effect. The bulk peat ages were a little younger than associated AMS determinations on hand-picked charcoal and residues from pollen preparations. As a group, paired charcoal and pollen based dates were indistinguishable in age. This implies that the sedimentary charcoal shows no significant storage and transport time in the catchment before deposition. This is important when interpreting pollen records and sedimentary charcoal to reconstruct fire and vegetation dynamics and inter-relationships.

INTRODUCTION

A common practice in the reconstruction of a vegetation and fire history from an area is to select a series of samples for radiocarbon analysis to establish a chronology. It is important that the deposition of pollen and charcoal in sediment result from contemporaneous processes, and in particular that charcoal and pollen production find their way into the sediment without significant storage and transport times from elsewhere in the catchment. In fluvial environments, for example, it is known that wood and charcoal may be incorporated into sediment after significant storage time in the flood plain (Blong and Gillespie 1978). If it can be shown that pollen and charcoal are of the same age then vegetation and fire histories can be compared.

In this study, we report and discuss a number of peat, shell, pollen preparations, and charcoal particles that were selected to establish an overall chronology to underpin a vegetation and fire history record from southwestern Australia (Dodson and Lu 2000). The samples were from a series of peats and clays from a freshwater swamp known as Byenup Lagoon (Figure 1), and they are Holocene in age.

^{14}C dating of fossil pollen preparations are thought to be reliable indicators of age since they do not contain a reservoir effect (Regnell 1992) and they have been shown to be reliable in hardwater regions (Regnell 1992), freshwater lake deposits (Long et al. 1992), and loess (Zhou et al. 1997).

The study region today has hot and relatively dry summers and mild, wet winters when the majority of the mean annual precipitation of about 900 mm is received. The main vegetation types in the area are mixed *Eucalyptus marginata–Corymbia calophylla* sclerophyll forest, open forest, and woodlands. Some open forests are subject to seasonal inundation and are dominated by *Melaleuca raphiophylla* with *Gahnia trifida* prominent in the understory. In the early Holocene, *Casuarina*-dominated woodland occurred, and from the mid to late Holocene, vegetation similar to the present has generally persisted (Dodson and Lu 2000). Currently there is some debate about the climatic significance of vegetation changes in the Holocene of southwestern Australia. Churchill (1968) has used pollen analysis as a basis to argue for changing precipitation patterns, whereas Newsome and Pickett (1993) believe that the vegetation changes at do not necessarily support a climate change hypothesis. In addition, other evidence suggests that in some regions of the southwest, the changes

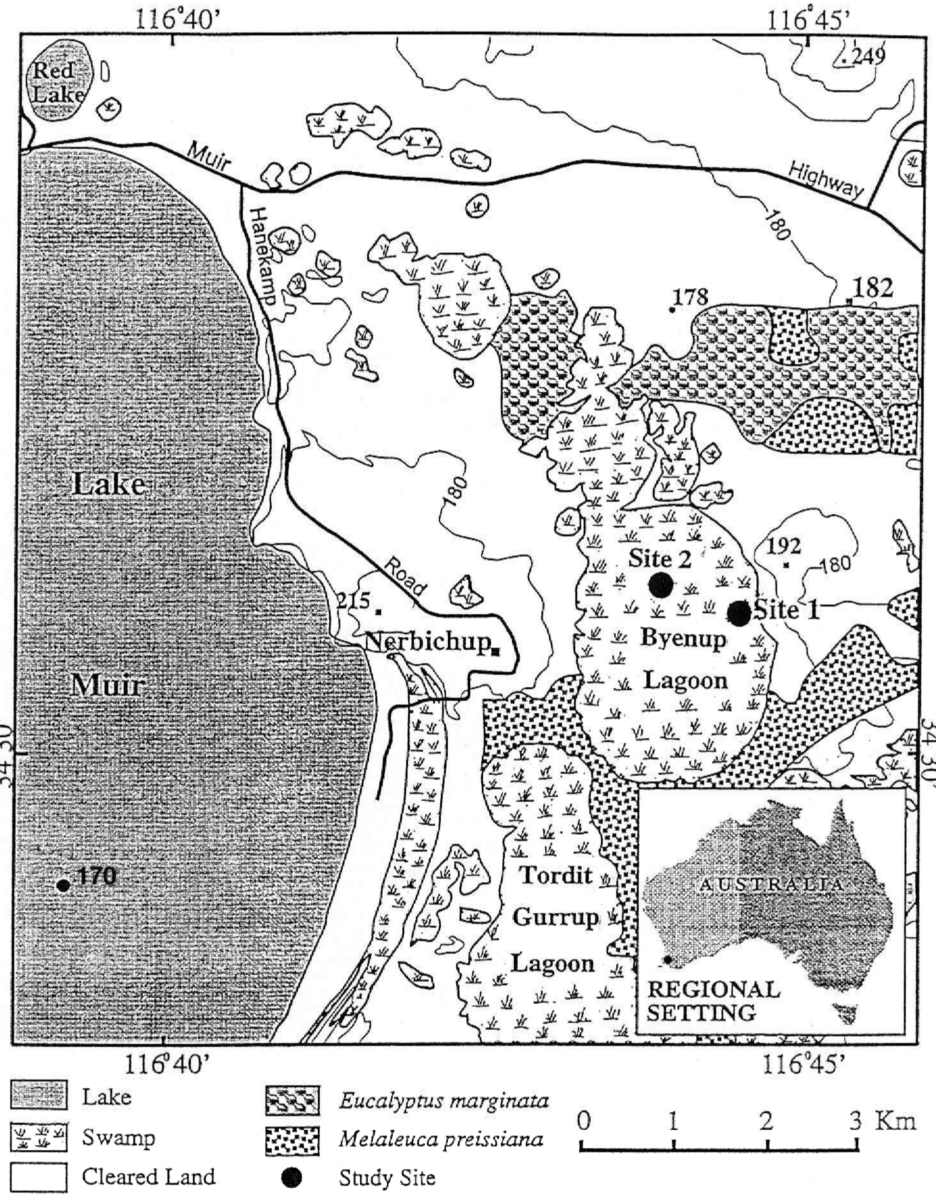

Figure 1 Map of southwestern Australia, showing location of Byenup Lagoon and coring sites for the analyses undertaken in this study

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might be diametrically opposite to those proposed by Churchill (1968) (e.g. Kendrick 1977). Whatever the overall patterns were, it is essential that the evidence is placed in a reliable time-frame for meaningful comparisons across the region.

METHODS

Sediment samples were collected from Byenup Lagoon with a Russian sampler (Jowsey 1966) in late 1996 (Site 1) and early 1997 (Site 2) after identifying the deepest organic sediment sections in the east and southeast of Byenup Lagoon (Figure 1). Core samples were wrapped in plastic film and aluminium foil in the field and stored at 4 °C after transport to the laboratory. Dodson and Lu (2000) described the sediment as follows: at Site 1 there was 165.5 cm of black fibrous peat below which 1 cm of pale brown peat (10YR 7/3), 2.7 cm of yellowish brown peat (10YR 5/4), and from 169.2 to 170.0 cm there was a greenish gray clay (5BG 6/1), 0.3 cm of dark gray clay (10YR 3/1), and the base of the core (to 170.8 cm depth) consisted of 0.5 cm of greenish gray clay. At Site 2 there was a black fibrous peat from the surface to 200 cm, then a transitional shift through 6 cm of dark gray clay (10YR 3/1), which persisted to the base of the core at 235 cm depth.

The chronology for the sediment sections was compiled from a series of conventional and accelerator mass spectrometry (AMS) ^{14}C dates on bulk sediment, individual shells of *Bothriembyron* sp., pollen preparations and hand-picked charcoal fragments retrieved from the sediment (Table 1). The conventional analyses were undertaken in the Radiocarbon Laboratory in the Department of Geography at The University of Western Australia, and staff at ANSTO undertook the AMS analyses. In addition, living snail shells and shell from a clay layer were analyzed by x-ray diffraction at Nanjing University to establish whether calcite was present. Calcite indicates either secondary deposition or recrystallization, since the shell is normally composed of aragonite. Both shell samples were composed of aragonite and their pretreatment at the Xi'an Laboratory followed the procedure given in Zhou et al. (1999) for converting them to CO_2 then graphite (Slota et al. 1987). The graphite was then dated by AMS.

Samples for the pollen preparations which were dated by AMS were washed and heated to 100 °C in 10% NaOH to remove all traces of humic acids then rinsed to neutrality in 2% HCl. They were then sieved through a 150 μm mesh and washed in a 2.2 gm cm^{-3} density lithium heteropolytungstate solution, a heavy liquid treatment, then washed in deionized water. The residues at this point contained abundant pollen, but some cellulose as cuticle, fungal hyphae, some fine charcoal, chitin, and some undifferentiated plant matter.

The charcoal samples were hand-picked from remains trapped on the sieved samples used for the pollen preparations. These had already been washed to remove humic acids or traces of carbonate and were also dated by the AMS method.

The shells of *Bothriembyron* sp. were hand-picked from the sediment. Living animals were collected from the samphire region around the shore of Lake Muir (Figure 1). Shells were boiled in 10% NaOH for 20 min and dried at 105 °C then submitted for dating by the AMS method.

Two peat samples of about 30 g were selected for conventional ^{14}C analysis. These were washed in hot 10% NaOH and rinsed to neutrality in 10% HCl before combustion.

Table 1 Samples for AMS and conventional radiocarbon dating for Byenup Lagoon

Site	Depth (cm)	Sample	Number	Age (yr BP)	1-σ error[a]
1	Surface	Shell (living)	XLLQ707	Bomb affected	NA
1	0–1	Charcoal	OZC521	Modern	NA
1	29–30	Charcoal	OZC522	2270	50
1	39–40	Charcoal	OZC523	3280	70
1	39–40	Pollen	OZC524	3000	60
1	49–50	Charcoal	OZC525	3420	150
1	49–50	Pollen	OZC526	3350	110
1	59–60	Charcoal	OZC527	3820	60
1	59–60	Pollen	OZC528	3500	170
1	69–70	Charcoal	OZC529	4170	70
1	69–70	Pollen	OZC530	4300	60
1	79–80	Charcoal	OZC531	4230	100
1	99–100	Charcoal	OZC532	4160	80
1	119–120	Charcoal	OZC533	4870	80
1	139–140	Charcoal	OZC534	4810	160
1	155–165	Peat	UWA1	3925	130
1	159–160	Charcoal	OZC535	4700	90
1	159–160	Pollen	OZC536	4630	70
1	169–170	Charcoal	OZC537	4650	90
1	200–210	Peat	UWA2	4285	180
2	225–230	Shell	XLLQ708	9695	85
2	Surface	Shell (living)	XLLQ707	Bomb affected	NA

[a]NA means not applicable.

RESULTS AND DISCUSSION

The ^{14}C results are shown in Table 1 and these are plotted against depth in Figure 2. The modern shell sample was bomb affected and the oldest age, early Holocene, was from a fossil shell of the same species. Four paired pollen residue and charcoal samples appear to be consistent in age, and when tested with a paired t-test analysis, there is no significant difference in the results (P=0.2). As a group the AMS ages are consistent, and along with the bulk peat samples, show that the lower organic and clay sections were deposited quickly compared to the rest of the sediment. For Site 1, the AMS ^{14}C determinations are relatively consistent. The major date anomaly comes from a bulk peat sample (UWA 1) that dates a few centuries younger than the AMS samples from charcoal and pollen residues collected around it. One could argue that samples are older than 4100 BP below 60 cm depth, and between 4600 and 4800 BP for samples between 120 and 170 cm depth from Site 1. The Site 2 dates are older than 4000 BP, including the bulk peat sample dated by conventional analysis. The oldest date may indicate relatively discontinuous deposition in the early Holocene at this site, then deposition rates were relatively rapid between about 4000 and 4700 BP then were lower since this time.

The whole sediment sequence has a range of Holocene ^{14}C ages. There are a group of dates which cluster between about 4000 and 4700 BP, and since these cover a large range of sediment depths, they indicate relatively rapid deposition during this phase.

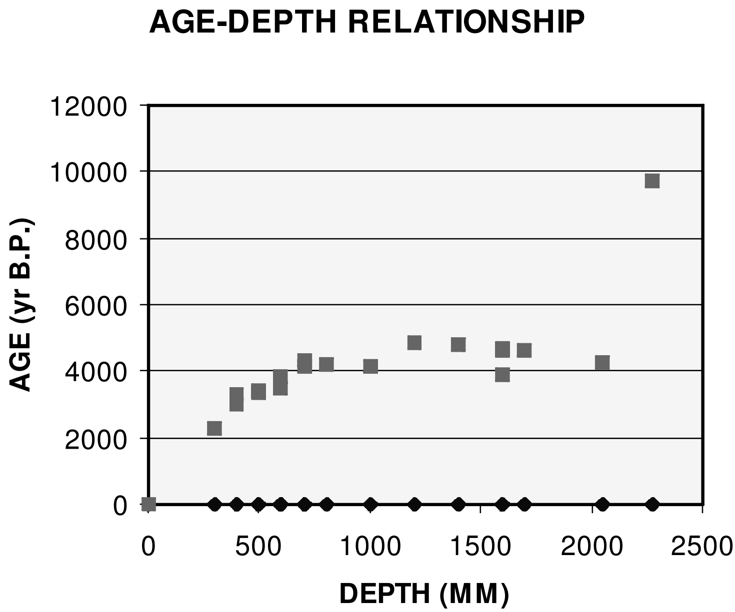

Figure 2 Plot of ^{14}C ages from Byenup Lagoon, southwestern Australia

The shell from a living snail indicated the carbon was bomb affected and suggests there was no ancient reservoir effect. The oldest date returned in the sequence was also a snail shell, and this has no corroborating age determination. The pollen analysis from this site showed that accompanying sediment from depths near this shell sample were dominated by *Casuarina* woodland rather than *Eucalyptus* and *Melaleuca* as is seen in levels of mid-Holocene age and younger. The vegetation change may be climatically significant, perhaps indicating warmer and/or drier conditions in the early Holocene, but whatever it means, it would take some time for a vegetation shift from this to the modern woodlands seen by the mid-Holocene. Indeed, the age difference seen in the dates is therefore not necessarily a dating problem and more likely indicates a stratigraphic hiatus. Thus, on the evidence available, the date of 9695 BP is credible.

The bulk peat samples appear to return younger ages than the surrounding AMS dates. UWA1 returned an age of 3925 BP, while bracketing AMS dates on charcoal and pollen residues were in the range of 4600 to 4800 BP. The second bulk peat age date (UWA2) of 4285 also appears to be younger than expected; however, with just two bulk peat ages the apparent lower age is best treated as a probable trend rather than a clearly demonstrated difference.

The pollen residue and charcoal samples prepared and analyzed by the AMS method returned a consistent group and trend in ages, and they were not significantly different when measured from the same sediment samples. This consistency has a number of important implications. Firstly, since pollen deposition arrives in the sediment through the atmosphere and with some water transport, with little likelihood of reworking from older material, and should not be influenced by reservoir effects (Regnell 1992), this suggests the same is true for charcoal in this deposit. Thus, if the charcoal has no large lag factor in the time since its production and incorporation into the sediment, it is valid to compare pollen and charcoal changes in reconstruction of vegetation and fire histories.

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The general conclusions from this study then are that bulk peat samples from southwestern Australia may return slightly younger ages than other materials and methods. Dates from the shell of *Bothriembyron* sp. snails are probably reliable. AMS determinations on pollen and charcoal were found to be consistent and are thus regarded as reliable ^{14}C ages. An important conclusion from this is that fossil charcoal in these peats was deposited contemporaneously with pollen in the same sediment, and this means it is valid to develop vegetation and fire histories from sequences such as these.

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