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and it is rather shallower than typical modern canoes. However, it would probably have been safe on the waters of Uniacke Lake, since the angular sections would have given great stability. Since this lake does not provide a route to major centres or waterways, and since dugouts ; ısually too heavy for regular portaging, it i. ılikely that this log-canoe was used for practical transportation. Sport fishing (trout occur in Uniacke Lake), and general recreation would have been more likely functions.

Such a dugout is of little significance in itself, but it does show that the two-log construction was in wider use in Canada than has been supposed.

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Note

[1] A full report of this survey is given by Carter & van Ryckevorsel (1980).

References

Beaudouin, F., 1970, *Les bateaux de l'Adour. Genèse d'une architecture nautique, Bayonne.* Cited by Lehmann,
l., Th., 1978, The flat-bottomed Roman boat from Druten, Netherlands. *IJNA*, 7: 259–67.
l, L. S., 1979, Recovery and preservation of a fresh water canoe. *IJNA*, 8: 261–3.
(. .er, J. & van Ryckevorsel, G., 1980, *An artifact survey in Lake Martha, Uniacke Estate, Nova Scotia.* Report to the Nova Scotia Museum by the Underwater Archaeology Society of Nova Scotia. Halifax.
Chapelle, H. I., 1951, *American small sailing craft—their design, development, and construction.* New York.
Greenhill, B., 1976, *Archaeology of the boat.* London.
MacKean, R. & Percival, R., 1979, *The little boats: inshore fishing craft of Atlantic Canada.* Fredericton, Canada.
Patterson, G., 1877, *A history of the County of Pictou, Nova Scotia.* Montreal.

The use of barnacles to establish past temperatures on historic shipwrecks

In order to fully understand the nature of the many factors which determine the survival of artefacts on an historic shipwreck a detailed knowledge of the site conditions is essential. Normally the conservator and the archaeologist are limited to data which can be obtained by direct measurement in the field. Because of financial constraints information on the annual variations in salinity, temperature and oxygen content have to be obtained from the literature. Since the majority of the historic wrecks off the Western Australian coast are in remote locations, modern reference data are rarely available. Even in the few cases where logs exist there is little or no information regarding water temperatures, so the conservator must find alternative sources.

The fouling of a ship's hull with barnacles (Pilsbury, 1907) and other marine growth has been extensively studied (Darwin, 1851) and is of major economic importance to the shipping trade. As barnacles grow and secrete their exoskeleton of calcium carbonate they act not only as a fouling mechanism but also as a recording device of the ambient temperature. The oxygen 18 to oxygen 16 isotopic ratio in the $CaCO_3$ of their skeletons is sensitive to changes in temperature; thus analysis of the $^{18}O/^{16}O$ ratios in the shell can be interpreted in terms of changes in temperature during the barnacles' growth. This type of information has been used (Killingley, 1980) to track the movements of California Gray Whales from Alaska to Mexico.

In May 1980 some barnacles attached to lead sheeting from the gripe and to leather casing around some forestay rigging were excavated from the wreck of the American China trader *Rapid* which sank off Pt. Cloates (22°44′S, 113°41′E) Western Australia on Monday, 7 January 1811.

Identification of the species is extremely important since many barnacles have relatively clearly defined regions of existence and so correct classification can help rule out some of the routes the vessel may have taken. The barnacles (Foster, 1981) were identified as being *Megabalanus tintinnabulum tintinnabulum* which is a tropic species. Examination of the barnacles showed that the juvenile colony had probably settled on the wreck at the Pt. Cloates site or had attached themselves as free swimming larvae (Wisely, pers. comm.) in the few days prior to wrecking. The barnacles were recovered from material which was buried about 0·5 m in the sediment. Traces of the lead sulphide galena (PbS) adhered to the base of the barnacles attached to the gripe showing that the samples had been in anaerobic conditions for quite some time. The wreck itself lies in 6 m of water on the leeward side of a coral reef about 1 km from the shore.

The calcite shells of the barnacles varied from 0·04 m in height with a 0·03 X 0·04 m base, to immature samples only 0·004 m high. Based on the observations of average growth rate of 20 mm/day for barnacles in Indian Seas the larger specimens were at least seven months old (Annandale, 1911).

The following procedures were performed on samples to obtain oxygen isotopic data. The shells were ultrasonically cleaned and treated with sodium hypochlorite after being cut in two with a diamond saw. Small samples were removed from the sequential growth lamellae of the sheath with a dental drill (0·5 mm diam., Fig. 1). Each sample (about 0·5 mg) was heated in a vacuum for 30 min at 250°C then analysed isotopically (Berger & Killingley, 1977) with an analytical precision of 0·07 per mil. The isotopic ratio is conveniently recorded as $\delta^{18}O$ (PDB) ‰ which is defined as $\delta^{18}O$ (per mil) = $\{(^{18}O/^{16}O)\ \text{sample}/(^{18}O/^{16}O)\ \text{standard} - 1\} \times 1000$ and is related to PDB, an international standard (Craig, 1957).

The results are shown in Fig. 2 where the $\delta^{18}O$ values for *Megabalanus tintinnabulum tintinnabulum* from the wreck at Pt. Cloates are plotted against the distance from the base of the sheath (terminal edge). There is an initial increase in $\delta^{18}O$ in the direction of shell growth

Figure 1. A sectioned view of part of the colon barnacles recovered from the wreck of *Rapid*. The sequential growth *lamellae* be seen with the oldest sections at the and the most recent growth at the base

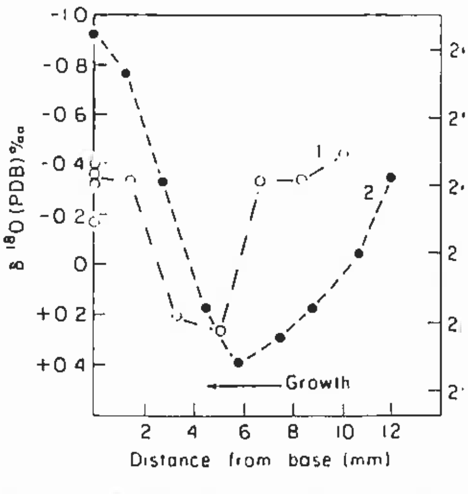

Figure 2. Variations in $\delta^{18}O$ of two specimen *Megabalanus tintinnabulum tintinnabu.* Each range of samples represents app mately the total life-span of the respe animals

reflecting decreasing water temperatures which passes through a maximum and then the isotope parameter begins to fall back towards the initial value. The $\delta^{18}O$ values can usually be used to calculate the temperature of the water from which the calcite precipitated by using a paleotemperature equation (Epstein *et al.*, 1953) that gives temperature as a function of the isotope composition of the precipitated calcite and the isotope composition of the water from which precipitation occurred. However, because barnacles do not exactly follow the equation, the temperature scale was calibrated using samples of the barnacle *Austromegabalanus nigrescens* which had grown on a reef at Kalbarri (27°42'S, 114°12'E) where the temperatures were known and the salinity was 35·6 ppt.

The barnacles recovered from the wreck site at Pt. Cloates showed a variation of temperatures from 21·5 to 26°C over the period of their growth. It seems likely that the barnacles in sample one attached themselves to the fittings of the *Rapid* shortly after she had been burnt to the waterline on 8 January 1811. This is indicated by initial isotopic temperatures of 24·5°C which agrees with our on-site measurements made in January 1979 and with the literature data. The captain had burnt the vessel to prevent following ships finding the 280,000 Spanish dollars (Henderson, 1981). The minimum temperature of 21·5°C, which typically occurs in August/September, was found at mid-growth in the barnacles and from then the temperature began to increase following the normal seasonal progression (Ministry of Defence, USSR, 1974).

When the isotope measurements were being made on the barnacles the name of the vessel and its previous route were not known. Since the ship was in ballast and carrying only 18,000 Spanish silver dollars it was thought that she may have foundered on the return journey from Macau. This possibility was ruled out on the basis of the maximum temperatures (26°C) recorded by the barnacles. If the ship had passed through tropical and equatorial waters where the barnacle species are also found, a maximum temperature of 28–29°C would have been recorded.

Both barnacles isotopically analysed from the site died at a time of increasing temperature (see Fig. 2) and the final temperatures via the $\delta^{18}O$ values, are typical of those between December and February. Since the barnacles were firmly attached to the lead sheeting and the leather cover around the heart-eye rigging when excavated, the objects must have had a significant change in their environment to cause the death of the barnacles. The change in site conditions was probably caused by the ship breaking up, either as a result of a cyclone or during salvage operations. It is known (Henderson, 1981) that some persons returned to the site and conducted salvage operations after the ship was wrecked. If explosive charges were used in the salvage work the forward sections of the vessel could have easily collapsed and so buried the barnacles.

We believe that the use of ^{18}O tracking techniques is a valuable tool for the conservator and maritime archaeologist. The present work has given access to on-site temperatures in 1811 which are not available from any other source. The time scale for the barnacles' life on the wrecked vessel has given important information as to how long the shipwreck remained intact.

This type of information helps to establish time frames of events and may assist in determining the fate of the bulk of the 280,000 coins!

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References

Annandale, N., 1911, Note on the rate of growth of barnacles in Indian seas. *J. Bombay Nat. Hist. Soc.*, XX: 1170–2.

Berger, W. H. & Killingley, J. S., 1977, *Glacial-holocene transition in deep-sea carbonates: selective dissolution and the stable isotope signal. Science*, 197: 563.

Craig, H., 1957, Isotopic standards for carbon and oxygen and correction factors for mass spectrometric analysis of carbon dioxide. *Geochim. Cosmochim. Acta.*, 12: 133.