A COMPARISON OF MARINE AND TERRESTRIAL RADIOCARBON AGES FROM NORTHERN CHILE

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ABSTRACT. The calibration of radiocarbon dates on marine materials involves a global marine calibration with regional corrections. Data from well-associated marine and terrestrial materials in archaeological artifacts from northern Chile indicated that the calibration is valid for the period AD 200–900 and suggest that coastal upwelling intensities during that period were similar to those of the early 20th century.

INTRODUCTION

The calibration of radiocarbon dates on marine materials involves different procedures from those required for terrestrial samples, because the specific ^{14}C activity of the reservoir in which these materials formed differed from that of the atmosphere. At times, the only datable material from a site is of marine origin, and thus, it is important to test the reliability of marine calibrations. Carbon from the ocean surface or mixed layer (including carbon from land-based species or individuals with marine diets) is "older" than coeval terrestrial carbon because the mixed layer receives an input of ^{14}C-depleted dissolved inorganic carbon (DIC) from the deep ocean. This offset has varied over time, because the long residence time of deep-water DIC buffers the deep ocean, and hence, to some extent, the surface, against production-induced variations in atmospheric $\Delta^{14}C$. Marine calibration curves (Stuiver and Brazuinas 1993) are used when converting marine ^{14}C ages into calendar dates to properly account for the reservoir age and its temporal variations.

Regional variations in the reservoir age due to spatial differences in upwelling of subsurface water can be estimated for the recent past from ^{14}C measurements on known-age marine mollusks (Stuiver, Pearson and Brazuinas 1986). ^{14}C ages corresponding to the calendar year of shell collection are derived from the marine calibration curve and compared to the ages actually measured for the shell samples. The difference represents a regional reservoir age correction ΔR, which must be subtracted from measured ^{14}C ages before the global calibration is applied. ^{14}C dates on three shells from Chile and Peru (Taylor and Berger 1967) yield a mean regional correction of 190 ± 40 yr.

The marine calibration curve differs from terrestrial ^{14}C calibrations because it is derived from a carbon-cycle model rather than from actual measurements on a time series of known-age materials. Because the model uses time-invariant ocean reservoir parameters, the calibration procedures involve the assumption that the ocean circulation at the time of interest was unchanged from that of the recent past. Previous tests of this assumption have used comparison of ^{14}C dates on marine and terrestrial materials in natural deposits (Southon, Nelson and Vogel 1990) or in debris from archaeological middens and hearths (Head, Jones and Allen 1983; Albero, Angolini and Piana 1986; Monge-Soares 1989; Talma 1990; Little 1993). In this study, we compared ^{14}C ages for well-associated marine and terrestrial samples from manufactured artifacts (bird-skin garments and a water bottle) from an archaeological site in northern Chile.

The material dated derives from 1966–1967 investigations in the early agricultural village of Caserones and its cemetery (Nunez 1966; True 1980). Caserones lies on the southern bank of the *quebrada*

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(river valley) Tarapaca in northern Chile (19°55′S, 69°31′W, 1300 m asl). The *quebrada* traverses the Atacama Desert and terminates in the interior basin of Pampa de Isluga. The Caserones site, 60 km from the ocean, consists of an extensive cluster of roughly rectangular structures surrounded by a D-shaped defense wall. ^{14}C dates suggest that it was probably occupied from 300 BC, with most concentrated occupancy between AD 400 and 600 and only intermittent use after AD 700 (Rodman and True, ms. in preparation). Abandonment was almost certainly related to water supply: flow in the *quebrada* presently terminates several kilometers upstream from the site.

Because of extreme aridity, preservation is excellent. Besides other organic artifacts, the refuse and graves contained locally produced and imported cordage of both camelid and cotton origin. Most of the cordage and yarns and some textile fragments were made of llama, alpaca or vicuna hair from interior highland regions, but local plant fibers and even rodent hair (*Lagdium viscacha* or chinchilla) were also spun and formed into looped and knotted textiles. Fish bones and molluscan remains, as well as feathers and skin from marine birds, attest to close contact with the ocean.

Three of the dated artifacts were fragments of sewn feathered garments (possibly capes, mantles or blankets), made from intact skins of the brown pelican (*Pelicanus occidentalis thagus*) sewn together with camelid hair fiber. Similar cloaks made from skins of cormorant (*Phalocrocorax*) or boobys (*Sulva variegata*) were reported previously from northern Chile (Bird 1946; Dauelsberg 1974; Moragas 1983). The fourth specimen was a water bottle, similar to one previously recovered at Punta Pichalo on the Chilean coast (Bird 1946). It was made from a parchment-like skin or bladder material, possibly the stomach of a seal or sea lion. The drawstring on the Caserones specimen was made of plant fiber cord and was sewn into the skin with camelid fiber thread. The string terminated in pull knobs made of fish vertebrae wrapped in the skin or bladder material and secured with fiber.

Feather and vegetable fiber samples were subjected to a standard acid-base-acid treatment (1N HCl and 1N NaOH washes under ultrasound at 50–60°C); the less-resistant skin samples and camelid hair were treated with acid only; a fish vertebra was decalcified by prolonged soaking in 1N HCL. Samples were combusted with CuO in evacuated sealed quartz tubes at 900°C and converted to graphite (Vogel, Nelson and Southon 1987). Aliquots were also taken for stable carbon isotopic analysis. ^{14}C was measured at the Center for Accelerator Mass Spectrometry (CAMS) at Lawrence Livermore National Laboratory (Southon *et al.* 1990).

Results and Discussion

Table 1 gives the stable isotope data and ^{14}C results. The $\delta^{13}C$ results for the camelid hair samples and from the bird feathers are just those which would be expected for proteinaceous materials from terrestrial and marine consumers, respectively (Nelson, Chisholm and Schwarcz 1982). The skin that forms the water bottle is clearly of marine origin. The ^{14}C ages of the marine samples are 450–530 yr greater than those of the plant fiber and hair samples.

We tested the marine calibration for the Chilean coast by deriving calibrated ages independently from the terrestrial and marine results for each artifact (Table 1, column 6). The terrestrial results were calibrated using decadal tree-ring data (Stuiver and Becker 1993). We subtracted 40 yr from the terrestrial ages prior to calibration to take account of the lower ^{14}C levels of the pre-industrial southern hemisphere atmosphere compared to those of the northern hemisphere tree-ring data sets (Vogel *et al.* 1993). The Stuiver and Brazuinas (1993) marine calibration was used with the 20th century regional correction of $\Delta R = 190 \pm 40$ yr (Taylor and Berger 1967). Good agreement between the two sets of calendar ages indicates that marine samples from this area with ^{14}C ages between 1800 and 2300 BP should yield reliable calibrated dates.

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TABLE 1. Caserones ^{14}C Ages: Marine-Terrestrial Comparisons

Sample ID	Material	CAMS -no.	δ^{13}C (‰)	^{14}C age*	Cal date (AD)†	ΔR‡
CAS512 Bird-skin cape	Feather	7610	−13.4	2120 ± 90		
CAS512 Bird-skin cape	Feather§	9374	−13.4	2040 ± 50		
Mean				2060 ± 40	480–620	
CAS512 Bird-skin cape	Yarn§	9372	−20#	1630 ± 70		
CAS512 Bird-skin cape	Yarn	9373	−20#	1560 ± 50		
Mean				1580 ± 40	430–600	160 ± 80
CASTr6/7 Bird-skin cape	Feather	10315	−11.5	2170 ± 60		
CASTr6/7 Bird-skin cape	Bird skin	10316	−12.2	2280 ± 50		
Mean				2225 ± 50	260–450	
CASTr6/7 Bird-skin cape	Yarn	10314	−20.2	1690 ± 60	340–530	245 ± 85
CAS93.031 Bird-skin cape	Feather	10318	−13.1	2310 ± 100		
CAS93.031 Bird-skin cape	Bird skin	10319	−13.6	2290 ± 60		
Mean				2295 ± 50	210–370	
CAS93.031 Bird-skin cape	Yarn	10317	−20.4	1850 ± 70	100–340	135 ± 110
CAS572 Water bottle	Fish vertebra	10321	−12.8	1740 ± 50		
CAS572 Water bottle	Skin? stomach?	10322	−14.5	1800 ± 60		
Mean				1770 ± 35	770–890	
CAS572 Water bottle	Plant fiber	10320	−23.5	1270 ± 60	690–900	160 ± 95

*^{14}C ages are conventional ages calculated according to Stuiver and Polach (1977).
†Calibrated ages were calculated independently from dates on terrestrial and marine samples (see text).
‡20th century known-age shell data (Taylor and Berger 1967) give ΔR = 190 ± 40 yr.
§Duplicate sample
#Estimated δ^{13}C

We determined ΔR values by using the marine calibration curve to find the marine ^{14}C ages corresponding to the calendar dates derived from the terrestrial ages (see Fig. 1). The difference between these calculated marine ages and the measured ages for the marine samples gives ΔR (Table 1, column 7). The ΔR uncertainties are large, because plateaus in the terrestrial calibration curve increase the calibrated age range associated with a terrestrial ^{14}C date, and this increase carries through the marine date calculations. However, agreement between the ΔR values and the 20th-century shell correction is excellent. Assuming that the dated marine predators incorporated carbon from local sources (*i.e.*, ate non-migratory species or juveniles), this suggests that upwelling intensities along the coast of northern Chile from *ca.* AD 200–900 were similar to those of the early 20th century. This conclusion should be treated cautiously, as it is based on just four "snapshots" of ocean-atmosphere ^{14}C differences within this period, but it nevertheless has important implications for long-term stability of the coastal climate and its effect on human populations.

These results highlight the likelihood of good association of marine and terrestrial material from manufactured artifacts. The marine and terrestrial components of such artifacts are typically both "fresh", *i.e.*, represent coeval samples, whereas material from other archaeological contexts, such as hearths and middens, may be more subject to disturbances that juxtapose marine and terrestrial samples from different periods. Marine-terrestrial pairs in archaeological artifacts represent a potentially valuable resource for researchers concerned with the stability of ocean circulation and climate, as well as for archaeologists and others concerned with ^{14}C calibrations.

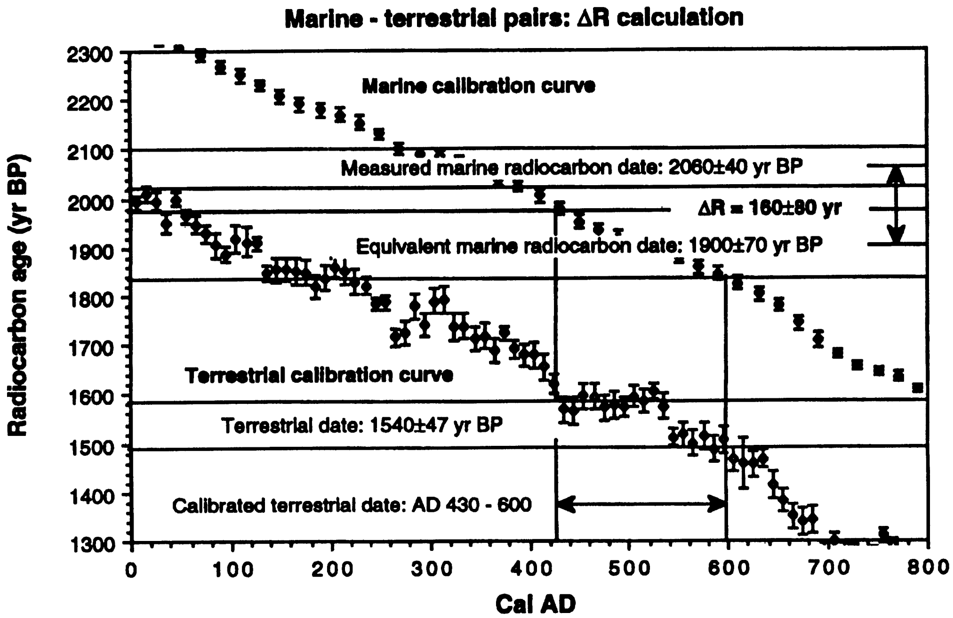

Fig. 1. Calculation of ΔR from the first set of paired marine and terrestrial samples in Table 1. The measured ^{14}C date on the terrestrial samples (1580 ± 40 yr BP) is corrected for the 40-yr southern hemisphere offset, and the calibration data uncertainty is folded in. The corrected value of 1540 ± 47 yr BP calibrates to AD 430–600. The marine calibration gives the ^{14}C date corresponding to AD 430–600 as 1900 ± 70 yr BP. ΔR is the difference between this calculated marine date and the measured ^{14}C date of 2060 ± 40 yr BP for the marine samples

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