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RESERVOIR CORRECTIONS FOR MARINE SAMPLES FROM THE SOUTH ATLANTIC COAST, SANTA CATARINA STATE, BRAZIL

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ABSTRACT. Coeval shell and charcoal from Santa Catarina State, Brazil, differ systematically in ^{14}C content, indicating a reservoir effect in marine samples. For modern samples (AD 1939–2000) and archeological samples (2500–1595 BP), the mean ^{14}C age difference between marine and atmospheric carbon is 220 ± 20 years, the marine carbon being older. For three samples dated AD 1939–1944, a distinct reservoir correction of 510 ± 10 years is also observed. The ages of archeological shell samples from Jabuticabeira may be corrected by subtracting 220 years from the apparent ^{14}C ages.

INTRODUCTION

While land plants typically derive their carbon from the atmosphere, aquatic flora and fauna obtain carbon from dissolved inorganic carbon (DIC). In radiocarbon dating of aquatic flora and fauna, this poses the question of whether their carbon source was in isotopic equilibrium with the atmosphere. Extended work on this question reveals that disequilibrium is more likely. In the case of marine organisms, this is because radiocarbon equilibration between the dissolved inorganic carbon (DIC) of ocean water and atmospheric carbon dioxide is limited by time, turbulence and the difference in $^{14}C/C_{TOTAL}$ between the atmosphere and surface ocean water.

The $^{14}C/C_{TOTAL}$ of surface ocean water is not the same throughout the world. In many near-coastal zones, deep-water upwelling brings older water to the surface. Mixing of the older water with surface water results in lower $^{14}C/C_{TOTAL}$, and consequently aquatic flora and fauna growing in near-coastal zones will have an apparent ^{14}C age older than that of coeval land plants. This difference in age is referred to as the R-value (R for reservoir). The R-value, with units of ^{14}C years, may be subtracted from the laboratory analysis radiocarbon date to yield reservoir-corrected ^{14}C date. This assumes that the R-value is constant with time.

R-values are space dependent, and possibly time dependent, and not confidently estimated from knowledge of present-day coastal upwelling of deeper ocean water. But it is precisely these upwelling zones that bring nutrient-rich water to the surface and promote growth of shellfish that attracted prehistoric humans as a source of food.

The radiocarbon community has responded to the need for coastal R-value data by publishing dates from coeval shells and charcoal from archaeological sites (see website in Stuiver et al. 2001). Note from the map at this website that data from the east coast of South America are very sparse (only one site, in Venezuela). Here we present the first reported radiocarbon dates on coeval shell and charcoal from the Atlantic coast of Brazil.

SITE DESCRIPTION AND SAMPLING

We investigated an archaeological site at Jabuticabeira, 28°36′S, 48°60′W, in Santa Catarina State, Brazil, near the Atlantic coast. The shell mound or sambaqui at the site consists of stratified deposits of abundant marine shell material with some associated charcoal. The ^{14}C dates of the charcoal span

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an interval of 2100 to 2500 BP, and uncorrected dates for the shells range from 1800 to 2900 BP. To extend the time range of this study to the near-present pre-atomic era, we assembled archived specimens collected on the coast of Rio de Janeiro State (approx. 23°S, 43°W) in AD 1939 and 1944. These shells had been archived in the collections of the National Museum of Brazil. In addition, in 2000 we collected live shell samples from the coast of Santa Catarina State. Of the samples collected in 2000, A11234 represented open coastline, and A11235 came from a coastal lagoon. We have compared our data with data from Santa Catarina Island (27°30′S, 48°W). Nadal De Masi (1999) dated samples including shells labeled AD 1942 and AD 1945 from the Gofferjé Collection, and a single ancient shell-charcoal pair from a lagoon environment.

Table 1 shows the percent modern carbon (pMC) of the specimens, normalized to $\delta^{13}C = -25‰$. Data given by Nadal de Masi (1999) have been recalculated as pMC; $\delta^{13}C$ data are not available for his samples. Assuming the charcoal derived from short-lived terrestrial plants, its ^{14}C level represents that of its contemporary atmosphere. For the AD 1939 to AD 1944 samples we estimated the atmospheric ^{14}C from decadal $\Delta^{14}C$ values in wood from the western US (Stuiver and Becker 1993). For $\Delta^{14}C$ values in the AD 2000 atmosphere we used our unpublished data for plants grown in southern Arizona well away from urban effects. Latitudinal differences in atmospheric ^{14}C levels are known for pre-industrial samples and would require a correction of 0.2 pMC between western USA and southern Brazil (Braziunas et al. 1995). The correction, if any is required for the post-industrial atmosphere, is smaller than the error of our measurements and has not been applied.

Figure 1 shows the age difference between shell and atmospheric carbon as a function of atmospheric pMC. There are two distinct ranges of age difference. With the exception of three data points for the interval AD 1939 to AD 1944, the age difference is consistent, with a mean ± standard error of 220 ± 20 years. For the three exceptions, the mean age difference is 515 ± 10 years.

Lagoon samples do not appear to differ from open coast samples on the indication of the limited data set presented in Table 1. For the sample pair A11234 and 11235, the ^{14}C contents are identical within error, indicating no measurable difference between lagoon and open sea. In the case of CAMS 42118 and 42119, there is no clear difference between the lagoonal shell and the atmosphere, and the result for the lagoonal shell overlaps the range for open-coast Jabuticabeira samples.

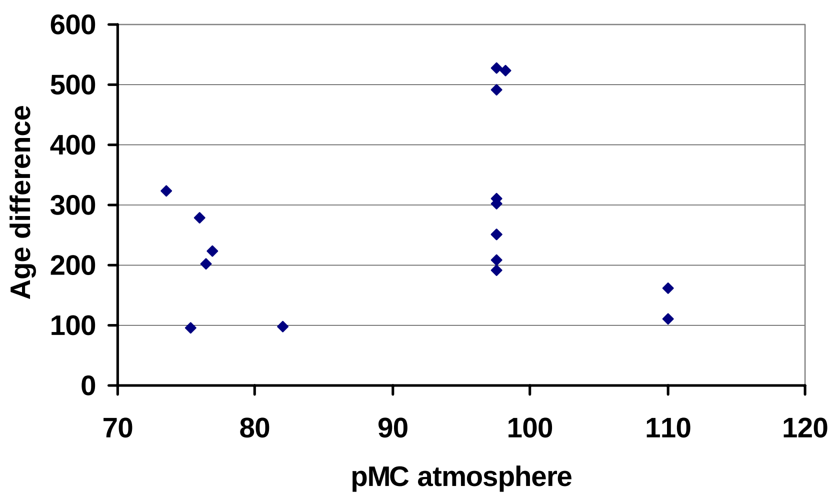

Figure 1 Plot of age difference between contemporaneous atmospheric and marine carbon vs. pMC of atmospheric carbon

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Table 1 pMC data

Sample	Lab nr	pMC	std. dev.	$\delta^{13}C$ ‰	Lab nr	pMC	std. dev.	$\delta^{13}C$ ‰	Age difference
Jabuticabeira		Charcoal				Shell			
JAII6	A9896	76.4	0.4	–26.5	A10243	74.5	0.4	–1.2	202
JAII8	A9893	76.0	0.6	–27.2	A10244	73.4	0.3	–0.1	280
JAII11	A9890	75.3	0.4	–29.4	A10245	74.4	0.3	–0.5	97
JAII13	A9899	76.9	0.6	–27.7	A10246	74.8	0.3	–0.8	222
JAII17	A9882	73.5	0.5	–26.5	A10247	70.6	0.3	–0.2	323
Modern shells		Atmosphere				Shell			
Fazenda Jap. 1944		97.6			A10037	95.1	0.5	0.0	208
Jurujuba 1939		98.2			A10038	92.0	0.3	–0.1	524
Praia Tapera 2000		110.0	0.5		A11234	108.5	0.5	–0.1	110
Lagoa de Conceira 2000		110.0	0.5		A11235	107.8	0.5	–1.5	162
From Nadal de Masi (1999)		Atmosphere				Shell			
Ponta das Canas 1942		97.6			CAMS51904	91.8	0.5		492
Ponta das Canas 1942		97.6			CAMS52524	91.4	0.5		527
Ponta das Canas 1942		97.6			CAMS51903	94.0	0.5		302
Ponta das Canas 1942		97.6			CAMS52523	93.9	0.5		310
Ponta das Canas 1942		97.6			CAMS52772	94.6	0.5		251
Ponta das Canas 1942		97.6			CAMS52773	95.3	0.4		192
Canasvieras 1942		97.6			CAMS48547	94.6	0.5		251
Canasvieras 1945		97.6			CAMS48546	>100			
		Charcoal				Shell			
Santa Catarina Island	CAMS42119	82.0	0.4		CAMS42118	81.0	0.7		99

The two ranges of age difference for AD 1939 to AD 1944 are present in both sets of data. Nadal De Masi (1999) discounted the samples with an age difference near 500 years. He suggested that they might be shells that actually grew prior to AD 1942, or that they were products of an unusually high level of ancient carbon in the ocean. The labeling of the shells is open to some doubt because of the >100 pMC result for the sample labeled AD 1945, but the shells in question would have to be hundreds of years old to account for their ^{14}C content, and it is unlikely that they would have been mistaken for newly grown shells. An unusually high level of ancient carbon in nutrients is precisely the effect we are attempting to identify. Therefore we must accept that both reservoir corrections are valid, and that the supply of ancient carbon varied rapidly between AD 1939 and AD 1944.

Application of the 220 ± 20 reservoir correction to Jabuticabeira archeological samples results in a modest increase in error, e.g., for A9882, the corrected age is 2250 ± 60 BP, compared to an uncorrected age of 2470 ± 55 BP.

These R values apply only to the area studied, and over limited time intervals. Temporal variability in ocean upwelling is clearly present in the study area at various scales. Shorter-term (seasonal to decadal) variations are most likely responsible for the scatter in our data, but longer term variations may also be present. Our data illustrate the hazards involved in applying an R value deduced from recent shells to ancient material. It is impossible to be certain whether or not short-term variations such as those observed between AD 1939 and AD 1944 occurred sporadically, for instance, between 2100 and 2500 BP. We did not detect any in our 5 charcoal-shell pairs, but the data set is small.

CONCLUSIONS

We estimate a reservoir correction of 220 ± 20 years for ^{14}C dates measured on shells from the Atlantic coast in Santa Catarina State, Brazil in the interval 2500–1595 BP, and at present on the coast of Santa Catarina State. The limited data available yield no evidence of different reservoir corrections in lagoonal and open coastal shells. A larger correction, 510 ± 10 years, obtains for certain specimens between AD 1939 and AD 1944 in Rio de Janieo and Santa Catarina States, and may have affected ancient material.

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