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APPARENT AGES OF MARINE SHELLS: IMPLICATIONS FOR ARCHAEOLOGICAL DATING IN HAWAI'I

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ABSTRACT. The conventional ^{14}C ages of 8 marine shells of known age and 11 marine shells stratigraphically associated with dated wood charcoal show considerable variation from expected ages. One source of this variation is seashore geology; comparison of 6 AMS dates on 3 species of shallow-water, herbivorous gastropod shells from Pleistocene limestone and Holocene volcanic coasts shows that shells from Pleistocene limestone coasts can have apparent, or reservoir, ^{14}C ages up to 620 yr greater than shells of the same species from volcanic coasts. The relatively great variation in apparent ages of Hawaiian marine shells poses problems for their use in dating archaeological sites. For best results, an archaeological marine shell should be sourced to a particular local environment, and the apparent age of shells in that environment determined by dating well-provenienced shells of known age.

INTRODUCTION

Hawai'i was discovered and settled sometime in the first millennium AD, *ca.* 1000 yr before the written observations of Cook and his crew brought the islands' prehistory to an end. The brevity of Hawaii's prehistoric period is appealing to those prehistorians who are interested in dating relatively short-term processes. In such a case, accurate calibration of radiocarbon dates is essential. Marine shells often offer substantial contextual advantages over wood charcoal for dating human activity at Hawaiian archaeological sites (Beggerly 1990). Despite these advantages, few marine shells have been dated because modest variation in their apparent ages, if not identified and corrected, could make these dates unreliable.

Calibration of marine shell ^{14}C dates is based on a model history of ^{14}C variations in the surface layers of the world ocean (Stuiver, Pearson and Braziunas 1986; Stuiver and Braziunas 1993). Regional deviations from this model are denoted by a factor, ΔR, which can be calculated from the conventional ^{14}C age of marine shells of known, pre-atomic-era calendar age, or estimated from the difference in age between stratigraphically paired samples of marine shell and a material, such as wood charcoal, from the terrestrial biosphere. Stuiver, Pearson, and Braziunas (1986) reported a ΔR value of 117 ± 50 for the Hawaiian islands from the conventional ^{14}C age of 1 of 2 *Trochus intextus* Kiener shells dated and identified incorrectly as *Trechus intertextus* by Broecker and Olson (1961). A second *T. intextus* shell, collected in 1936 at Pearl Harbor, O'ahu, yielded an unexpectedly old conventional ^{14}C age of 4300 ± 100 (Broecker and Olson 1961). Broecker and Olson advanced two hypotheses to explain the apparent age of the shell, which is clearly an outlier. Pollution of Pearl Harbor with fossil fuels during its use as a naval base in this century might also explain the questionable nature of this sample, which is unlikely to provide useful information on natural variability in the apparent ages of Hawaiian marine shells.

VARIABILITY IN APPARENT AGES OF DATED MARINE SHELLS OF KNOWN AGE

The ^{14}C ages of six other marine shells of known age show considerable variation from expected ages (Table 1). Athens (1985) and Beggerly (1990) dated marine shells from several locations on O'ahu Island and the south shore of Moloka'i Island, including three specimens of *Tellina (Quidnipagus) palatam* Iredale, a filter-feeding bivalve found in silty sands at 2–3 m depth (Kay 1979). The habitat and eating behavior of *T. palatam* suggest that it takes most of its carbon from the general ocean reservoir. ΔR values calculated from the ^{14}C ages of the *T. palatam* shells vary between 210 ± 40 and –60 ± 60, with a weighted mean of 60 ± 90, where the error term is the "scatter" sigma of the unweighted mean following Stuiver, Pearson and Braziunas (1986:982). The scatter sigma is used here because it potentially incorporates all sources of uncertainty in the error term, unlike the sigma calculated from errors in the ^{14}C ages, which incorporates only laboratory uncertainties.

The ^{14}C ages of other shell species vary widely from *T. palatam*. Beggerly (1990) dated a *Macoma (Cissulina) dispar* (Conrad) shell, a close relative of *T. palatam* found more often in areas with significant freshwater discharge (Kay 1979), and two *Conus distans Hwass*, a carnivorous gastropod that feeds on polychaete worms (Kay 1979). The *M. dispar* shell was more active than the modern standard, yielding a ΔR of –500 ± 120. The two *C. distans* shells, collected just a few miles from each other on the windward coast of O'ahu Island, yielded ΔR values >400 yr apart. No hypotheses have been advanced to account for the extreme variability in the apparent ages of these shells.

TABLE 1. Conventional Dates on Marine Shells of Known Age

Lab no.	Species	Collection location	Colln. yr	$\delta^{13}C$ (‰)	Conventional ^{14}C age (yr BP)	ΔR value
O'ahu Island						
Beta-12749	*C. distans*	Waimanalo	1936	1.14	960 ± 70	480*
Beta-13805	*M. dispar*	Kane'ohe	1918	2.81	–30 ± 120	–500*
Beta-15793	*T. palatam*	Pearl Harbor	1927	–0.20	430 ± 60	–40*
Beta-15794	*C. distans*	Kane'ohe Bay	1947	0.64	510 ± 60	25*
Beta-14024	*T. palatam*	Waikane	1925	–0.16	680 ± 40	210**
L-576J†	*T. intextus*	O'ahu	1840	2.20	629 ± 50	117‡
L-576D	*T. intextus*	Pearl Harbor	1936	2.90	4300 ± 100	3820‡
Moloka'i Island						
Beta-12903	*T. palatam*	Puko'o	1905	–1.12	410 ± 60	–60**

*Beggerly (1990)
**Athens (1985)
†L = Lamont
‡Broecker and Olson (1961)

MARINE SHELLS STRATIGRAPHICALLY ASSOCIATED WITH DATED WOOD CHARCOAL

In the 1950s and early 1960s, as part of an investigation into the suitability of various archaeological materials for ^{14}C dating, R. M. Chatters, of the Radioisotopes and Radiation Laboratory at Washington State University, dated seven paired *Cypraea* spp. and charcoal samples from successive 3.8- and 7.6-cm levels of a single excavation unit at the H8 site at South Point, Hawai'i Island (Emory and Sinoto 1969). The shells were presumably brought to the site from the nearby coast, which consists of Holocene lavas >4000 to a few hundred yr old (Lockwood *et al.* 1988), and is similar to coasts for many kilometers in either direction.

The methods used >30 yr ago to collect and date the charcoal and shell samples fall short of modern standards, and increase the uncertainty in estimates of the apparent ages of the shells. These shortcomings include: 1) the excavation method, which proceeded by arbitrary levels without control for intrusive features, does not guarantee the stratigraphic association of the paired samples; 2) no record was kept to indicate which of the 34 species in the Hawaiian genus, *Cypraea*, was dated; because habitat and feeding behavior vary widely among species (Kay 1979) interspecific variation in apparent age may occur; and 3) the ^{14}C ages of both the charcoal and shell samples were not corrected for isotopic fractionation. The effects of the first two sources of uncertainty cannot be estimated with confidence, but the latter can, and the ^{14}C ages of the shell samples have been recalculated under the assumption that $\delta^{13}C = 0.0‰$ (Taylor 1987).

Four of the 7 paired ^{14}C ages show a reasonably consistent relation, with *Cypraea* spp. ^{14}C ages between 350 and 545 ^{14}C yr older than those from wood charcoal (Table 2). The three other pairs yielded widely discrepant results. The WSU-489/WSU-514 pair inverts the usual relation, with a wood charcoal ^{14}C age 75 yr older than that from *Cypraea* sp. shell. The WSU-480/WSU-549 and WSU-478/WSU-558 pairs yielded large differences, apparently due to problems with the ^{14}C ages of the wood charcoal. Wood charcoal sample, WSU-480, yielded a future age, and WSU-478, from the base of the stratigraphic column, yielded a younger age than the five wood charcoal samples overlying it. Excluding the WSU-480/WSU-549 pair, with its obviously anomalous future wood charcoal ^{14}C age, the unweighted mean difference of the six pairs is 540 ± 210. If the WSU-489/WSU-514 and WSU-478/WSU-558 pairs are also excluded, the unweighted mean difference of the four remaining pairs is 450 ± 40, with the error term calculated as above. Weighted-mean ΔR estimates of 210 ± 200 for the 6 pairs and 70 ± 30 for the 4 pairs are derived following a procedure detailed by Stuiver and Braziunas (1993).

TABLE 2. Comparison of Charcoal and *Cypraea* Spp. Shell ^{14}C Age Determinations on Samples of Presumed Similar Age from Archaeological Site H8, Wai'ahukini, Hawai'i*

Lab no.	Material	^{14}C age** (yr BP)	Apparent ^{14}C age (yr)	ΔR value
WSU-480†	Charcoal	−1400 ± 300	--	
WSU-549	Shell	1380 ± 220	2780	--
WSU-479	Charcoal	685 ± 300	--	
WSU-548	Shell	1230 ± 180	545	120
WSU-486	Charcoal	965 ± 310	--	
WSU-551	Shell	1460 ± 150	495	80
WSU-487	Charcoal	1195 ± 210	--	
WSU-544	Shell	1610 ± 160	415	60
WSU-488	Charcoal	1100 ± 140	--	
WSU-513	Shell	1450 ± 310	350	−10
WSU-489	Charcoal	1185 ± 320	--	
WSU-514	Shell	1110 ± 300	−75	−440
WSU-478	Charcoal	400 ± 160	--	
WSU-558	Shell	1900 ± 160	1500	1040

*Source: Emory and Sinoto (1969)
**$\delta^{13}C = 0.0‰$ assumed for shell samples; −25.0‰ assumed for charcoal samples
†WSU = Washington State University

Four stratigraphically paired marine shell and charcoal dates from archaeological sites at Barbers Point, O'ahu (Davis 1990) yield estimates of ΔR that are significantly different from the values derived from shells of known age (Table 1) and estimated from the H8 site *Cypraea* spp. shells (Table 2). Barbers Point is located on the 'Ewa Coral Plain, an emerged Pleistocene reef that forms the coastal lowlands of southwestern O'ahu (Macdonald and Abbott 1970). Present-day freshwater discharge along most of this arid coast is primarily the result of sugar cane plantation irrigation water added to the caprock aquifer (Stearns and Vaksvik 1935). Before the establishment of plantations on the 'Ewa Plain at the end of the last century, the aquifer would have been "supplied by losses from ephemeral streams . . . and by direct penetration of rainfall" (Stearns and Vaksvik 1935:227). Seawater circulates freely along this coast because the well-developed fringing reef is narrow, exposing the shoreline to wave action.

Davis (1990) dated *Nerita picea* Recluz, a small gastropod that browses algae between the splash zone and the high water mark (Kay 1979). *N. picea* is common along rocky coasts throughout Hawai'i, including Barbers Point, and it is one of the most common shell species found as food refuse in archaeological sites. There is no reason to believe that the shells dated by Davis were brought into the site from a volcanic coast, the closest of which is >8 km away. Stratigraphic contemporaneity for 3 of the 4 paired samples was assured by selecting shell and wood charcoal pairs from the same hearth feature. The fourth pair (Beta-9058/Beta-11715) is from the same living floor; the charcoal sample is from a hearth feature and the *N. picea* shells are from a small concentration of shells located 3–4 m from the hearth (Davis 1990). Conventional ^{14}C ages are available for the wood charcoal samples, but not for the *N. picea* samples. If a $\delta^{13}C$ value of 0.0‰ is assumed for the marine shells, as above, then their ^{14}C ages are 1030–1740 yr greater than the paired wood charcoal samples (Table 3). A weighted-mean ΔR value of 990 ± 145 differs significantly from the ΔR values derived from the *T. palatam* shells of known age and the paired wood charcoal and *Cypraea* spp. shells from the H8 site.

TABLE 3. Comparison of Charcoal and *Nerita Picea* Shell ^{14}C Determinations on Samples of Presumed Similar Age from Archaeological Sites at Barbers Point, O'ahu*

Lab no.	Material	^{14}C age** (yr BP)	Apparent ^{14}C age (yr)	ΔR value
Beta-9543	Charcoal	400 ± 70	--	
Beta-9547	Shell	1870 ± 60	1470	1000
Beta-9052	Charcoal	550 ± 50	--	
Beta-9059	Shell	1580 ± 90	1030	600
Beta-9057	Charcoal	270 ± 50	--	
Beta-9549	Shell	2010 ± 70	1740	1310
Beta-9058	Charcoal	220 ± 70	--	
Beta-11715	Shell	1630 ± 60	1410	970

*Source: Davis (1990: 318–319)
**$\delta^{13}C$ = 0.0‰ assumed for shell samples

Effects of Pleistocene Limestone Substrate on the Apparent Ages of Gastropod Shells

Six marine shells of known, pre-atomic-era age were dated by Beta Analytic and Lawrence Livermore Laboratory, using accelerator mass spectrometry (AMS) to test the effects of Pleistocene limestone substrate on the apparent ages of three species of shell that are commonly recovered from archaeological sites—*N. picea, Cypraea caputserpentis* Linnaeus and *Cellana exarata* (Reeve). The limpet, *C. exarata*, grazes the intertidal and splash zones, particulary on volcanic substrates, and often occurs with *N. picea. C. caputserpentis* is largely herbivorous and is found from the shallow water at the shoreline to the edge of fringing reefs (Kay 1979).

I selected shells for dating from two coastlines, one dominated by Pleistocene limestone and the other by Holocene lavas. *C. caputserpentis* and *C. exarata* shells collected at Kaulana in 1923 are from Holocene lavas >4000 yr old (Lockwood *et al.* 1988). *N. picea* shells collected in 1924 at "Kea'au," a town *ca.* 6 km inland, probably derive from the adjacent coast, where lava flows range in age from 350 to >4000 yr (Holcomb 1987). The apparent ^{14}C ages of these shells should approximate the estimates derived from the H8 site *Cypraea spp.* shells (Table 2). *C. caputserpentis* and *C. exarata* shells collected at Barbers Point in 1914 and 1915, and *N. picea* shells collected at Kualakai are all from coasts that are composed primarily of Pleistocene limestones of the 'Ewa Coral Plain. The apparent ^{14}C ages of these shells should approximate the estimates derived from the archaeological *N. picea* shells from Barbers Point (Table 3).

Marine shells from volcanic coasts yield ΔR values between 140 ± 80 and 270 ± 100 (Table 4), whereas those from the Pleistocene limestone coast yield ΔR values between 510 ± 80 and 800 ± 80. Variance in ΔR between the two types of coast is greater than interspecific variance in shells from either coast. Intraspecific differences in shells from the two types of coasts are greatest in the two species that graze the intertidal and splash zones. *C. exarata* collected from Pleistocene limestone yields an apparent ^{14}C age 530 yr older than shells from a lava coast. The difference in *N. picea* shells is 620 yr. In contrast, *C. caputserpentis* shells collected from shallow offshore waters differ by only 250 yr.

TABLE 4. AMS Dates on Marine Shells from Pleistocene Limestone and Holocene Volcanic Coasts

Lab no.	Species	Substrate	Colln. yr	Convent. ^{14}C age	ΔR value
Beta-54332	*C. exarata*	Limestone	1914	1270 ± 80	800
Beta-54336	*C. exarata*	Volcanic	1923	740 ± 100	270
Beta-54331	*C. caputserpentis*	Limestone	1915	980 ± 80	510
Beta-54334	*C. caputserpentis*	Volcanic	1923	730 ± 80	260
Beta-54333	*N. picea*	Limestone	1930	1230 ± 80	760
Beta-54335	*N. picea*	Volcanic	1924	610 ± 80	140

DISCUSSION AND CONCLUSION

The apparent ^{14}C ages of marine shells from Hawai'i vary significantly for reasons that are only partially understood. Excluding the anomalous age on *T. intextus* from Pearl Harbor, a weighted mean ΔR for 13 marine shells of known age is 220 ± 100. The scatter sigma of 100 yr is nearly 5 times the sigma derived from the errors reported with the ^{14}C ages, which runs counter to the 24 examples from around the world listed in Stuiver, Pearson and Braziunas (1986), where the scatter sigma is, on average, *ca.* 10% greater than the average ^{14}C age sigma.

One factor in this relatively great variation is the influence of old carbon from Pleistocene limestone, which increases the apparent age of marine shells up to 620 yr. The weighted mean ΔR for the three shells from the Pleistocene limestone coast is 690 ± 90. The relatively low discharge of freshwater and the free circulation of seawater along the coast of the 'Ewa Plain suggest that old carbon from the limestone makes its way into the shells of animals that ingest it, either indirectly from the algae that they eat, or directly by dissolving and scraping the limestone as they browse. The relatively young apparent age of the *C. caputserpentis* shell, when compared to *N. picea* and *C.*

exarata shells from the ‘Ewa coast, might be due to differences in the diets of the gastropods, or to differences in their habitats. The shallow-water offshore habitat of *C. caputserpentis* is likely to include Holocene reef and reef detritis in addition to Pleistocene limestone.

The effects of factors other than local seashore geology can be seen in the large standard deviation of a pooled ΔR value for shells from volcanic coasts; a weighted mean ΔR for 10 shells (excluding L-576D for its unlikely date, and assuming from the apparent age of L-576J that it derived from a volcanic coast) is 110 ± 80. Stuiver and Braziunas (1993) note instances of regional and temporal variability in the apparent age of the ocean reservoir due to differences in upwelling and the influence of carbon transported in rivers. Both sources of variability could be active in Hawai‘i, where interspecific differences in the uptake of carbon from the environment could also be a factor.

Variation in the apparent ages of Hawaiian marine shells potentially introduces an unacceptable degree of uncertainty in the calibration of archaeological samples. Identification of significant environmental factors, such as the difference in apparent ages of shells from volcanic and Pleistocene limestone coasts, reduces the error terms for ΔR estimates. Generalized ΔR estimates for volcanic and Pleistocene limestone coasts, and a specific estimate for the bivalve, *T. palatam*, should prove useful in certain archaeological situations. Additional dates on marine shells of known age and identification of other sources of variability might further reduce the error terms for ΔR estimates, thereby increasing the utility of marine shell as a material for dating Hawaiian archaeological sites.

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Geological samples

O‘ahu Island

Beta-54331/CAMS-3217. Barbers Point **980 ± 80**

Cypraea caputserpentis Linnaeus, BPBM 62407 collected 1915 by W. A. Bryan and E. L. Bryan, B. P. Bishop Museum.
Comment: Cf. Beta-54334, below.

Beta-54332/CAMS-3218. Barbers Point **1270 ± 80**

Cellana exarata (Reeve), BPBM 64557 collected 1914 by W. A. B. and E. L. B.
Comment: Cf. Beta-54336, below.

Beta-54333/CAMS-3219. Kualakai **1230 ± 80**

Nerita picea (Recluz), BPBM 195632 bought 1930 at Honolulu fish market by J. S. Emerson, private collector.
Comment: Cf. Beta-54335, below.

Hawai'i Island

Beta-54334/CAMS-3220. Kaulana 730 ± 80

Cypraea caputserpentis Linnaeus, BPBM 197121 collected 1923 by T. T. Dranga, private collector.
Comment: Cf. Beta-54331, above.

Beta-54335/CAMS-3221. Kea'au 610 ± 80

Nerita picea (Recluz), BPBM 198771 collected 1924 by L. A. Thurston and T. T. D., private collectors.
Comment: Cf. Beta-54333, above.

Beta-54336/CAMS-3222. Kaulana 740 ± 100

Cellana exarata (Reeve), BPBM 198945 collected 1923 by L. A. T. and T. T. D.
Comment: Cf. Beta-54332, above.

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