Radiocarbon Content of Marine Shells from the California and Mexican West Coast

Abstract. *The radiocarbon content of contemporary pre-bomb marine shells from the upwelling environment of the California and the West Mexican coast has been determined. In addition, factors leading to the apparent ages of different magnitude for various marine environments are discussed.*

The usefulness and reliability of radiocarbon dates based on marine shells has been questioned repeatedly in the face of the known attack of ground waters on shell and of measurements yielding a nonuniform radiocarbon content of contemporary shells. However, in several cases, good agreement between shell and charcoal dates from the same stratigraphic horizon has been found. The reasons for avoiding radiocarbon age determinations based on marine shells appear to be rooted in the lack of sufficient controlled measurements which would permit general deductions to be drawn. Another major factor is the complexity of different marine conditions which are not sufficiently well understood.

It was recognized earlier that the environment of growth of marine shells plays an important part in the determination of the radiocarbon content of shell carbonate. For example, different shell species from open ocean beach, ocean inlets, and a tidal creek from the lower Atlantic coast between Georgia and the Virginia capes yielded a count rate of 20.00 to 20.77 count/min. However, shells from the Gulf of Mexico had a lower radiocarbon content. Oysters collected from Galveston Bay, Texas, possessed a radiocarbon concentration of 17 count/min which is equivalent to a 15-percent depletion with respect to the standard used. *Rangia* shells from Lake Pontchartrain, Louisiana, were only 18.6 count/min, or −7 percent (*1*).

While such sizable differences can occur in the radiocarbon content of contemporary sea shells, the average difference or apparent age of most shells is not so large with respect to the standard. This is demonstrated by the measurements of modern marine shells by different laboratories listed in Table 1.

Table 1. Apparent age (years before present) of contemporary marine shells and sea water.

Lab. No.	Species	Location	Date collected	Apparent age	Ref.
LJ–86	*Mytilus californianus*	SIO Pier, La Jolla, Calif.	1953	720 ± 90	*16, 17*
LJ–97	*M. californianus*	SIO Pier, La Jolla	1959	300 ± 40	*16, 17*
LJ–648	*Mulinia coloradaensis*	El Chinero Barrier Is., Baja Calif.	1962	210 ± 10	*17*
LJ–894	*Mytilus californianus*	Tres Hermanas (Punta Banda), Baja Calif. Norte	1962	186 ± 20	*17*
LJ–896	*M. californianus*	Nuevo Arbolitos (Punta Banda), Baja Calif. Norte	1959	240 ± 50	*17*
LJ–957	*Chione fluctifraga*	El Moreno, Baja Calif. Norte	1962	270 ± 20	*17*
LJ–978	*Strombus gigas*	Isla Cancún, Yucatan Peninsula	1963	<100	*17*
LJ–988	*Tegula gallima*	Near Punta Banda, Baja Calif. Norte	1956	270 ± 125	*17*
M–1220	*Strombus gigas*	Key Largo, Dade Co., Florida	1960	300 ± 75	*18*
M–1221	*Tivela stultorum*	Balboa Beach (Newport), Orange Co., Calif.	1959	40 ± 75	*18*
M–1222	*Haliotis fulgens*	La Jolla, San Diego Co., Calif.	1959	125 ± 75	*18*
A–322	*H. rufescens*	Santa Rosa Is., Calif.	1961	210 ± 50	*19*
A–357	*H. corrugata*	San Miguel Is., Calif.	1961	170 ± 50	*19*
A–358	*Mytilus californianus*	Dos Pueblos Ranch, Santa Barbara Co., Calif.	1961	80 ± 50	*19*
M–1148	*M. californianus*	Arlington Springs site, Santa Rosa Is., Calif.	1960	0 ± 75	*18*
M–1134	*Haliotis rufescens*	San Nicolas Is., Calif.	*c.* 1960	275 ± 150	*20*
LJ–127	Sea water	SIO Pier, La Jolla, Calif.	1959	840 ± 100	*17*
LJ–701	Sea water	El Moreno, near San Felipe, Baja Calif.	1963	210 ± 10	*17*

In the radiocarbon literature, dates have been reported on shell/charcoal (or wood) pairs which are thought to have been deposited contemporaneously. All dates reported so far on shell/charcoal or wood pairs which do not show a significant difference in radiocarbon ages or a difference in the right direction equivalent to an apparent age are listed in Table 2.

An examination of the differences in the dates listed in that table gives the impression that several sample pairs may be suspected of either not being contemporaneous or originating from an environment with greater than normal differences in apparent age between contemporary shells and wood. In addition, the contamination of samples with radiocarbon of different specific activity, either by intrusion of humic acid–like substances or exchange between shell carbonate and groundwater carbonates, can be assumed to be almost always present. The difficulties encountered may, as experience shows, sometimes defy a priori recognition by the collector.

In order to study the effect of upwelling ocean water along the California and Mexican West coast, a series of contemporary marine shells from these regions were obtained and their carbon-14 contents determined. On this coast, the prevailing winds cause the removal of surface ocean water and its replacement by water welling up from deeper layers characterized by a greater apparent radiocarbon age. The shells were collected before the testing of nuclear weapons began to raise the radiocarbon level in the oceans in the early 1950's. In this manner, the level of radiocarbon activity in the shells may also be compared with specimens found in archeological contexts. There are, however, a number of factors which influence the certainty of these measurements.

The question of the constancy of the radiocarbon level in the surface ocean with respect to time can be only partially answered at present. During the period of the Suess or Industrial Effect—from the end of the last century to the advent of bomb testing—the terrestrial biospheric levels of radiocarbon dropped by some 2 to 3 percent, while ocean shells showed a decrease of several tenths of 1 percent but never reached more than 1 percent (*2, 3*). In the period before the Suess Effect, the deVries Effect (*4*) is observed in wood; it appears to be caused by changes in the strength

Table 2. Carbon-14 measurements of shell and charcoal or wood pairs.

Lab. No.	Material	Date (years before present)	Ref.
Courtenay, Vancouver Island. B.C.			
GSC–24	Wood	12,200 ± 160	*21*
GSC–38	Shell*	12,360 ± 140	
Parksville, Vancouver Island, B.C.			
L–391D	Wood	12,150 ± 250	*22*
L–391E	Shell (?)	12,350 ± 250	
Valle de Rosario, Baja Calif. Norte			
LJ–85	Charcoal	960 ± 150	*23*
LJ–84	Shell†	1,060 ± 150	
San Antonio del Mar, Baja California			
LJ–645	Charcoal	1,660 ± 200	*11*
LJ–611	Shell‡	1,800 ± 300	
Punta Minitas, Baja California			
LJ–922	Charcoal	2,200 ± 200	*11*
LJ–925	Shell†	2,600 ± 200	
LJ–923	Charcoal	5,480 ± 200	*11*
LJ–924	Shell†	6,140 ± 250	
Morett site, Colima, West Mexico			
UCLA–187	Charcoal	1,500 ± 80	*24*
UCLA–1035	Shell§	1,480 ± 80	
UCLA–1034	Shell¶	1,630 ± 80	
Punta San Isidoro-Punta Cabras, Baja Calif.			
W–27	Charcoal	2,500 ± 200	*25*
W–26	Shell†	2,540 ± 200	
La Jolla Canyon, California			
W–155	Charcoal	600 ± 200	*26*
W–154	Shell†	580 ± 200	

* Pelecypod. † *Mytilus californianus.* ‡ *Tivela stultorum.* § *Chiome undatella.* ¶ *Polymesoda egeta.*

of the geomagnetic field influencing the production rate of radiocarbon. Another view stresses the effect of variations in the activity of the sun as affecting the formation of C^{14} (*5*). The deVries Effect can be roughly compared in magnitude to the Suess Effect, even though the variations oscillate on both sides of a hypothetically straight C^{14} production line. Therefore, variations on the order of a percent or so in sea shells should be expected. The variations of the deVries Effect have been measured on a large number of samples for the period of the past 2000 years (*5*). It is reasonable to assume that it may have also occurred during previous millennia, although its magnitude and extent then is not securely known at present.

Another question which can be raised concerns the constancy of the circulation of the eastern Pacific over the last several tens of thousands of years. The climatic differences on land are qualitatively well known for the western part of the North American continent during the late Pleistocene (*6*). It can be argued that the temperature gradient between the equator and the ice cover of the last glaciation was much greater than it is now between similar latitudes. As a consequence, a much more intensive air circulation must have existed during the Wisconsin than today. This would have resulted in stronger trade winds, coupled with stronger ocean currents, leading to faster mixing in some regions and in more extensive upwelling. There is, however, the possibility that the climatic changes of the Pleistocene had a much smaller effect on the large-scale ocean currents of the Pacific at the latitudes with which this study is concerned (*7*). At this time it would appear that prior to 11,000 to 12,000 years ago marine shells had either a very similar or possibly a somewhat lower radiocarbon content than analogous modern shells.

Many measurements of C^{14} in seawater carbonate as a function of geographic location and depth have been carried out by Bien, Rakestraw, and Suess (*8*) in the Pacific and by Broecker *et al.* in the Atlantic (*9*). If the radiocarbon content of shell carbonate is typical of the surrounding ocean carbonate, as has been discussed elsewhere (*3*), then a measure of the degree of reduction in the C^{14} content of shells of earlier millennia is found. Therefore, shell/charcoal sample pairs from the Wisconsin might provide an answer to the question of different oceanic conditions during the Pleistocene.

For this study, the West Mexican and California shells were obtained through the courtesy of donors from a number of different institutions. Before carbon dioxide was retained for proportional counting of the radiocarbon, the outer portion of the shell carbonate was removed by an acid treatment to avoid surface contamination. After measurement of the radiocarbon activity, the C^{13}/C^{12} ratio with respect to the PDB standard was determined and the data corrected to ΔC^{14}. The results are listed in Table 3 and the geographic locations are illustrated in Fig. 1.

When the difference of the C^{14} activity of shell carbonate to the NBS standard is taken from Table 3 and compared also with earlier data of Table 2, the general magnitude of the upwelling effect as expressed by the apparent age can be estimated. For California shells from open ocean areas, this is equal to about -160 ± 80 years, or -2.0 ± 1 percent, while a slightly larger effect of -240 ± 80 years, or -3.0 ± 1 percent, is typical of West Mexican marine shells from a similar environment. As can be expected, the West Mexican shells show a lesser content of radiocarbon since they are located downstream in the California current.

In the Gulf of California, samples

Table 3. Carbon-14 content of marine shell from Mexican and Baja California coast.

UCLA Lab. No.	Location and collection date	Shell species	Uncorrected δC^{14}(%)*	C^{13}/C^{12} (per mille)†	Corrected ΔC^{14}(%)‡
913	Mazatlan, Sinaloa (1939)	*Anadara grandis* (B & S)	−3.41 ± .56	−1.7	−3.08
914	Kino Bay, Sonora (1935)	*Tivela bryonensis* (Gray)	−7.05 ± .59	−0.4	−6.98
915	Manzanillo, Colima (1930)	*Ostrea fischeri* (Dall)	−3.0 ± .58	+1.1	−3.21
917	Carmen Is., Gulf of Calif. (1911)	*Strombus granulatus* (Swainson)	−6.97 ± .60	+0.5	−7.06
916	Cape San Lucas, Baja Calif. (1932)	*S. granulatus* (Swainson)	−4.65 ± .52	−0.6	−4.54
936	Isabel Island, Nayarit (1938)	*Muricanthus regius* (Wood)	−3.46 ± .58	−0.4	−3.38
940	Banderas Bay, Jalisco (1938)	*S. granulatus* (sby)	−2.55 ± .58	−0.8	−2.39
939	Magdalena Bay, Baja Calif. (1938)	*Arca tuberculosa* (sby)	−3.37 ± .62	−1.6	−3.06
963	Cedros Is., Baja Calif. (1939)	*Pecten (Lyropecten) subnodosus* (Sowerby)	−2.53 ± .60	−0.2	−2.49
938	Guatulco Bay, Oaxaca (1938)	*Turritella leveostoma* vgl.	−2.40 ± .58	+0.8	−2.56
1033	Seal Beach, Calif. (1921)	*Lunatia lewisii* (Gould)	−1.84 ± .56	−0.5	−1.74
149	Monterey, Calif. (1878)	*Mytilus californianus* (Conrad)	−2.0 ± .65		

* Expressed with respect to 0.95 NBS oxalic acid standard. † C^{13}/C^{12} ratios obtained from Isotopes, Inc. Error on these values is ± 0.1 per mille. ‡ Correction used is $\Delta C^{14} = \{[(1 + \delta C^{14})/(1 + 2\delta C^{13})] - 1\} \times 100$.

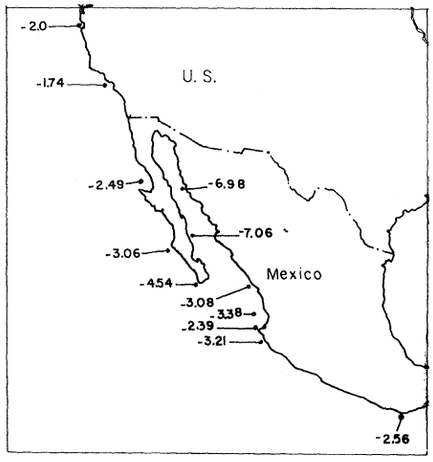

Fig. 1. Collection sites of shells used in this study.

UCLA-914 and UCLA-917 have a considerably higher apparent age than those from open ocean coasts. As has been pointed out by Hubbs and Roden (*10*), there occurs localized upwelling in this gulf along the eastern coast in the winter and along the western coast in the summer. Besides this mechanism for the introduction of C^{14}-poor water into the surface of the gulf, strong tidal currents cause extensive mixing of surface with subsurface waters. Since the upwelling in the gulf is thought to be less pronounced than on the Pacific Ocean coast of Baja California, the dominant mixing mechanism in the gulf must be due to the action of tidal currents, if the C^{14} content of water from similar depths in the open ocean and the Gulf is the same.

In the shallow northern portion of the Gulf of California, upwelling and tidal current effects apparently cannot draw on sea water of lower C^{14} content. This would explain the relatively low C^{14} depletion of -2.6 percent measured by the LaJolla Radiocarbon Laboratory for shells and sea water near San Felipe (LJ-648, LJ-701) (*11*). But at the mouth of the Gulf, near Cabo de San Lucas, strong currents result in the mixing of ocean water, as seen by UCLA-916, resulting in a depletion of -4.5 percent.

As a result of this study, several conclusions can be drawn of importance to the collectors of shells for archeological investigations, if no wood, charcoal, and so forth is available for C^{14} dating. First, it is necessary to establish the previous use of the shells in question. Those that had earlier been gathered primarily for their food content most likely had been gathered from places near the sites where the archeologists find them. But heirlooms may have already possessed an unknown age at the time of their last use, or may even have been obtained over great distances from a completely different oceanic environment. An example of the problem encountered with heirlooms has recently been discussed by Furst (*12*) and by Long and Taylor (*13*).

Once the origin of the shells has been established, the respective oceanographic conditions have to be ascertained. An area of restricted circulation with the open ocean and heavy admixture of river water, such as Galveston Bay or Lake Pontchartrain, will yield shells of very low C^{14} content. Similarly, shell beds exposed to upwelling and strong currents will also produce shells of high apparent age. Only areas of open interaction with the ocean, free from special mixing phenomena with deeper water layers, will produce shells with the least likelihood of possessing an unexpectedly low C^{14} content. Such shells cause only minimum errors that are due to an unknown high apparent age difference between marine and land-based samples of the same true calendar age.

Future study should determine to what extent it may be possible to follow local processes of upwelling in order to find the depth of origin of the rising water masses. This might be accomplished by measuring shells originating at different depths. As Sverdrup and Fleming estimate, the upwelling water rises only from depths of less than 200 m (*14*). But the vertical profiles of the ΔC^{14} content at stations in the Pacific Ocean indicate a relatively rapid rise in apparent age with increasing depth for the first 1000 m (*8*). As the average life-span of marine shells lasts from a few years to some 25 years (*15*), shells will acquire a radiocarbon content determined by the magnitude of seasonal changes in upwelling which carries ocean water of changing C^{14} content over the shell bed.

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Magnesium in Sea Water: An Electrode Measurement

Abstract. *Magnesium ion in standard I.A.P.O. sea water was measured with a magnesium-sensitive electrode. The results, presented either as magnesium-ion activity (0.017) or as the amount of ionized magnesium (0.048*M *or about 90 percent of the total magnesium), agree well with the data from the chemical model for sea water proposed by Garrels and Thompson.*

A recently developed (*1*) cation-sensitive electrode has considerable sensitivity to magnesium ion. It is approximately equally sensitive to divalent cations and responds to calcium or magnesium about ten times as strongly as to sodium ion; it is indifferent to *p*H between 5 and 10. One can use this many-functioned electrode to measure