AGE RELATIONS AND ZOOGEOGRAPHIC IMPLICATIONS OF LATE PLEISTOCENE MARINE INVERTEBRATE FAUNAS FROM TURTLE BAY, BAJA CALIFORNIA SUR, MEXICO

William K. Emerson[1], **George L. Kennedy**[2],
John F. Wehmiller[3], and **Everly Keenan**[3]

ABSTRACT

Two Pleistocene marine terraces at Turtle Bay, northwestern Baja California Sur, Mexico (27.7° N. lat.) have been dated at approximately 120,000 and 95,000 years B.P. on the basis of amino-acid racemization in fossil mollusks. These ages imply a correspondence to the early and middle-to-late parts, respectively, of marine oxygen-isotope stage 5. Faunal differences between the upper (24–27 m), 120,000–B.P. terrace and the lower (12 m), 95,000–B.P. terrace conform to the age relations and faunal-temperature aspects documented previously in other localities on the Pacific coast of North America. Faunal assemblages from these terraces contain both extralimital northern and southern species, an enigmatic situation not uncommon in East Pacific Pleistocene deposits. However, nearly 50% of the species from the upper terrace are warm-water (subtropical and tropical) taxa, whereas only 5% are cool-water (warm temperate) taxa. Conversely, the lower terrace fauna is composed of 21% extralimital northern taxa, and only a minor (9%) southern, warm-water element.

INTRODUCTION

Pleistocene marine invertebrate faunules from two marine-terrace deposits at Turtle Bay[4], northwestern Baja California Sur, Mexico (Figs. 1, 2), contain distinct warm- and cool-water elements (Emerson, 1980). These faunal differences, in comparison with similar faunal differences known to represent discordant ages elsewhere (Kern, 1977; Kennedy, 1978; Lajoie *et al.*, 1979), suggest that the warmer and cooler water assemblages at Turtle Bay might also represent different ages. To test this hypothesis, we examined the extent of amino-acid racemization in mollusks from each assemblage, and derived estimates of both relative and absolute ages. We also considered the zoogeographic implications of the temporally distinct assemblages (Emerson, 1980).

Amino-acid racemization methods can serve as both relative and semi-quantitative tools for

[1]Department of Invertebrates, American Museum of Natural History, New York, New York 10024
[2]U.S. Geological Survey, Menlo Park, California 94025
[3]Department of Geology, University of Delaware, Newark, Delaware 19711

[4]Turtle Bay (27°41'N., 114°52'W.) is also known as Bahía Tortugas, the port of which is Bahía San Bartolomé or Puerto Bartolomé.

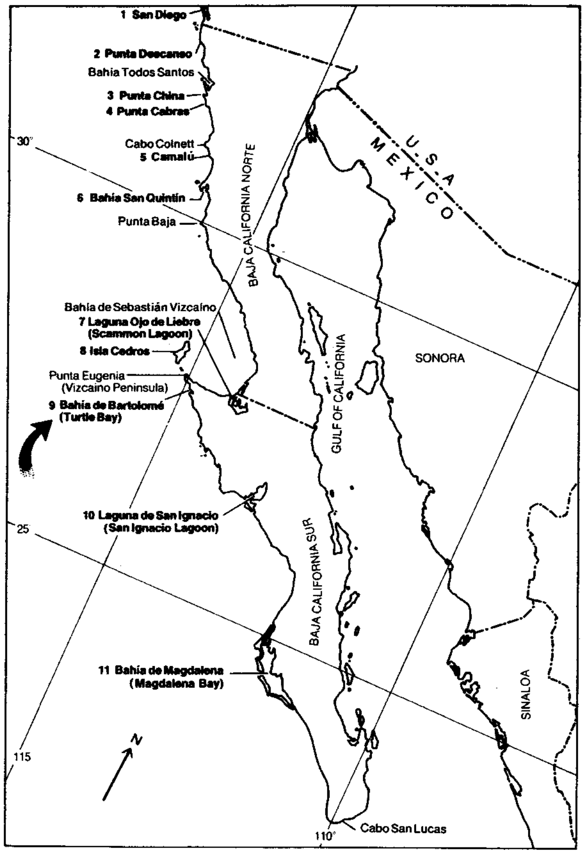

FIG. 1. *Index map of Baja California, Mexico, showing Pleistocene localities (numbered 1 to 11), Turtle Bay (locality 9), and geographic place names representing the modern range endpoints of some components of the Turtle Bay faunas.*

dating Quaternary mollusks (see Hare *et al.*, 1980, for recent review and references). Recent studies of Pleistocene mollusks from both the Atlantic and Pacific coasts of the United States have shown that D/L values increase with age in Pleistocene samples with known stratigraphic relations. In addition, the temperature dependence of amino-acid racemization has been documented with D/L data from three roughly coeval (~120,000-yr.) uranium-series-dated localities over a broad latitudinal range on the Pacific coast (24° N. to 35° N.) (Wehmiller and Emerson, 1980). The ~120,000-yr. amino-acid isochron thus generated allows interpolation of amino-acid enantiomeric ratios (D/L values) at intermediate temperatures, such as for the localities at Turtle Bay.

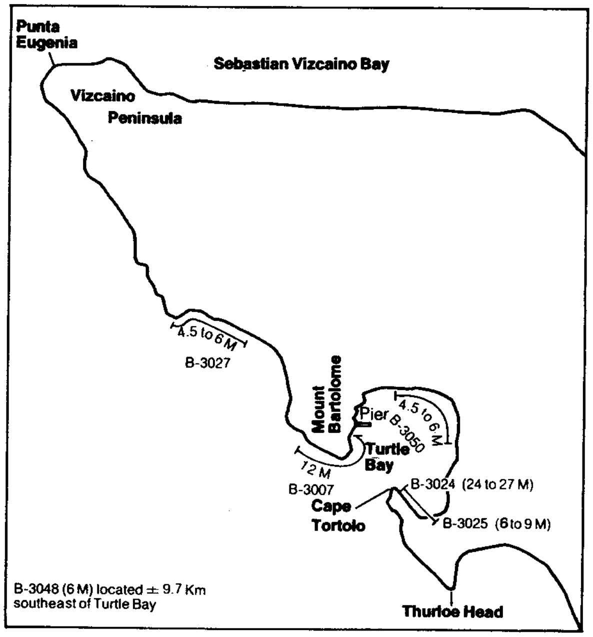

FIG. 2. *Sketch map (not to scale) showing the approximate location of fossiliferous terrace remnants in the Turtle Bay area.*

The fossils used herein are part of a collection made in 1956 by the late E. C. Allison from six localities in the vicinity of Turtle Bay (Fig. 2) (see "Register of Localities" for collection data). These collections are now in the University of California Museum of Paleontology (UCMP), Berkeley. Specimens for amino-acid analysis are from two of these localities, one containing a warm-water assemblage (UCMP loc. B-3024) and the other a cool-water assemblage (UCMP loc. B-3007). Locality B-3024 is on a 24 to 27-m-high terrace along the inner, bay side of Cabo Tortolo, a peninsula forming the southwest margin of Turtle Bay; locality B-3007 is on a 12 m-high terrace along the northwest margin of the bay, round its mouth. Although terrace remnants are present at several elevations around Turtle Bay (Ortlieb, 1979; Emerson, 1980), we herein refer to localities B-3024 and B-3007 as the upper and lower terraces, respectively.

PROCEDURE

We analyzed a total of 13 samples of the venerid bivalve mollusks, *Saxidomus nuttalli* Conrad, 1837, *Chione undatella* (Sowerby, 1835), and *C. californiensis* (Broderip, 1835), to determine the extent of racemization of their component amino acids. Multiple analyses, including repeats of the same shell, were necessary to discriminate the slight differences in age expected between the two localities. Amino-acid analyses were performed according to the procedures of Kvenvolden *et al.* (1972), Frank *et al.* (1977), Wehmiller *et al.* (1977), and Wehmiller and Emerson (1980). Capillary column gas chromatography was performed on either NTFA-isopropyl derivatives or NTFA-(+)-2-butyl derivatives of the total amino-acid mixture. The NTFA-(+)-2-butyl derivatives were analyzed with a Perkin-Elmer Sigma 2 gas chromatograph, using a 100-m glass capillary column coated with OV225, programmed as follows: increase from 115° to 140°C at 1.5°/min, 36 min isothermal; increase at 2°/min to 165°C, 150 min isothermal. Chromatographic conditions for the NTFA-isopropyl derivatives are found in Wehmiller and Emerson (1980). When both procedures were used, sample extracts were split and derivatized after all the hydrolysis and desalting steps. Excellent baseline resolution for at least seven amino acids is possible by the combination of these two procedures. The enantiomeric ratios (D/L) reported herein represent mean values of peak-height ratios from at least two chromatograms.

Table 1 lists the enantiomeric ratios of seven amino acids in the Turtle Bay samples. These data generally satisfy the criterion of reproducibility and are consistent, within typical analytical uncertainty, with relative intergeneric and intrageneric racemization (Lajoie *et al.*, 1980). The only significant deviations occurred in the glutamic acid data for *Saxidomus* from locality B-3007. In these samples, the glutamic acid D/L values were too high in comparison with the ratios of other amino acids, particularly leucine.

Table 1. Amino Acid Enantiomeric (D/L) Ratios From Chione and Saxidomus From Turtle Bay, Baja California Sur, Mexico

(UCMP localities B-3007 and B-3024)

Sample #	Species	Loc.	LEU	GLU	VAL	ALA	PRO	PHE	ASP	%Cal.	Method
79-62-1	C. undatella	B-3007	.57	.53	.50	.83	.64	.70	nd	<.8	B
"			.56	.51	.50	.87	nd	.58	.76	<.8	P
79-62-2			.56	.57	.47	.87	nd	.58	.76	nd	P
79-62-3			.52	.55	.53	.91	nd	.49	.75	nd	P
79-62-4			.53	.55	.53	.91	nd	(.6)	nd	nd	P
79-63-1	S. nuttalli	B-3007	.65	.61	.51	nd	nd	.61	.62	<.8	P
79-63-1R			.62	.58	.49	.97	nd	.65	.59	<.8	P
79-62-2			.64	.63	.53	.94	nd	.65	.69	<.8	P
79-62-2R			.63	.52	.47	.91	nd	.60	.60	<.8	P
79-64-1a	C. californiensis	B-3024	.58	.63	.55	.93	nd	.57	.69	nd	P
79-64-1b			.60	.59	.58	.94	nd	.59	.66	nd	P
79-64-2			.71	.64	.61	.89	.70	.76	nd	<.8	B
"			.69	.62	.59	.94	nd	.59	.70	<.8	P
79-64-2R			.61	.55	.48	1.0	nd	.66	.64	<.8	P
79-64-3			.61	.57	.55	.91	nd	.62	.73	nd	P
"			.63	.57	.56	.86	.72	.70	nd	nd	B
79-65-1	S. nuttalli	B-3024	.73	.62	.51	.92	.84	.75	nd	<.8	B
"			.71	.63	.54	.93	nd	.65	.67	<.8	P
79-65-1R			.69	.58	.51	.99	nd	.66	.58	<.8	P
79-65-2			.64	.59	.45	.86	.78	.74	nd	<.8	B
"			.67	.57	.48	.94	nd	.60	.69	<.8	P
79-65-3			.64	.58	.50	.94	nd	.59	.65	<.8	P

Notes for Table 1:

Amino acid abbreviations:

LEU Leucine
GLU Glutamic Acid
VAL Valine
ALA Alanine
PRO Proline
PHE Phenylalanine
ASP Aspartic Acid

%Cal. % Calcite
nd not determined

Methods: B - (+)-2-butyl derivative on OV 225 column.
P - isopropyl derivative on Chirasil Val column.

Samples labelled "R" represent second fragment cut from a shell valve; Samples split for analysis by two chromatographic methods represent single fragments, the hydrolyzate of which was split after desalting for separate derivatization.
Samples 79-64-1a and 79-64-1b are the two valves of a single articulated specimen of Chione.

DISCUSSION

Enantiomeric ratios for the Turtle Bay samples (Table 1) imply a small but significant difference in age between the two sample localities. Differences in enantiomeric ratios between each locality, however, are slight and fall barely outside the range of normal analytical scatter, especially for the *Saxidomus* data. Although the ratios from each locality overlap slightly, the difference in mean D/L values is 2–5% for *Saxidomus* and 6–10% for *Chione*, depending on which amino acid is compared. According to Miller and Hare (1980), these differences would be significant at the 90–95% confidence level. It might be argued, however, that the amino-acid results do not reflect any age difference, but are instead due to typical analytical scatter (in the case of *Saxidomus*), or species-level effects on racemization kinetics (in the case of *Chione*). Because of our accumulated observations on numerous samples of both species of *Chione* and two species of *Saxidomus* (Lajoie *et al.*, 1980; unpublished data), we believe the best interpretation is of a real age difference.

Figure 3 plots D/L leucine values against local mean annual air temperature for three uranium-series dated localities along the Pacific coast, at Cayucos, San Diego (Nestor Terrace), California, and at Magdalena Bay, as well as D/L leucine values for Bird Rock Terrace at San Diego.

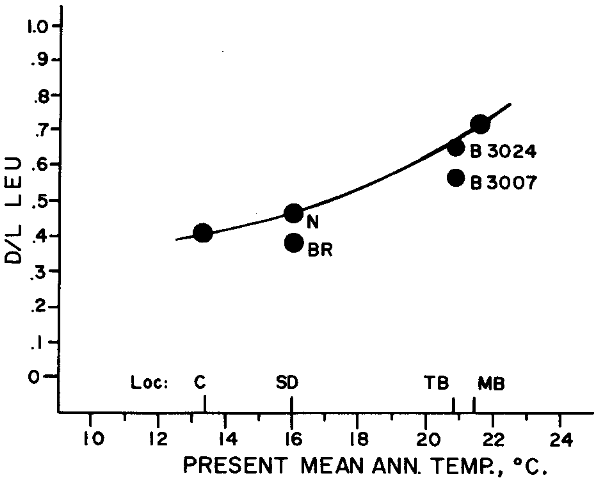

FIG. 3. *Comparison of D/L leucine values from Turtle Bay samples with 120,000-yr. B.P. isochron of D/L leucine vs. present mean annual temperature (after Wehmiller and Emerson, 1980). Calibration localities, connected by solid line, are: Cayucos (*C, *35.3°N. lat.); Nestor Terrace (*N, *at San Diego,* SD, *32.7°N. lat.); Magdalena Bay (*MB, *24.6°N. lat.). Data for Bird Rock Terrace (*BR, *at SD), which is known to be younger than the Nestor Terrace (Kern, 1977), imply a leucine kinetic model age of 80,000±10,000 years (Wehmiller* et al., *1977). The plotted D/L leucine values for Turtle Bay (*TB*), 0.57±0.03 for loc. B-3007 and 0.65±0.03 for loc. B-3024, are mean values of all data, factored to account for intergeneric differences in* Chione, Protothaca, *and* Saxidomus *(Lajoie* et al., *1980), and for differences produced by the two analytical methods used in this study (Wehmiller and Emerson, 1980:32, footnote). The present mean annual temperature at Turtle Bay is 20.9°C. (Hastings, 1964). The leucine model age for loc. B-3007 is 95,000±15,000 years, using 120,000 years as the "calibration" age for loc. B-3024 and a slightly cooler Effective Quaternary Temperature for B-3007.*

The age of Bird Rock Terrace, which occurs below the 120,000-B.P. Nestor Terrace, is estimated at 80,000±15,000 B.P. by amino-acid dating (Wehmiller *et al.*, 1977) and from its geologic relation to the Nestor Terrace (Kern, 1977). Both the faunal characteristics and relative extent of racemization of the Nestor/Bird Rock Terrace pair resemble those of the upper and lower terraces at Turtle Bay and invite comparison along these lines.

The data points plotted in Figure 3 are mean values of all the D/L leucine determinations in *Chione, Protothaca,* and *Saxidomus* from each locality. These data have been factored slightly to allow comparison of results obtained from different genera[5] and by the two analytical methods mentioned previously (see Wehmiller and Emerson, 1980:32, footnote).

The Turtle Bay data are plotted at a mean annual air temperature of 20.9°C (Hastings, 1964). The data point for the upper terrace (loc. B-3024) lies just below the smooth 120,000-yr. (early stage 5) isochron drawn through the three uranium-series-dated calibration points. The separation between the isochron and locality B-3024 data point is analytically only marginally significant, and can not be considered as reliable evidence for an age significantly less than 120,000 B.P. because of uncertainties in their local Effective Quaternary Temperature histories[6]. For example, if the difference in the assigned temperatures of Magdalena Bay and Turtle Bay was 0.3°C greater than that used herein, the B-3024 data point would lie on the isochron. Small differences in effective-temperature histories create an inherent uncertainty in amino-acid dating, especially in cases where only small increments of time are being resolved.

The data point for the lower terrace (loc. B-3007) plots well below the 120,000-yr. isochron and cannot be considered contemporaneous unless unreasonably large effective-temperature differences are invoked. Assuming an equal effective Quaternary temperature history for both terraces (and an age of 120,000 B.P. for the upper terrace), the age estimate for the lower terrace would be approximately 85,000± 15,000 B.P., using the leucine kinetic model of age estimation (Wehmiller *et al.*, 1977). Because localities younger than 120,000 B.P. probably have had a slightly cooler (0.3–0.5°C.) effective-temperature history (Wehmiller *et al.*, 1976; Wehmiller *et al.*, 1977: fig. 16, table 1), the age

[5] *Protothaca* and *Chione* are assumed to have equivalent kinetics; *Saxidomus* data have been converted to "equivalent-*Protothaca*" values (Lajoie *et al.*, 1980).

[6] The Effective Quaternary Temperature (EQT) is the temperature representing the average rate constant, and integrated temperature history, for a fossil sample (see Wehmiller *et al.*, 1977; Kvenvolden *et al.*, 1979; Wehmiller and Emerson, 1980; Wehmiller, 1981).

estimate for the lower terrace is herein revised to approximately 95,000 B.P. (see Wehmiller *et al.*, 1977:68, for discussion of similar temperature modeling of the Bird Rock Terrace age estimate).

In summary, the early and middle-to-late stage 5 amino acid age estimates for the upper and lower terraces at Turtle Bay are based on small differences in analytical results that could also be due to factors other than age. Nevertheless, the simplest, and we believe the best, interpretation is of a real difference in age (within a single interglacial stage) between the two terrace remnants at Turtle Bay (locs. B-3024, B-3007). Implications of an apparent difference in the age and faunal character of the terraces at Turtle Bay and elsewhere along the Pacific Coast (Kern, 1977; Kennedy, 1978) are discussed below.

Faunal comparisons of Turtle Bay assemblages

The upper Pleistocene terrace deposits from Turtle Bay have yielded 138 species of metazoan invertebrates, mostly mollusks (Emerson, 1980). When these fossils were collected, they were believed to represent a single period of deposition. Although most of the terrace deposits around Turtle Bay are horizontal in attitude, some are clearly deformed or faulted (McIntyre and Shelton, 1957; Minch *et al.*, 1976), and the differences in elevation were attributed to this post-depositional deformation. The fossiliferous terrace remnants in the vicinity of Turtle Bay (Fig. 2) actually represent several terrace levels: at 4.5 to 6 m (UCMP locs. B-3027, B-3050, B-3048), at 6 to 9 m (loc. B-3025), at 12 m (loc. B-3007), and at 24 to 27 m (loc. B-3024) (elevations determined by E. C. Allison, see Fig. 2 and Emerson, 1980). However, Ortlieb (1979:Fig. 1) recorded terrace elevations in the Turtle Bay area at 5, 12, 20, and 50 m.

Two of the terrace localities (UCMP loc. B-3024, B-3025) contain warm-water (subtropical and tropical) species and were correlated with marine oxygen-isotope substage 5e (~Sangamon interglaciation) (Emerson, 1980) on the basis of faunal comparisons with other dated assemblages (Kennedy, 1978). Four other assemblages from Turtle Bay (locs. B-3027, B-3050, B-3007, and B-3048) lack these warm-water species and were not assigned to any interglacial or isotopic stage on the basis of their faunal composition (Emerson, 1980).

Emerson (1980) reported 83 positively identified species (53 gastropods, 28 bivalves, 1 chiton, and 1 echinoid) from locality B-3024 and 34 taxa (16 gastropods, 17 bivalves, and 1 echinoid) from locality B-3007 (Tables 2–5). In all, 20 species (12 gastropods and 8 bivalves), about 20% of the total number of taxa, are common to both localities. No extinct species have been recognized in these faunas.

Comparison of the modern geographic ranges of the species from the upper and lower terraces (locs. B-3024 and B-3007, respectively) show basic differences in the zoogeographic composition of each fauna. Combined, the faunas contain 25 tropical (Table 2), 17 subtropical (Table 3), and 8 warm-temperate (Table 4) species. The warm-water fauna of the upper terrace contains 19 gastropods and 5 bivalves that have modern northern endpoints of range south of Turtle Bay (Table 2). An additional 14 species (6 gastropods, 7 bivalves, and 1 chiton) occur only as far north as the Isla Cedros-Bahía de Sebastián Vizcaíno area, and three other species (two gastropods and one bivalve) range only as far north as Bahía de Todos Santos in Baja California Norte (Table 3). Thus, the assemblage from the upper terrace contains distinct tropical and subtropical elements representing nearly one half (49%) of the fauna. On the other hand, the assemblage from the lower terrace contains only three southern species (one gastropod, one bivalve, and one echinoid) that do not occur today as far north as Turtle Bay (Tables 2, 3). The two mollusks are common to both localities.

Table 4 lists warm-temperate species with southern endpoints of range north, or in the vicinity, of Turtle Bay. This northern element is represented by only four species (three gastropods, one bivalve) on the upper terrace and by seven species (two gastropods and five bivalves) from the lower terrace. Of these, two gastropods and one bivalve are common to both localities. The northern species from the upper

Table 2. Southern (tropical) Faunal Elements From Turtle Bay Localities B-3024 and B-3007

[Names in brackets for species not collected at locality B-3024, but recorded from SDSNH 0624 (=locality B-3024; Emerson, 1980].

Species with modern northern endpoints of range that occur south of, or in the vicinity (*) of Turtle Bay.

	Collecting Stations	
Mollusca: Gastropoda	B-3024	B-3007
Bulla punctulata	x	-
Cancellaria cassidiformis	x[1]	-
Cantharus elegans	x[1]	-
Cerithium maculosum	x	-
Columbella major	x	-
**Conus fergusoni*	x[1]	-
Conus perplexus	x[1]	-
[*Conus purpurascens*]	x	-
[*Cypraea annettae*]	x	-
[*Cypraea arabicula*]	x	-
Hormospira maculosa	x[1]	-
Nerita scabricosta	x	-
Oliva incrassata	x[1]	-
Oliva polpasta forma *davisae*	x[1]	-
Phyllonotus erythrostomus	x	-
Strombus gracilior	x	-
[*Strombus granulatus*]	x	-
Thais biserialis	x[1]	-
Trigonostoma goniostoma	x	-
Bivalvia		
[*Arcopsis solida*]	x	-
Chione picta	x	-
Ostrea angelica	x[1]	-
Semele flavescens	x[1]	-
Trachycardium panamense	x[1]	-
Echinodermata: Echinoidea		
Eucidaris thouarsii	-	x

[1]Species also recorded from SDSNH loc. 0624 (Chace, 1956; Emerson, 1980, table 1).

Table 3. Southern (subtropical) Faunal Elements From Turtle Bay Localities B-3024 and B-3007

[Names in brackets are species not collected at locality B-3024, but recorded from SDSNH 0624 (=locality B-3024, Emerson; 1980].

Species with modern northern endpoints of range occurring on the west coast of Baja California, north of Turtle Bay in the Isla Cedros-Bahía de Sebastian Vizcaíno area, unless otherwise indicated.

	Collecting Stations	
Mollusca: Gastropoda	B-3024	B-3007
Acanthina lugubris[2]	x[1]	-
Anachis coronata forma *hannana*	x	-
Crucibulum scutellatum	x[1]	-
Eupleura muriciformis	x[1]	-
Macron aethiops[3]	x[1]	x
Terebra armillata	x[1]	-
Turbo fluctuosus	x[1]	-
[*Vitularia salebrosa*]	x	-
Bivalvia		
Argopecten circularis s.s.	x[1]	-
[*Barbatia gradata*]	x	-
[*Barbatia reeveana*]	x	-
Chione gnidia	x[1]	-
Dosinia ponderosa	x	-
Megapitaria squalida	x[1]	-
Protothaca grata[4]	x[1]	x
Tellina simulans	x	-
Polyplacophora		
[*Stenoplax magdalenensis*]	x	-

[1]Species also recorded from SDSNH loc. 0624 (Chace, 1956; Emerson, 1980, table 1).

[2]Northern endpoint of range: Bahía Todos Santos.

[3]Northern endpoint of range: 24 km north of Bahía San Quintín.

[4]Northern endpoint of range: Cabo Colnett.

terrace represent less than 5% of the assemblage, in comparison with 21% for the lower terrace assemblage.

The remaining 46 species, all mollusks (Table 5), have modern ranges that overlap the latitude of Turtle Bay. Many of these species terminate their ranges to the north at Point Conception, California (41%), and to the south on the west coast of Baja California Sur (65%).

Amino-acid racemization data are not avail-

Table 4. Northern (warm temperate) Faunal Elements From Turtle Bay localities B-3024 and B-3007

[Names in brackets for species not collected at locality B-3024, but recorded from SDSNH 0624 (=locality B-3024; Emerson, 1980). Same usage in Table 5].

Species with modern southern endpoints of range that occur north of, or in the vicinity (*) of Turtle Bay.

	Collecting Stations	
Mollusca: Gastropoda	B-3024	B-3007
Cypraea spadicea	x	x
**Lottia gigantea*	x[1]	-
**Olivella biplicata*	x[1]	x
Bivalvia		
**Chaceia ovoidea*	-	x
**Glans carpenteri*	-	x
**Milneria minima*	-	x
Saxidomus nuttalli	x	x
**Transennella tantilla*	-	x

[1]Species also recorded from SDSNH loc. 0624 (Chace, 1956; Emerson, 1980, table 1).

Table 5. Other Species (non-extralimital) From Turtle Bay Localities B-3024 and B-3007

Species with modern northern and southern endpoints of range occurring north and south, respectively, of Turtle Bay. Species with northern endpoints of range extending no farther north than Point Conception, California indicated by an asterisk (*); species with southern endpoints of range terminating on the west coast of Baja California Sur indicated by a number sign (#).

	Collecting Stations	
Mollusca: Gastropoda	B-3024	B-3007
#Alia carinata	x	x
*#*Astraea undosa*	x[1]	x
[*Bursa californica*]	x[1]	x
#Caecum crebricinctum	-	x
#Caecum dalli	x	x
#Collisella limatula	x	-
#Conus californicus	x[1]	x
[*Crepidula onyx*]	x	-
Crucibulum spinosum	x[1]	-
**Elephantulum carpenteri*	x	-
#Fartulum occidentale	x	x
#Fissurella volcano	x	x
*#*Haliotis fulgens*	x	-
[*Hipponix antiquatus*]	x	-
#Hipponix tumens	x	-
*#*Nassarius tegula*	x[1]	-
**Neverita reclusiana*	x[1]	-
*#*Norrisia norrisi*	-	x
*#*Pseudomelatoma penicillata*	x	-
*#*Pteropurpura festiva*	x[1]	x
*#*Serpulorbis squamigerus*	-	x
*#[*Tegula aureotincta*]	x	x
*#*Tegula eiseni*	x	x
*#*Tegula gallina*	x[1]	x
#Trivia solandri	x	-
*#*Truncatella californica*	x[1]	-
	Collecting Stations	
Bivalvia	B-3024	B-3007
*#*Amiantis callosa*	x	-
Anomia peruviana	x	x
**Chione californiensis*	x	x
#Corbula luteola	x	x
**Crassinella pacifica*	x	-
Cryptomya californica	x	x
[*Diplodonta orbellus*]	x	x
*#*Donax californicus*	x	-
#Epilucina californica	-	x
Felaniella sericata	x	-
#Hinnites giganteus	-	x
*#*Leporimetis obesa*	x[1]	x
Lucinisca nuttallii	x[1]	-
#Macoma indentata	x	-
#Macoma nasuta	-	x
Parvilucina approximata	-	x
[*Penitella fitchi*]	x	-
#Penitella penita	-	x
*#*Semele decisa*	x	-
Tagelus californianus	x	-

[1]Species also recorded from SDSNH loc. 0624 (Chace, 1956; Emerson, 1980, table1).

able for most of the Turtle Bay assemblages, and so any temporal correlations must be made on the basis of faunal or geomorphic evidence. E. C. Allison, who collected these fossils, believed loc. B-3025 to be on a tilted remnant of the 24 to 27 m terrace represented at loc. B-3024. Locality B-3025 was previously referred (Emerson, 1980) to isotopic substage 5e, owing to the presence of four extralimital tropical and subtropical mollusks in its fauna (*Conus regularis, Oliva polpasta* forma *davisae, Thais biserialis,* and *Ostrea angelica*). The remaining six taxa in the small fauna all have modern geographic ranges that overlap the latitude of Turtle Bay. The presence of an extralimital southern element and the geologic setting suggest that localities B-3024 and B-3025 are probably coeval and referable to the warm-water phase of the Sangamon Interglaciation (Emerson, 1980).

Assemblages from the remaining Turtle Bay localities – B-3027 (northwest of the bay on the outer coast), B-3050 (inner northeastern margin of the bay), and B-3048 (southeast of the bay on the outer coast) (see Fig. 2) – are dominated by species still living in the region, but include both extralimital northern and southern taxa. Extralimital southern species present at these localities are *Thais biserialis, Trachycardium panamense,* and *Protothaca grata,* each of which occurs in loc. B-3024, and the latter two in loc. B-3007. Three northern extralimital species also occur in loc. B-3050 (*Lottia gigantea, Saxidomus nuttalli,* and *Tresus nuttallii*), two of which are present in loc. B-3024. Because of the small size of these other faunas and the presence of both extralimital northern and southern species, we hesitate to assign precise ages to them at this time. Further amino-acid racemization determinations on elements of these faunas would probably resolve the question of their ages.

In summary, it is difficult to imagine that faunas (from locs. B-3024 and B-3007) with such striking differences in their zoogeographic composition could have been deposited contemporaneously, and the amino-acid data presented herein support their temporal difference. Although both assemblages contain both extralimital northern and southern species, indicative of a shift in the geographic ranges of a few component species subsequent to deposition, the overall faunal composition of each assemblage reflects different hydroclimatic conditions. Thus, nearly half (49%) of the assemblage from the upper terrace is made up of warm-water (subtropical and tropical) faunal elements, in comparison with only 9% of these elements on the lower terrace. In contrast, 21% of the taxa from the lower terrace are northern, cool-water (warm temperate) species, in comparison with only 5% of the taxa from the upper terrace (Tables 2–4).

Comparison with other faunas from Baja California Sur

Late Pleistocene megainvertebrate faunas from the west coast of Baja California Sur have been reported from only three areas in addition to Turtle Bay (lat. 27°41′N.) (Fig. 1): (1) Laguna Ojo de Liebre (Scammon Lagoon, lat. 27°57′N.) – 24 molluscan species from "raised beaches near Scammon's Lagoon" (Jordan, 1924); (2) Laguna de San Ignacio (San Ignacio Lagoon, lat. 26°45′N.) – 88 species of mollusks (Hertlein, 1934; including taxa cited previously by Jordan, 1924); and (3) Bahía de Magdalena (Magdalena Bay, lat. 24°30′N.) – 442 species-group taxa, mostly mollusks (Jordan, 1936; incorporating previous records of Dall, 1918, Smith 1919, and Jordan, 1924). The Magdalena Bay fauna is the largest Pleistocene fauna described from anywhere in Baja California.

No amino-acid or radiometric dates are available for the faunas at Scammon Lagoon or San Ignacio Lagoon. However, at Magdalena Bay, uranium-series dates on both corals and echinoids indicate an average age of 116,500 ± 6,000 B.P. for Magdalena Terrace (Omura *et al.,* 1979). These radiometric dates suggest that Magdalena Terrace is correlative with a highstand of sea level at approximately 125,000 to 120,000 B.P., equivalent to the early, warm-water phase of the last interglacial stage (substage 5e) of the marine oxygen-isotope record (Shackleton and Opdyke, 1973). The uranium-series date on the Magdalena Terrace has been used subsequently by Wehmiller and Emerson (1980) to calibrate the southern temperature range of the 120,000-yr. isochron shown in Fig. 3.

Amino-acid racemization data suggest that the fauna from the upper terrace at Turtle Bay (loc. B-3024) and that from Magdalena Bay (CAS loc. 754 of Jordan [1936] = loc. F-6 of Omura *et al.* [1979]) probably were deposited contemporaneously. Faunal comparison (Table 6) of these two assemblages suggests a slightly warmer hydroclimate at Magdalena Bay, not totally unexpected because of its more southerly location (Fig. 1). Both the absolute number and the percentage of tropical and subtropical taxa are greater at Magdalena Bay than at Turtle Bay, although both sites supported similar faunas rich in these elements. Conversely, the number of warm-temperate (*i.e.*, extralimital northern) taxa at Turtle Bay is greater than at Magdalena Bay.

Comparison of the fauna from the lower terrace at Turtle Bay (loc. B-3007) with the noncontemporaneous fauna at Magdalena Bay shows greater discrepancies (Table 6). Thus, although three-fourths of the non-extralimital species at Turtle Bay also occur at Magdalena Bay, only three of the seven warm-temperate taxa occur there. Moreover, two of the three tropical and subtropical species are common to both localities.

Table 6. Comparison of Positively Identified Species in Turtle Bay Faunas with Those of the Magdalena Bay Faunas.

	(A)			Present at CAS loc. 754 and loc. F-6		Present at Magdalena Bay (cf. Jordan, 1936)	
	#	=	%	#	% of (A)	#	% of (A)
Loc. B-3024							
Total Species	83	=	100%	63	76%	74	89%
Tropical	24		29	21	87%	23	96%
Subtropical	17		20%	13	76%	15	88%
Non-extralimital	38		46%	28	73%	33	86%
Warm temperate	4		5%	1	25%	3	75%
Loc. B-3007							
Total species	34	=	100%	15	44%	23	68%
Tropical & subtropical	3		9%	1	33%	2	66%
Non-extralimital	24		70%	13	54%	18	75%
Warm temperate	7		21%	1	14%	3	43%

Comparison with more northern localities

The temporal and faunal relations of the upper and lower terraces at Turtle Bay invite comparison with other terrace pairs on the Pacific coast. The best known of these pairs is at Point Loma in San Diego, California, where Nestor and Bird Rock Terraces occur in superposition. The upper terrace (Nestor) has been dated by uranium-series methods on corals at 121,000 ± 10,000 B.P. (Ku and Kern, 1974), and the lower terrace (Bird Rock) by amino-acid methods (Wehmiller *et al.*, 1977) and geologic evidence (Kern, 1977) at approximately 80,000 B.P. Thus, the terraces at Point Loma can be correlated to the early and late phases of marine oxygen-isotope stage 5 and correspond to the ages obtained herein for the terrace pair at Turtle Bay.

Although it is inappropriate to make a direct species comparison of the San Diego and Turtle Bay faunas because of the distance separating them (~600 km) and of the different depositional settings, their zoogeographic relationship can be examined. The fauna of Nestor Terrace contains both extralimital northern and southern species, but is dominated by southern species; this observation suggests seasonal temperatures warmer than those now prevailing in the San Diego area (Kern, 1977). The fauna of lower and younger Bird Rock Terrace contains few (4%) extralimital northern elements, but lacks extralimital southern species; this observation suggests marine temperatures lower than those of the San Diego area (Kern, 1977).

The similarity of the radiometric and amino-acid age estimates for these widely separated terrace pairs (southern California and northern Baja California Sur), as well as their similar zoogeographic compositions, is strong evidence that near-shore marine waters were successively warmer and cooler than those of today during the early and middle-to-late parts, respectively, of marine oxygen-isotope stage 5 (130,000–80,000 B.P.).

Provincial assignments of Turtle Bay assemblages

The original usage of a single provincial designation for a geographically prescribed area (Valentine, 1961; Addicott, 1966) must now be tempered by the recognition of more than one marine-terrace level (and associated fauna) at elevations previously believed to represent contemporaneous deposition (Kennedy, 1978, 1979). In the San Diego, California area, for example, assemblages from late Pleistocene terrace deposits that previously were considered coeval are now referable, on the basis of radiometric and amino-acid age estimates, to three temporally distinct episodes of deposition (Ku and Kern, 1974; Kern, 1977; Masters and Bada, 1977; Wehmiller *et al.*, 1977; Lajoie *et al.*, 1979; Deméré, 1980; and Karrow and Bada, 1980). The recognition of several possible terrace ages that relate to highstands of sea level during different glacial minima requires that provincial faunas be identified by their respective ages (Kennedy, 1978). Establishment of a geochronology that is related to the deep-sea isotopic chronology of glacial minima and maxima (Shackleton and Opdyke, 1973) facilitates the assignment of an isotopic-stage number to the modern or Pleistocene provincial name most representative of that fauna (Kennedy, 1978).

Valentine (1961:393) proposed the Magdalenan Province for late Pleistocene molluscan assemblages characterized by tropical and subtropical faunas at Magdalena Bay and elsewhere along the coast of Baja California Sur, the Gulf of California, and the adjacent mainland of Mexico. The Magdalenan Province is here restricted to faunal assemblages that are referable to the 130,000- ~120,000-B.P. highstand of the sea, correlative with the early part of marine oxygen-isotope stage 5 (substage 5e). The warm-water assemblages at Turtle Bay (loc. B-3024 and probably loc. B-3025) are herein assigned to the Magdalenan Province. Other warm-water faunas from along the southern Baja California coast at San Ignacio Lagoon (Hertlein, 1934) and at Scammon Lagoon (Jordan, 1924) probably also can be assigned to the Magdalenan Province. However, provincial assignments based entirely on faunal inferences should be tempered by some means of absolute dating, especially if their faunas are small and contain a mixture of northern and southern species.

The cooler water, middle-to-late stage 5 assemblage at Turtle Bay (loc. B-3007) is not as readily assigned a Pleistocene provincial designation because the more northerly Verdean and Cayucan Provinces also have been restricted to early stage 5 faunas (Valentine, 1980). Until more of the known localities along the Baja California coast are dated, either biochemically or radiometrically, and can be shown to represent either early or late stage 5 time, provincial delineation will remain difficult. Fossil localities with faunas that still need provincial assignment include those at Cedros Island (Hertlein, 1934), and in Baja California Norte at San Quintín (Jordan, 1926), Punta Cabras (Addicott and Emerson, 1959), Punta China (Emerson, 1956), and Punta Descanso (Valentine, 1957). A fauna at Camalú has been assigned already to the Pleistocene Verdean Province by Valentine (1980).

Register of Localities

University of California Museum of Paleontology, Berkeley, California. All fossils were collected by E. C. Allison. For locality data of Magdalena Bay localities, see Omura *et al.*, (1979).

UCMP loc. **B-3007.** Terrace deposit at an elevation of about 12 m, N. 30°E. of peak on south side of entrance to Turtle Bay. Collected June 18, 1956.

UCMP loc. **B-3024.** Terrace, traceable for several hundred meters, at an elevation of 24 to 27 m, along the southwestern part of Turtle Bay in back and south of small fishing camp. Collected June 26, 1956.

UCMP loc. **B-3025.** Terrace at an elevation of 6 to 9 m southeast of loc. B-3024 and possibly equivalent to the terrace at loc. B-3024, because it appears to be tilted in that direction. Collected June 26, 1956.

UCMP loc. **B-3027.** Terrace at an elevation of 4.5 to 6 m immediately behind long sandy beach along southwestern part of peninsula northwest of Turtle Bay. Collected June 27, 1956.

UCMP loc. **B-3048.** Terrace at an elevation of approximately 6 m that extends along the open coast adjacent to a long sand-gravel beach about

9.7 km southeast of Turtle Bay. Collected July 2, 1956.

UCMP loc. **B-3050.** Terrace at an elevation of 4.5 to 6 m along the northeast side of Turtle Bay. Collected July 3, 1956.

ACKNOWLEDGMENTS

Fossils from Turtle Bay used for amino-acid analysis were kindly loaned by Joseph H. Peck, Jr., of the University of California Museum of Paleontology, Berkeley. Technical assistance was provided by William E. Old, Jr., of the American Museum of Natural History, New York. Amino-acid research at the University of Delaware, Newark, was supported by U.S. Geological Survey Grants 14-08-0001-G592 and 14-08-0001-G680. The manuscript was critically reviewed by Kenneth R. Lajoie, Leslie F. Marcus, and Louie N. Marincovich, Jr.

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