# PLEISTOCENE INVERTEBRATES FROM PUNTA CHINA, BAJA CALIFORNIA, MEXICO

## WITH REMARKS ON THE COMPOSITION OF THE PACIFIC COAST QUATERNARY FAUNAS

WILLIAM K. EMERSON

BULLETIN
OF THE
AMERICAN MUSEUM OF NATURAL HISTORY
VOLUME 111 : ARTICLE 4 NEW YORK : 1956

# PLEISTOCENE INVERTEBRATES FROM PUNTA CHINA, BAJA CALIFORNIA, MEXICO

# PLEISTOCENE INVERTEBRATES FROM PUNTA CHINA, BAJA CALIFORNIA, MEXICO

•

## *WITH REMARKS ON THE COMPOSITION OF THE PACIFIC COAST QUATERNARY FAUNAS*


WILLIAM K. EMERSON

*Assistant Curator of Invertebrates*
*Department of Fishes and Aquatic Biology*



BULLETIN
OF THE
AMERICAN MUSEUM OF NATURAL HISTORY

VOLUME 111 : ARTICLE 4 NEW YORK : 1956

BULLETIN OF THE AMERICAN MUSEUM OF NATURAL HISTORY
Volume 111, article 4, pages 313–342, text figure 1, plates 22, 23, tables 1, 2

*Issued October 31, 1956*

*Price: 50 cents a copy*

# CONTENTS

# INTRODUCTION

FIELD PARTIES FROM THE University of California Museum of Paleontology recently have made collections of Pleistocene invertebrates from previously unrecorded localities along the northwestern coast of Baja California, Mexico. In December, 1952, Warren O. Addicott and the present writer undertook a general reconnaissance of the coastal region from the United States-Mexico Boundary to the vicinity of San Quintín Bay (latitude 30° 21′ N.). Although only limited access to the coast is available to automobile travel, fossils were obtained from several terrace deposits. As a result of this and four subsequent trips, large collections of metazoan invertebrates were made from localities extending from the border to Punta Baja (latitude 29° 57′ N.). These collections are contained in the University of California Museum of Paleontology, Berkeley. Numbered localities cited in the text are those of the Museum of Paleontology unless otherwise stated.

The purpose of the present paper is to describe and discuss in terms of the known Pacific coast Quaternary record an especially rich marine invertebrate fauna from Pleistocene terrace deposits in the Punta China area. Paleoecologic interpretations based on a collected fauna totaling 105 identified metazoan species are undertaken, and faunal comparisons are made with other Pleistocene assemblages reported from the southern California-Baja California region. Fossils from other previously unrecorded localities will be enumerated in a separate publication.

## BRIEF REVIEW OF PREVIOUS LITERATURE

Although Pleistocene fossils have been recorded from several terrace deposits along the northwestern coast of Baja California, only incidental mention has been made to the fauna herein described. In a paper on the middle Cretaceous gastropods from Punta China, Allison (1955, p. 404) recognized this terrace deposit as a distinct lithologic unit and listed two invertebrates from the fossiliferous sand. The present writer has briefly referred to this fauna in a preliminary paper (Emerson, 1956). The only other mention of Pleistocene invertebrates from the extreme northern part of the peninsula is by Valentine (1955b, p. 465); he records the occurrence of fossils in "unnamed terrace deposits at Punta Baja and in the Punta Descanso region, and between Rosarito Beach and the International Boundary," but does not enumerate them. Several references concerning the physiography of other marine coastal terraces in this general area are discussed below (p. 323).

The Pleistocene faunas of western Baja California are much better known in the region from San Quintín Bay south to Magdalena Bay. Within this area, large numbers of invertebrate fossils, mostly mollusks, have been recorded and described from the following localities:

1. San Quintín Bay, latitude 30° 21′ N. (Dall, 1921a, 1921b; Orcutt, 1921a, 1921b; Jordan, 1926[1]; Manger, 1929, 1934; Berry, 1926; Santillán and Barrera, 1930). Jordan records approximately 250 species of mollusks from the richly fossiliferous sand forming a series of low cliffs on the east side of the Bay, in the area immediately south of the old San Quintín village (California Acad. Sci. Geol. Dept., locality 910).
2. Cedros Island (Cerros Island), latitude 28° 03′ N. (Hertlein, 1934). Fifteen molluscan species are cited from "raised beaches" about 15 to 30 meters above sea level on the west side of the island and near South Bay (California Acad. Sci. Geol. Dept., localities 801, 931, and 2323).
3. Scammon Lagoon (Ojo de Liebre), latitude 27° 57′ N. (Jordan, 1924). A short list of 24 molluscan species from "raised beaches near Scammon's Lagoon" is given.
4. San Ignacio Lagoon, latitude 26° 45′ N. (Jordan, 1924; Hertlein, 1934[1]). Hertlein records 88 species of mollusks from this region, including those listed earlier by Jordan.
5. Magdalena Bay, latitude 24° 30′ N. (Dall, 1918; Smith, 1919; Jordan, 1924, 1936[1]). Jordan (1936), in a paper including

[1] Major paper for area concerned.

citations to the previously reported species, lists 442 species and subspecies of mollusks and two barnacles from the vicinity of this bay. This is the largest Pleistocene fauna described from Baja California.

Pleistocene metazoan invertebrates, mostly mollusks, also are known from several localities in the Gulf of California area. Durham (1950b) records a total of 209 identified species from 21 stations on the east coast of Baja California and on certain of the Gulf islands in a comprehensive account of the megascopic paleontology of the 1940 "E. W. Scripps" cruise to the Gulf of California. Shorter lists have been contributed by Vokes (*in* Wilson, 1948) for the Santa Rosalia area, and Hertlein (1931) for several localities on the eastern Baja California coast. Grant and Gale (1931) incidentally mention the occurrence of a few species from previously unrecorded localities. Only one assemblage, totaling 62 identified species from near Puerto Peñasco (Hertlein and Emerson, 1956), has been described from the Sonora coast of the Mexican mainland. Additional west Mexican Pleistocene invertebrates are known from the Tres Marias Islands, latitude 21° 16′ N., longitude 106° 16′ W. (Hertlein, 1934), and the Oaxaca coast, near the Rio Colotepec (Palmer and Hertlein, 1936).

## ACKNOWLEDGMENTS

It is a pleasure to acknowledge the assistance that has been received in the completion of this study. I am especially indebted to Drs. J. Wyatt Durham, Leo G. Hertlein, and Norman D. Newell, and to Messrs. Warren O. Addicott, Edwin C. Allison, and Allyn G. Smith for reading all or part of the manuscript. The following made contributions of various kinds: Dr. S. Stillman Berry, Mr. Ralph O. Fox, Dr. Carl L. Hubbs, Dr. Harry K. Fritchman, II, Mr. Elton L. Puffer, Dr. John D. Soule, Dr. Rudolph Stohler, Mr. Robert Talmadge, and Mr. James W. Valentine. Mr. Owen J. Poe prepared the location map, and Dr. J. Wyatt Durham provided the photographs.

The University of California Museum of Paleontology sponsored the field work of this investigation.

# PUNTA CHINA TERRACE DEPOSITS

## DESCRIPTION OF AREA

### General Description

Collections of Pleistocene fossils were made from six stations in the lowest coastal terrace in the vicinity of Puerto Santo Tomás, a small village situated approximately 120 kilometers south of the International Boundary (see fig. 1). The region specifically covered by the present report is bounded to the north by Bahía Soledad, latitude 31° 35′ N., and to the south by Punta San José, latitude 31° 28′ N. In this area, remnants of the terrace deposit were observed to extend along the coast line, at an elevation of from 25 to 30 feet, from Punta Santo Tomás to a point about 2 miles south of Punta China. Henceforth, for expediency, this deposit and its contained fossils are referred to as the "Punta China terrace" and the "Punta China fauna," respectively.

### Geologic Setting

Three distinct lithologic units are exposed on the south side of Punta China. Allison (1955) refers a two-member basal sequence of reddish to greenish tuffaceous sediments and volcanic breccia with interbedded biohermal limestone to the middle Cretaceous Alisitos formation, and the overlying conglomerate, siltstone, and sandstone to the upper Cretaceous Rosario formation. The Punta China terrace sediments, together with talus cover, locally overlie rocks of either middle or upper Cretaceous age.

### Punta China Terrace

A partially buried remnant of this terrace is preserved on the south side of Punta China. Approximately 400 yards east of the headland (locality A-9002), 1 to 6 feet of fossiliferous Pleistocene sand and gravel unconformably rest, at an elevation of about 25 feet, on both the middle and the upper Cretaceous beds and are overlain by from 20 to 25 feet of unfossiliferous sandy gravel, conglomerate, and soil (pl. 22). A large series of fossils were collected from sand lenses in the poorly sorted terrace sediments, which range in size from fine sand to boulders up to 6 feet in diameter.

In a small cove on the north side of Punta China, a thin stratum of locally fossiliferous sand unconformably rests, at an elevation of from 12 to 15 feet, on middle Cretaceous sandstone and is overlain by 10 feet of sparsely fossiliferous sand and from 2 to 3 feet of soil (pl. 23). A small number of fossils were collected at this locality from the basal 1 to 3 feet of poorly sorted, coarse-grained sand, containing boulders up to 18 inches in diameter (locality A-9596).

North of Punta China the terrace extends, at an elevation of from 20 to 25 feet, along the coast line to the vicinity of the mouth of the Rio de Santo Tomás as a nearly uninterrupted topographic feature. Fossils occur in the cliff face of the small bay immediately north of Punta China in a thin sand lens at the base of 4 feet of gravel which rests on upper Cretaceous sandstone and are overlain by from 25 to 30 feet of gravel and reddish soil (locality A-9593). North of the river only small patches of the terrace deposit are preserved. In a protected area on the north side of Punta Santo Tomás (locality A-9594), fossils were found in 5 feet of well-indurated pebbly conglomerate overlying Cretaceous volcanic flows at an elevation of from 20 to 25 feet.

Two sparsely fossiliferous terrace remnants were noted south of Punta China at an elevation of about 25 feet. Approximately 1 mile south of this headland, fossils were collected from sand lenses in a conglomerate overlying upper Cretaceous sandstone (locality A-9595). Fossils also were found about a mile south of this locality in a sandy conglomerate resting on upper Cretaceous sediments which have yielded specimens of the ammonite *Baculites* (locality A-9546).

### Terrace Cover

Poorly sorted, unconsolidated sand, gravel, and conglomerate overlie the marine terrace deposits, or in their absence lie immediately on Cretaceous rocks. The few "fossils" found in the terrace cover are marine invertebrates of a tide-pool and rock-cliff habitat and are believed to be derived specimens.

The reddish brown soil formed by the cover contains locally abundant Recent

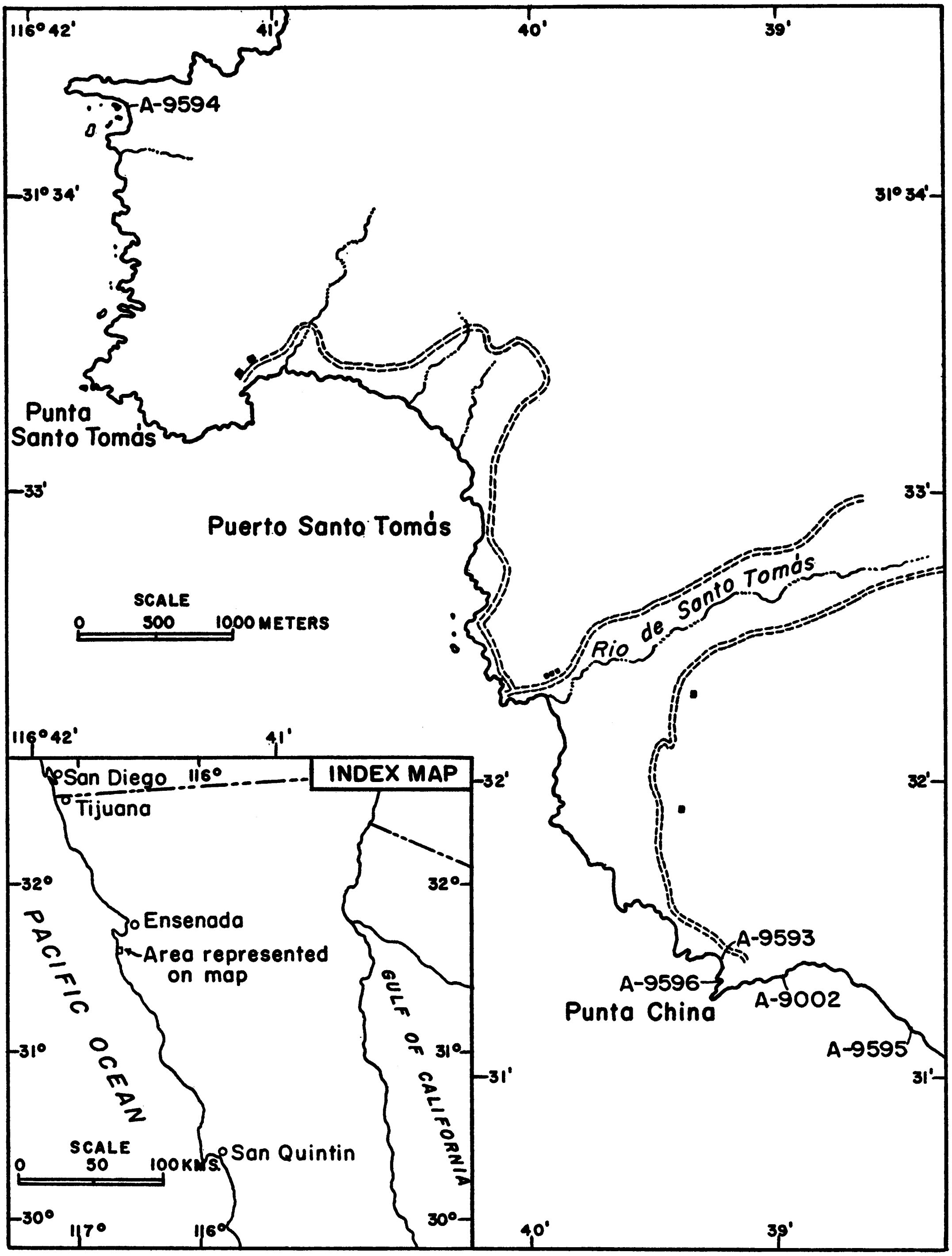



FIG. 1. Generalized map of Puerto Santo Tomás and vicinity, showing location of principal Pleistocene collecting stations (sketch map modified after Allison, 1955, p. 401).

invertebrates which are thought to have originated from aboriginal kitchen midden accumulations. With the exception of one species, *Cryptochiton stelleri*, all of the mollusks noted in the middens are now living along rocky parts of the coast. Most of the *Tegula* shells have the apex broken open, an indication that these specimens were used as food by the natives. The more common molluscan constituents of the middens are as follows, listed in order of relative abundance:

*Mytilus californianus* Conrad, 1837
*Lottia gigantea* Gray, 1834
*Septifer bifurcatus* (Conrad), 1837
*Tegula funebralis* (A. Adams), 1859
*Fissurella volcano* Reeve, 1849
*Acmaea cassis* Eschscholtz, 1833
*Haliotis cracherodi* Leach, 1814
*Haliotis* cf. *H. rufescens* Swainson, 1822
*Cryptochiton stelleri* Middendorff, 1846

A few shell implements, apparently used as crude scrapers by the Indians, were noted. Massey (1947, p. 355) briefly discussed anthropological specimens, chiefly flake and cobble tools, from coastal middens of northwestern Baja California and referred a similar lithic culture to sites occurring as far south as Bahiá Sebastian Vizcanio (latitude 28° 15′ N.).

## RELATION TO OTHER TERRACES

### General Comments

Terraces, many of which contain Quaternary invertebrates, occur along virtually the entire west coast of the peninsula. Pleistocene fossils are recorded from several of the numerous lower terraces at elevations of from 20 to 100 feet. Recent invertebrates, mostly mollusks, are reported to be scattered over wide areas of the coastal region to maximum elevations of about 1800 feet and are thought to represent kitchen midden material. Beal (1948, pp. 28–32) has briefly discussed the distribution of the coastal terraces and has adequately summarized the pertinent literature. For the purposes of this discussion, only the lower coastal terrace deposits in southwestern San Diego, California, and northwestern Baja California are considered.

### Local Terraces

Ellis (1919, p. 26, pl. 6) described and named some of the terraces occurring along the coastal region from the southernmost part of San Diego County to a point some 20 kilometers south of the International Boundary. He found "Quaternary fossils" to be abundant in a broad terrace south of Tijuana, at an elevation of about 100 feet. As a result of his studies of the terraces occurring on both sides of the International Boundary, Ellis (1919, p. 27) concluded that uplift has been greater and more rapid in the region immediately south of the border than in the San Diego Bay area. Beal (1948, p. 28) observed two terraces for a distance of nearly 40 kilometers along the coast south of Tijuana, one at an elevation of 100 feet and the other at 50 feet. Stephens (1929) and Emerson and Addicott (1953) have described Pleistocene fossils from the small portion of the latter terrace, which extends for a short distance across the United States side of the International Boundary, the "Border locality."

Near Ensenada (latitude 31° 52′ N.), Lindgren (1888) noted "old shore lines" at Bahía de Todos Santos and wave-built terraces at Punta Banda, the lowest of which was reported to be from 30 to 40 feet above sea level. South of Punta China, a series of terraces, some attaining 600 feet in elevation, were observed by the present writer along the coast from the region of Punta San José (latitude 31° 28′ N.) to Bahía San Quintín (latitude 30° 21′ N.) Within this coastal area, invertebrate fossils were collected from five stations in low terrace remnants preserved along the shore line, at elevations of from 12 to 30 feet, between Punta Cabras and Punta San Isidro (latitude 30° 30′ N.). On the east shore of San Quintín Bay, poorly consolidated sand forms a series of low cliffs, about 20 feet in elevation, which have yielded the large San Quintín fauna (Jordan, 1926). In the area immediately to the south, B. L. Clark identified Quaternary fossils from "*. . . las mesas al N. de Rosario y en las terrazas que estan entre Soccorro y San Quintín*" (Santillán and Barrera, 1930, p. 25). Pleistocene fossils also were collected from low coastal terraces at Punta Baja (latitude 29° 57′ N.).

Our limited knowledge of the composition, distribution, and geologic history of the marine terraces occurring in northwestern

Baja California precludes interregional correlations based primarily on physiographic evidence. Owing to the nature of the available data, interpretations of interregional contemporaneity must be confined largely to faunal comparisons, an often singularly unreliable method for correlation.

## DEPOSITIONAL ENVIRONMENT

### Ecological Requirements

The general composition of the Punta China fauna strongly suggests the dominant depositional facies to have been a tide-pool and rock-cliff environment. The Pleistocene topography appears to have been very much the same as that existing today on the adjacent seashore, where headlands divide the coastline into a series of small beaches with local "reefs" of algal-covered rocks and intervening areas of gravelly and sandy bottom. A strand-line deposit is indicated not only by the physiographic and biologic data, but also by the depositional evidence, the fossiliferous sediments being composed of sands containing pebbles, cobbles, boulders, and organic matter.

Ecologic evaluations of Pleistocene invertebrate faunas can be drawn from comparisons with present habitat requirements of component species. On the basis of ecologic data available for most of the mollusks comprising the fauna, over 80 per cent of the species require a rocky or "rubble-reef" substrate. The gastropods are the most common faunal components and include such typical rock dwellers as *Acmaea*, *Aletes*, *Crepidula*, *Diodora*, *Fissurella*, *Haliotis*, *Hipponix*, *Littorina*, and *Tegula*. The unusually large assemblage of chitons, all of which are intertidal or shallow-water species, indicate a rocky substrate. A majority of the pelecypods are attaching forms or inhibitants of rocky rubble: *Barbatia*, *Chama*, *Cumingia*, *Glans*, *Hinnites*, *Modiolus*, *Mytilus*, *Petricola*, *Pododesmus*, *Saxicava*, and *Septifer*. At several localities, especially A-9002, lenses of well-sorted sand were found to contain numerous *in situ* specimens of pelecypods (*Lucina californica*, *Protothaca staminea*), a gastropod (*Olivella biplicata*), and other species that are known to live in sandy stretches of protected beaches exposed at low tides and in similar infratidal habitats. The few off-shore elements present (including *Dentalium*, *Tellina*, *Clinocardium*, and *Kellettia*) are indicative of the deeper portions of the sublittoral zone (50–200 meters). The deeper water faunal constituents are represented by very few individual specimens, all of which are worn or fragmental, probably indicating wave or current transport, and most are considered to be allochthonous elements of the thanatocoenose. It is concluded that the Punta China fauna reflects a near shore environment, dominantly an open coast, intertidal habitat, on the basis of the ecologic requirements of its apparent autochthonous constituents.

### Climatic Inferences

In an attempt to evaluate the paleotemperature requirements of the Punta China fauna in terms of the present geographical distribution of its component species, two major factors must be given consideration. These are the limitations of the available range data, and the problem of discontinuous distribution for some oligothermal (cold-water) elements of the fauna.

Although considerable information on the distribution of the Recent eastern Pacific shallow-water mollusks has been accumulated for the region north of San Diego (Dall, 1921c; Keen, 1937; Burch, 1945–1946), our knowledge of the occurrences of the mollusks and other invertebrates along the Pacific coast of Baja California is much less complete. Many of the early records for the mollusks of Pacific Baja California cited by Dall (1921c) and Jordan (1924) are based on collections made by Charles R. Orcutt and Henry Hemphill, pioneer west-coast amateur conchologists. A paper by Orcutt and Dall (1885), which records 151 species of mollusks from Todos Santos Bay, Ensenada, is the only published faunal list for northwestern Baja California. A number of Dall's (1921c) records for this region have proved to be erroneous, having been based on unreliable locality data, fossil specimens, and misidentifications. As new information has become available, Keen (1937) and Burch (1945–1946) have revised the recorded ranges for many species. The southern range limits of many of the Temperate northeastern Pacific species are, however, not known owing to a paucity of bathymetric data. Additional collecting, both tidal and infratidal, must be undertaken before the southern end points of range can be determined for a large part of this fauna. Although our knowledge of the present geographic distribution and bathymetric requirements of these organisms is not complete, it appears to be sufficient for reasonably accurate paleoecologic interpretations (Emerson, 1953).

Our understanding of the composition of the shallow-water floras and faunas of Pacific Baja California is further complicated by the occurrence of upwelling of cold water in localized areas along the west coast of the peninsula. Dawson (1951) has shown the coastal region of northwestern BajaCalifornia to be characterized by geographically discontinuous areas of seasonal upwelling in which centers of intensity are located on the south sides of prominent headlands. Within the upwelling areas many organisms indicative of cool, North Temperate waters occur far south of their expected latitudinal range, producing a discontinuous inner-neritic distributional pattern for these species (Emerson, 1952). The appearance of eurybathyal, frigophilic (cold-limited) organisms in the intertidal zone of the "warm-temperate" Transition faunal province of northern Baja California necessitates a critical appraisal of the possible role of upwelling as an ecological agent during deposition of the Punta China terrace. Valentine (1955a), in a study of the ecologic requirements and depositional environments of certain Pleistocene molluscan faunas from southern California and northern Baja California, interpreted the composition of assemblages with cold-water elements from apparently exposed coastal habitats to reflect the local influence of upwelling. This phenomenon has been suggested as a possible explanation for apparent critical changes in local temperature requirements of some assemblages in the west American Pliocene-Pleistocene faunal record (Emerson, 1956).

The preservation of the highly fossiliferous Punta China terrace deposits at a known modern site of local upwelling affords a rare opportunity to compare the living fauna with a Pleistocene assemblage. The available data, based on the stratigraphic evidence and the composition of the Pleistocene fauna, suggest the coastal physiography to have been essentially the same as today during the deposition of the terrace deposit.[1] It can be reasonably assumed, therefore, that the configuration of the Pleistocene coast presented, on the south side of the headland, a potential site for development of a local area of strong upwelling. The results of a preliminary investigation to determine if the effects of upwelling could be detected in the fossil assemblage were not conclusive (Emerson, 1956). A detailed analysis of the fauna has led to the more definite conclusions presented below.

The large sample of the Punta China fauna now available for study appears adequately to reflect the environment of deposition and permits a detailed analysis of the paleo-temperature requirements for the supposedly autochthonous constituents of the assemblage. From an ecological standpoint, it is notable that all but seven of the 105 identified species occur in the main fossiliferous locality (A-9002). (See table 2 for a check list of the fossils.) This faunule should serve as the standard of reference for the fauna. The faunal constituents, all of which are benthonic dwellers, may be segregated on the basis of our present knowledge of their thermo-bathymetric tolerances into two main groups: (1) thermophilic (warm-limited) and (2) frigophilic (cold-limited) species. Although this differentiation is, of course, somewhat arbitrary, as some component species are not referable to either category, it is helpful for the purposes of this discussion. The thermophilic species obviously are more reliable indices for determining former climatic conditions, as these forms usually are restricted to the narrower temperature limits of the near-shore coastal waters. On the other hand, some eurybathyal, frigophilic species frequent intertidal or shallow water in high latitudes and occur in progressively deeper water as they range to-

[1] As noted by Allison (1955), the resistant middle Cretaceous rocks at Punta China formed a topographic high upon and against which the clastic Rosario sediments were deposited; the existence of the headland in late Cretaceous time is thus indicated. A hiatus occurs here between the Cretaceous rocks and the overlying terrace deposit.

wards the Equator, but also may appear intertidally in local upwelling areas in a warm temperate-subtropical faunal province (Emerson, 1956).

SOUTHERN SPECIES: The absence in the Punta China fauna of the tropical elements that characterize some of the late Pleistocene deposits of southern California and Pacific Baja California, although negative evidence, is extremely significant because of the size of the known Punta China fauna. There is present one warm temperate molluscan species, *Acanthina lugubris*, which has been considered to be a subtropical-tropical organism on the basis of a recorded modern range of Todos de Santos Bay, Baja California, to Panama and the Galapagos Islands (Burch, 1945, [1945–1946]). This species, however, apparently does not range south of Magdalena Bay, Baja California (L. G. Hertlein, 1956, *in litt.*). The verified ranges of two additional species having southern implications are:

*Astraea undosa:* Mugu Lagoon, Ventura County, California, to Cedros Island, Baja California, Mexico (Burch, 1945 [1945–1946]).

*Triphora pedroana:* Redondo Beach, California, to San Geronimo Island, Baja California, Mexico, off Punta Baja, latitude 29° 57′ N. (Burch, 1945 [1945–1946]).

These organisms at the present time are not known to range north of Point Conception, California, the northern boundary of the modern Transition faunal province. The lack of a truly tropical element in the fossil fauna suggests water temperatures much lower than temperatures required for the faunas now living in some of the larger lagoonal bays of Pacific Baja California.

NORTHERN SPECIES: Generally, the significance of the cold-water elements in a fossil assemblage is difficult to evaluate because of the bathymetric factor. However, the dominant, near-shore, strand-line facies represented in the Punta China fauna, together with the fragmental preservation of the apparent offshore, allochthonous components of the thanatocoenose, serves considerably to negate this difficulty. Included in the fossil fauna are several organisms that are not recorded to live south of Point Conception, California, or are restricted to infratidal waters south of that headland. These and their verified ranges are:

Mollusca

Gastropoda

*Acmaea instabilis:* Kodiak Island, Alaska, to Cayucos, California, latitude 35° N. (Burch, 1945 [1945–1946]); lives subtidally on kelp stems.

*Acmaea mitra:* Pribilof Island, Alaska, to San Diego, California (Dall, 1921c). Infratidal in southern part of range, except in upwelling areas (Emerson. 1956).

*Acmaea scutum:* Sitka, Alaska, to Point Conception, California (Keen, 1937).

*Calliostoma ligatum:* Prince William Sound, Alaska, to San Luis Obispo County, California (Burch, 1945 [1945–1946]).

*Ocinebra lurida:* Forrester Island, Alaska, to Catalina Island, California. Infratidal south of Cayucos, California (Burch, 1945 [1945–1946]).

*Opalia wroblewskii chacei:* Depoe Bay, Oregon, to Catalina Island, California (Burch, 1945 [1945–1946]). Infratidal in southern part of range.

*Tegula brunnea* and forma *fluctuata:* Crescent City, California, to Cayucos, California (Burch, 1945 [1945–1946]); Santa Barbara and San Nicholas Islands, California (Dall, 1921c).

"*Tegula*" *montereyi:* Bolinas Bay to Cayucos, California (Burch, 1945 [1945–1946]). Santa Barbara Islands, California (Dall, 1921c).

Amphineura

*Cryptochiton stelleri:* Hokkaido, Japan, to the Pribilof Islands, Alaska, south to Monterey County, California (Berry and Hubbs, 1954).

*Lepidozona cooperi:* Mendocino County, California, to Catalina Island, California (Dall, 1921c).

*Tonicella* cf. *T. lineata:* Northern Japan (Dall, 1921c) to Morro Rock, San Luis Obispo County, California (A. G. Smith, 1947).

Pelecypoda

*Clinocardium fucanum:* Sitka, Alaska, to Monterey Bay, California (Keen, 1954).

Coelenterata

Hexacorallia

*Balanophyllia elegans:* British Columbia to Point Conception and the Channel Islands, California, shore to 160 fathoms (Durham and Barnard, 1952). Infratidal south of Monterey, California, except in upwelling areas (Emerson, 1956).

Most of these species are characteristic of the cool, coastal waters of the North Temperate province but should not be confused with wide-ranging, stenobathic species that are not adapted to an intertidal or a near-shore habitus. In addition, several other northern species in this fauna have a known southern range limit in the San Pedro-San Diego area.

Special consideration must be given to the cold-water organisms, as some of these appear in the modern upwelling sites along the Baja California coast, and others are not known to occur at present south of Point Conception, California. Two of these northern species (the limpet, *Acmaea mitra*, and the stony coral, *Balanophyllia elegans*) were found living in the tidal zone on the south side of Punta Santo Tomás, an intense upwelling "cold-spot," approximately 6 miles north of Punta China (Emerson, 1956). The intertidal occurrence of these organisms, together with other northern species of mollusks, echinoderms, crustaceans, fishes, and algae (Burch, 1946 [1945–1946]; Dawson, 1951; Emerson, 1956; Hubbs, 1948), in the local upwelling areas reflects the lowered water temperature existing in these sites and indicates a discontinuous coastal distribution for these organisms. Further collecting in the upwelling areas may reveal the presence of additional northern species.

Most of the northern species in the Punta China fauna have not been reported living in the present upwelling sites; these, including *Tegula brunnea*, "*T.*" *montereyi*, *Cryptochiton stelleri*, *Lepidozona cooperi*, *Tonicella lineata*, and *Clinocardium fucanum*, are characteristic elements in the modern North Temperate fauna of the central California coast. The presence of this shallow-water, northern element in the assemblage indicates that the water temperatures required to support the fossil fauna were colder than those now existing at this latitude. On the basis of the composition of the Punta China fauna alone, however, it is not possible to determine if the lowered temperature requirements reflect a general isothermal shift along the coast, and influence of local upwelling, or a combination of the two phenomena. More definite conclusions may be reached if the fauna is viewed in the light of our knowledge of the Quaternary history of this region.

## Inferred Age

The reasons for referring the fossiliferous sands of the Punta China terrace to the Pleistocene epoch should be mentioned before comparisons with faunas of the same apparent age are undertaken. Both the stratigraphic and faunistic data indicate a late Pleistocene[1] age for the deposit. It is topographically the lowest marine terrace in the area and, on the basis of the very inadequate physiographic evidence, is possibly correlative with other terraces of approximately the same elevation occurring elsewhere as remnants along the northwestern Baja California coast. In common with the marine deposits of late Pleistocene age in southern California, there has been no deformation of the terrace sediments.

All the faunal constituents are extant species. However, some are not at present living at this latitude, and others are apparently now restricted to off-shore waters in this region.

[1] The Holocene of some European workers.

# FAUNAL COMPARISONS

## GENERAL COMMENTS

A REVIEW OF OUR UNDERSTANDING of the marine Pleistocene history of western North America is desirable before an evaluation of the Punta China fauna in terms of the Quaternary sequence is attempted. Notwithstanding inherent difficulties such as the Pliocene-Pleistocene boundary problem and the lack of precise means for interregional correlation, considerable data are available regarding the major events in this record, but varying interpretations have resulted in conflicting conclusions. Paleo-temperature requirements for the marine faunas of this age occurring from Alaska to southwestern Baja California, however, are interpreted by most investigators to require northward and southward shifts of the isotherms for hundreds of miles, presumably the result of successive glacial and interglacial periods (Durham, 1950a). Other lines of evidence, including the poorly preserved floral record, appear to corroborate this interpretation. The early faunal studies of James P. Smith (1919) suggested a general lowering of temperatures during the early Pleistocene and a decided amelioration of climate in the late Pleistocene. These conclusions were based largely on the well-known, richly fossiliferous section in the San Pedro area of southern California, but subsequent investigations indicate this explanation to be overly simplified.

The presence in several of the Pleistocene deposits, including the Punta China terrace, of faunal elements that are geographically or bathymetrically separated in their modern distribution cannot be singularly explained by the occurrence of northern and southern shifts of the isotherms. As Valentine (1955b) has recently pointed out, previously suggested causes for this "anomalous" distribution, including reworking (Crickmay, 1929), topographic barriers (Grant and Gale, 1931), and changes in physiological tolerances (Woodring, 1951), would not appear to be the *causa prima* for this faunal distribution. A more specious explanation for the apparent anomalous mixtures is the probable influence of local cold-water upwelling on the distribution of northern, frigophilic organisms during periods when near-shore waters were warm enough to support southern, thermophilic species (Valentine, 1955b; Mason, 1934). This interpretation seemingly fufills the necessary requirement for both warmer and colder temperatures in restricted areas during the Pleistocene environments of deposition.

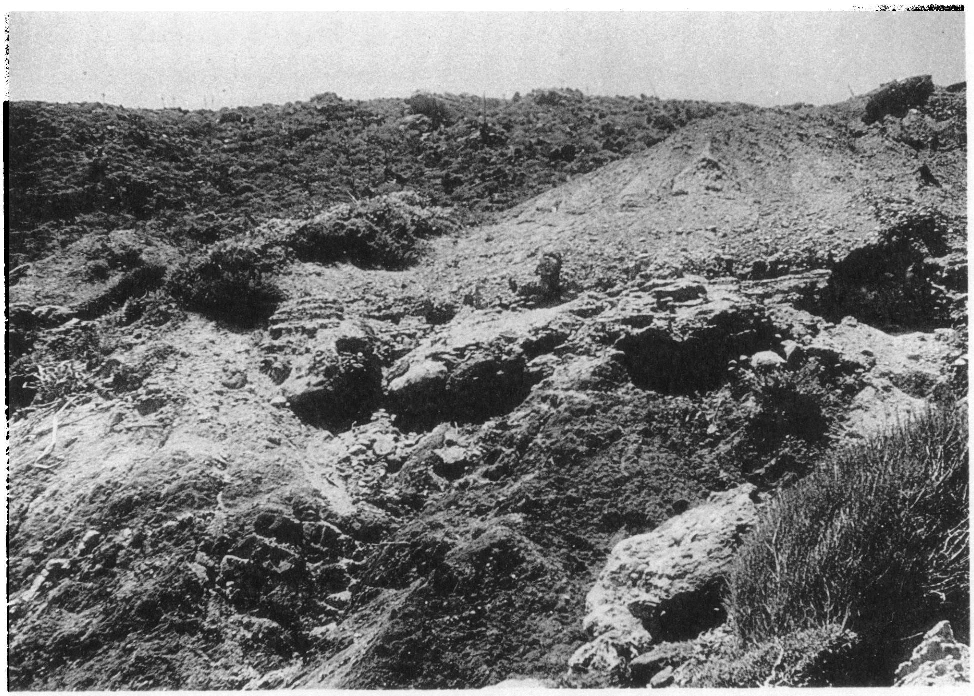
## NEONTOLOGICAL EVIDENCE

### THERMAL DIVERSITY

Since McEwen's (1916) initial recognition of upwelling off California and Baja California, considerable additional data have been compiled on the distribution of near-shore water temperatures in this region. The recent thermal surveys of Hubbs (1948), Dawson (1951), and Manar (1953) also indicate an irregular distribution of water temperatures along this coast. Relatively warm-water masses result from solar heating of isolated or protected shoal water and from seasonal introduction from the south of warm, equatorial water by northerly directed counter currents. Cold-water masses are produced by the presence of southward flowing currents and the influence of upwelling. Valentine (1955b), in summarizing the distribution and intensity of upwelling in this area, records the highest surface water temperatures from the shallow lagoons, where summer readings of 90° F. are common, and a seasonal lowering of 3° to 9° F. of near-shore surface temperatures in regions of upwelling. Water temperatures have been found to vary considerably in short distances along this coast, especially on the opposite sides of large headlands. For example, differences of from 7° to 10° F. were observed between the south and north sides of Punta Banda, Baja California, during the upwelling season (Emerson, 1956). Hubbs (*in* Walton, 1955) has recorded a maximum temperature differential of 21° F. between the two sides of this promontory.

### FAUNAL DIVERSITY

As mentioned above, the present distribution of the benthonic organisms reflects this geographically discontinuous pattern of water

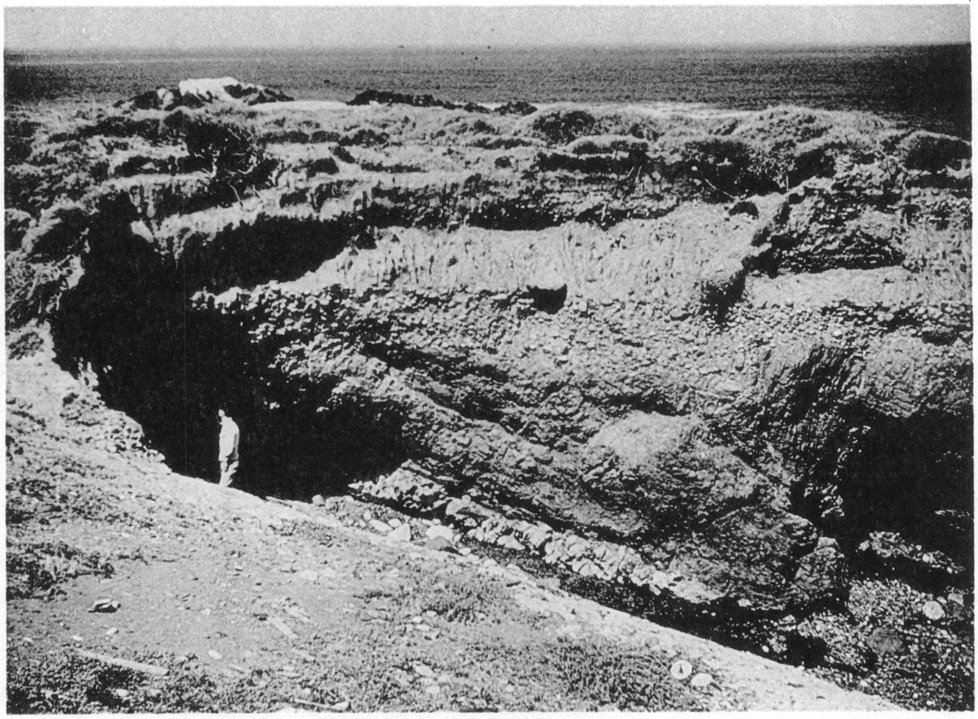


1

2

1. Pleistocene sand and conglomerate exposed on south side of Punta China, near locality A-9002. Fossiliferous stratum resting on Cretaceous rocks and overlain by talus and soil cover

2. Main Pleistocene collecting station, locality A-9002, on south side of Punta China. Fossils from 5–6-foot stratum of sandy gravel resting on Cretaceous rocks and overlain by unfossiliferous gravel, conglomerate, and soil cover



1

2

1. Pleistocene sand and conglomerate exposed in small cove on west side of Punta China, locality A-9596. Fossils from 1–3-foot stratum, resting on Cretaceous rocks and overlain by sand and soil cover

2. Coquina lens in Pleistocene deposit, resting on Cretaceous rocks and overlain by fossiliferous conglomerate, locality A-9596

temperatures. Some warm-water species that are characteristic of the tropical Panamic faunal province occur far north of their expected ranges in large, shallow-water embayments, including Scammon Lagoon, San Ignacio Lagoon, and especially Magdalena Bay. The presence of warm-water relict species in these bays and certain euryopic southern species in adjacent near-shore waters has prompted some students of biogeography to extend the northern limit of this faunal province, on the Pacific coast of the peninsula, from Cape San Lucas (latitude 22° 52′ N.) to the latitude of Cedros Island (28° 03′ N.).

Conversely, a number of shallow-water, North Temperate organisms range south of Point Conception, California, the presently recognized boundary between the North Temperate and the Transition[1] faunal provinces, but south of this headland the intertidal occurrence of these species is largely restricted to the northern Channel Islands, off southern California. Most of these species do not frequent the southern California coast, or, if present, are rarely encountered. This distribution appears to be correlated with the presence or absence of upwelling water masses. Data presented by Manar (1953, fig. 6) demonstrate the presence, in September, 1953, of severe upwelling in the region south of Point Conception, including the Santa Barbara Islands. Hewatt's (1946) marine ecological studies of the invertebrates from one of these, Santa Cruz Island, indicates the intertidal presence of several North Temperate species, together with euryopic Transition species, a "mixed fauna." The distribution of diatoms off southern California also shows the region south of Point Conception to reflect the influence of intense upwelling (Sverdrup and Allen, 1939). Other, cold-water forms, which are indicative of the North Temperate faunal province, appear intertidally in the previously discussed southern upwelling sites. Nearly contemporaneous associations of assemblages containing both warm-water and cold-water organisms thus are demonstrated in the Transition province by the composition of some intertidal communities occurring on the opposite sides of headlands (Burch, 1946 [1945–1946]) and in well-circulated embayments (Dawson, 1952). As Valentine (1955b, p. 468) has pointed out, "It is necessary only to postulate an intensification of . . . [the] conditions and processes, which occur along the Pacific coast today, to explain much of the Pleistocene and post-Pleistocene faunal redistribution."

## PALEONTOLOGICAL EVIDENCE

### General Considerations

Quaternary marine fossils are known from numerous coastal localities from southern Mexico to northern Alaska. For the purpose of this discussion, however, faunal comparisons are restricted to some late Pleistocene assemblages reported from northwestern Baja California and California.

Protected, shallow-water assemblages of late Pleistocene molluscan faunas from the Palos Verdes and Bay Point formations[2] are characterized by the presence of several locally extinct "warm-water" species. Notable among these are *Cardium procerum*, *Dosinia ponderosa*, *Chione gnidia*, *Crassinella branneri*, and *Nassarius cerritensis*. These and several additional southern species are not now living north of Scammon Lagoon, Baja California, and are largely confined in their distribution on the west coast of this peninsula to the protected bays of relatively warm water situated south of Cedros Island. Although this conspicuous warm-water element is not known to occur in late Pleistocene deposits north of Santa Monica, California, 34° N. (Woodring *et al.*, 1946), certain locally extinct southern mollusks, including *Chione californiensis*,[3] *Semele decisa*, and *Tagelus californianus*, appear in the fauna of the

[1] Here defined as the "littoral" fauna and flora occurring between Point Conception, California, and Cape San Lucas, Baja California. Garth (1955) further expands the bounds of this province to include the northern part of the Gulf of California on the basis of the discontinuous distribution of certain brachyuran Crustacea. Hubbs (1948) believed similar distributions of some northern, euryopic fishes in the upper part of the Gulf of California, where great seasonal extremes of water temperature occur, to represent relict elements.

[2] Type localities: Palos Verdes sand, Arnold's Lumber Yard locality, San Pedro, California (Woodring *et al.*, 1946); Bay Point formation, Crown Point (Mission Bay), San Diego, California (Hertlein and Grant, 1939).

[3] As *Venus* (*Chione*) *succinta* [*sic*] Vallenciennes [*sic*] (Weaver, 1949, p. 104).

Pleistocene Millerton formation in the Tomales Bay area, 38° N. (Weaver, 1949). Paleotemperatures greater than those now existing along this coast are thus required at times during the Pleistocene to support marine faunas known at least as far north as the San Francisco Bay area.

### Exposed Coast Facies

Molluscan assemblages from apparently windward sites of some late Pleistocene terrace deposits in the Los Angeles and San Diego areas are dominantly composed of typical strand-line inhabitants. Most of these species at present frequent rock and sand-rubble substrates in the shallow sublittoral and the intertidal zones of an exposed or semi-protected open coast. The intertidal element of this association has been designated the "rock-cliff and tide-pool" facies by Woodring *et alii* (1946, p. 93). Many of these deposits carry certain "northern" species which are now exclusively found in moderately deep water at these latitudes; at some localities, protected shallow-water forms also are present. Particularly significant is the "mixed" faunal composition of some of the assemblages having a prevailing rock-cliff and tide-pool aspect. These include elements of both northern and southern species which are now either locally extinct or are close to the present limits of their range. Notable examples are faunas described by Woodring *et alii* (1946) and the Chaces (1919) from the "older terraces" (second to sixth inclusive) of the Palos Verdes Hills, San Pedro, and by Webb (1937) and Berry (1922) from the lowest terrace on Point Loma, San Diego (see table 1 of the present paper). In attempting to account for the faunal mixture, the Chaces (1919, p. 43) attributed the presence of the northern species in "the Chiton bed" locality to transportation by storm waves from infratidal habitats, and Berry (1922, p. 409) referred this faunule to the early Pleistocene because of the conspicuous cold-water element, which occurs at present intertidally on the northern California coast. Webb (1937, p. 342) believed the northern species in the Point Loma deposit to have been "washed up from deeper water," and Berry (1922, p. 413) considered the cold-water species in this "decidedly southern" fauna to be "adventitious northern elements." In a consideration of the totality of the faunal composition, the intertidal occurrence of cold-water species in these deposits necessitates a nearly contemporaneous distribution of both warmer and colder water temperatures than exist at these latitudes today. It should be noted, however, that the "tropical" warm-water element which characterizes the protected, shallow-water facies of the Palos Verdes and Bay Point formations is not present in these assemblages.

### Protected Coast Facies

Woodring *et alii* (1946) record mollusks from 38 stations in the marine deposits (the Palos Verdes sands) on the lowest (youngest) terrace in the Palos Verdes Hills. Habitat and paleo-temperature requirements are inferred for some of the faunules. Collections from the east and northeast coast, the leeward side of the Pleistocene Palos Verdes Island, consist principally of protected, shallow-water assemblages, including several locally extinct southern species which are not living at present north of Scammon Lagoon, Baja California. The rarity of rock-cliff and tide-pool species in these deposits is attributed to the absence of a suitable depositional substrate. A beach facies, indicated by the presence of certain species in cross-laminated sand, also was noted at three localities; none of the characteristic southern species occurs in these assemblages. A significant lateral change in faunal composition of the semi-protected, shallow-water assemblages is evident if comparisons are made of deposits from seaward to landward stations relative to the Palos Verdes depositional environment. Assemblages from stations facing the open ocean during Palos Verdes time, Arnold's "Crawfish George's" and United States Geological Survey locality 107, lack the characteristic southern species but contain several locally extinct northern species and others that at present are living in moderately deep waters at this latitude.[1] The presence of northern species from moderate depths in predominantly shallow-water assemblages was attributed by Woodring (1935) to transportation by storm waves.

[1] Arnold (1903) lists the "rare" occurrence of one southern species, *Nassarius cerritensis*, in his "Crawfish George's" locality.

TABLE 1

SOME RECENT MOLLUSKS LOCALLY EXTINCT IN LATE PLEISTOCENE DEPOSITS OF SOUTHERN CALIFORNIA AND NORTHWESTERN BAJA CALIFORNIA

| | "Older Terraces," Palos Verdes Hills | | Palos Verdes Formation, *Sensu Lato* | | | | | | Bay Point Formation, *Sensu Lato* | | | | Punta China Fauna |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Point Fermin (Chace and Chace, 1919)[a] | Terraces 2–12 (Woodring *et al.*, 1946)[b] | Palos Verdes Sand (Woodring *et al.*, 1946) | Lumber Yard (Arnold, 1903) | Signal Hill (De Long, 1941) | Playa del Ray (Willett, 1937) | Santa Monica (Woodring *et al.*, 1946)[c] | New Port (Bruff, 1946) | Spanish Bight (Hertlein and Grant, 1944) | Foot of 26th Street (Arnold, 1903) | Point Loma (Webb, 1937) | Border Locality (Emerson and Addicott, 1953) | This Paper (Table 2) |
| SOUTHERN SPECIES, WITH PRESENT KNOWN RANGE | | | | | | | | | | | | | |
| *Anadara perlabiata* Magdalena Bay, Baja California, to Tumbez, Peru (Hertlein and Strong, 1943) | — | — | x | — | — | — | — | ?[d] | — | — | — | — | — |
| *Cardium procerum* Lagoon Head, latitude 28° 15′ N., Baja California, to Lobos Islands, Peru (Hertlein and Strong, 1947) | — | — | x | — | x | x | x | x | x | x | — | — | — |
| *Chione gnidia* Cedros Island, Baja California, to Paita, Peru (Hertlein and Strong, 1948) | — | — | x | x | x | — | x | x | x | — | — | — | — |
| *Crassinella branneri* Scammon Lagoon, Baja California (Woodring *et al.*, 1946) | — | — | x | x | x | x | x | — | x | x | — | x | — |
| *Diplodonta sericata* San Ignacio Lagoon, Baja California, to Guayaquil, Ecuador (Hertlein and Strong, 1947) | — | — | x | x | x | — | — | x | x | x | — | — | — |
| *Dosinia ponderosa* Scammon Lagoon, Baja California, to Paita, Peru, and Galapagos Islands (Hertlein and Strong, 1948) | — | — | x | — | x | — | x | x | — | x | — | — | — |
| *Pecten vogdesi* Magdalena Bay, Baja California, to Peru (Hertlein and Strong, 1946) | — | — | x | x | — | x | — | — | — | — | — | — | — |
| *Acanthina lugubris* Todos de Santos Bay, Baja California, to Panama, and Galapagos Islands (Burch, 1945 [1945–1946]), see page 324 | — | x | — | — | — | — | x | — | — | — | x[e] | — | x[f] |

TABLE 1—(*Continued*)

| | "Older Terraces," Palos Verdes Hills | | Palos Verdes Formation, *Sensu Lato* | | | | | | Bay Point Formation, *Sensu Lato* | | | | Punta China Fauna |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Point Fermin (Chace and Chace, 1919) | Terraces 2–12 (Woodring *et al.*, 1946) | Palos Verdes Sand (Woodring *et al.*, 1946) | Lumber Yard (Arnold, 1903) | Signal Hill (De Long, 1941) | Playa del Ray (Willett, 1937) | Santa Monica (Woodring *et al.*, 1946) | New Port (Bruff, 1946) | Spanish Bight (Hertlein and Grant, 1944) | Foot of 26th Street (Arnold, 1903) | Point Loma (Webb, 1937) | Border Locality (Emerson and Addicott, 1953) | This Paper (Table 2) |
| *Eupleura muriciformis*<br>Cedros Island, Baja California, to Lobitos, Peru (Hertlein and Strong, 1955) | — | — | x | x | — | — | — | x | — | — | — | — | — |
| *Nassarius cerritensis*<br>Ballenas Bay, Baja California, to Guaymas, Mexico (Woodring *et al.*, 1946) | — | — | x | x | x | x | x | — | x | — | — | — | — |
| *Thais biserialis*<br>Cedros Island, Baja California, to Peru (Woodring *et al.*, 1946) | — | — | x | — | — | x | x | — | — | — | — | — | — |
| *Turritella gonostoma broderipiana*<br>(?Scammon Lagoon, Baja California) Gulf of California, to Peru (L. G. Hertlein, personal communication) | — | — | — | — | — | — | — | — | — | — | $x^{g}$ | — | — |
| Northern Species, with Present Known Range | | | | | | | | | | | | | |
| *Acmaea mitra*<br>Pribilof Islands, Alaska, to San Diego, California (Dall, 1921c) | $x^{h}$ | — | $x^{i}$ | — | — | — | — | — | — | — | $x^{h}$ | — | $x^{j}$ |
| *Calliostoma ligatum*<br>Prince William Sound, Alaska, to San Luis Obispo County, California (Burch, 1946 [1945–1946]) | — | — | x | x | — | — | x | — | — | — | — | x | x |
| *Fusitriton oregonensis*<br>Bering Sea, to off San Diego, California (Burch, 1945 [1945–1946]) | — | — | — | — | — | $x^{k}$ | — | — | — | — | — | $x^{k}$ | — |
| *Tegula brunnea*<br>Crescent City, to Cayucos, California (Burch, 1946 [1945–1946]); Channel Islands, California (Dall, 1921c) | x | ? | x | x | — | — | — | — | — | — | — | — | x |

TABLE 1—(*Continued*)

| | "Older Terraces," Palos Verdes Hills | | Palos Verdes Formation *Sensu Lato* | | | | | | Bay Point Formation, *Sensu Lato* | | | | Punta China Fauna |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Point Fermin (Chace and Chace, 1919) | Terraces 2–12 (Woodring *et al.*, 1946) | Palos Verdes Sand (Woodring *et al.*, 1946) | Lumber Yard (Arnold, 1903) | Signal Hill (De Long, 1941) | Playa del Ray (Willett, 1937) | Santa Monica (Woodring *et al.*, 1946) | New Port (Bruff, 1946) | Spanish Bight (Hertlein and Grant, 1944) | Foot of 26th Street (Arnold, 1903) | Point Loma (Webb, 1937) | Border Locality (Emerson and Addicott, 1953) | This Paper (Table 2) |
| *Tegula marcida*<br>Sitka, Alaska, to off San Diego, California (Burch, 1946 [1945–1946]) | — | — | x | — | — | x | — | x | — | — | x | — | ? |
| "*Tegula*" *montereyi*<br>Bolinas Bay, to Cayucos, California (Burch, 1946 [1945–1946]); Santa Barbara Islands, California (Dall, 1921c) | — | x | x | x | — | — | — | — | — | — | x | — | x |
| *Cryptochiton stelleri*<br>Pribilof Islands, Alaska, to Monterey County, California (Berry, 1954) | — | — | — | — | — | — | — | — | — | — | x[l] | — | x |
| *Lepidozona cooperi*<br>Mendocino County, California, and Catalina Island, California (Dall, 1921c) | x | — | x[m] | — | — | — | — | — | — | — | — | — | x |
| *Tonicella lineata*<br>Northern Japan (Dall, 1921c), to San Luis Obispo County, California (A. G. Smith, 1947) | x | — | — | — | — | — | — | — | — | — | — | — | ? |

[a] Second terrace (*fide* Woodring *et al.*, 1946).
[b] Some additional southern species recorded from these deposits are "*Chione*" *picta* and *Crassinella nuculiformis*, which also occur in the Palos Verdes sand.
[c] Also after Valentine (1956, pp. 194–201).
[d] As "*Anadara multicosta* Sowerby."
[e] Recorded by Berry (1922) from the "Coal Mine" locality, on the west side of the peninsula.
[f] Presently living at this latitude.
[g] Reported by Stephens (1929) from the northeast end of the peninsula (San Diego Soc. Nat. Hist. locality 70).
[h] Presently living at this latitude in subtidal water only.
[i] Reported by Arnold (1903) from "Crawfish George's" locality, San Pedro, California.
[j] Presently living in subtidal water at this latitude but occurs intertidally in severe upwelling areas along the northwestern Baja California coast.
[k] Presently living at moderate depths at this latitude.
[l] Reported by Berry (1922) from the "Coal Mine" locality on the west side of Point Loma and "two miles north of Point Loma" (California Acad. Sci. Geol. Dept. locality 108). Webb (1937) lists two species of chitons but does not specifically identify them.
[m] Reported by Berry (1922) from Arnold's "Crawfish George's" locality, San Pedro, California.

Crickmay (1929) reported a similar "mixed" association from Deadman Island, an islet that formerly stood in the present San Pedro harbor channel, off Times Point; he considered the cold-water species to represent derived specimens. Assemblages from the landward side of the Pleistocene Palos Verdes Island, facing the coastal channel, include the protected, shallow-water, southern species together with a reduced number of northern forms. This faunal composition also occurs in deposits described from Santa Monica to Newport Beach in the Pleistocene embayment of the Los Angeles basin (see table 1). The composition of these assemblages requires decidedly warmer water than needed for the faunules from unprotected, exposed, coastal environments. Depositional sites intermediately situated between exposed and semi-protected localities, such as Arnold's (1903) Lumber Yard locality, carry most of the warm-water species but also a significant northern element.

A similar lateral change in faunal composition is apparent in the San Diego area where several late Pleistocene faunules have been described from low terrace deposits, the Bay Point sands.[1] During late Pleistocene time, Point Loma, now a promontory protecting the northwestern portion of San Diego Bay, was an island and formed a near-shore barrier for part of the relatively small San Diego embayment. As mentioned above, assemblages from deposits on the west or windward side of the island represent a predominantly rock-cliff and tide-pool facies. These faunules contain several species having southern implications, including a locally extinct one, but also contain a distinctive northern element (Webb, 1937; Berry, 1922). On the semi-protected leeward side, a warm-water faunule, including a tropical species, *Turritella gonostoma*, has been recorded by Stephens (1929, p. 225). Faunas in the San Diego embayment from depositional sites southeast of the Pleistocene island, Spanish Bight (Hertlein and Grant, 1944) and Indian Point (Arnold, 1903), include southern, warm-water species which characterize the protected, shallow-water facies of the Palos Verdes formation and lack cold-water forms (see table 1). Assemblages from apparently exposed coast and near-shore environments, namely, Pacific Beach (Arnold, 1903) and the "Border locality" (Emerson and Addicott, 1953), contain a mixture of southern and northern species.

The "thermally anomalous" composition of late Pleistocene faunules in the Los Angeles and San Diego districts appears, therefore, to be plausibly explained by the location of the depositional sites in relation to the configuration of the Pleistocene coast. If the totality of faunal composition is considered, the "mixed associations" appear to reflect the requirements of the local environments of deposition. Similar distributional patterns are known to occur at the present time along the southwestern coast of Baja California, where relict, tropical elements are now largely confined to shallow, warm-water lagoons and where Dawson (1952) has demonstrated the near association of both relatively warm- and cold-water algal floras in well-circulated coastal waters. To account for the composition of these faunules, we need only postulate during the deposition of the Palos Verdes and Bay Point sands the existence of near-shore water temperatures slightly warmer than those now supporting tropical elements in some of the west coast bays of Baja California and the presence of severe local upwelling.

## CONCLUSIONS

The suggested temperature requirements and the inferred environmental relationships for some late Pleistocene faunas in the southern California district having been outlined, the composition of the Punta China fauna may now be evaluated in terms of comparable depositional facies. Obviously, faunal comparisons also must be viewed with respect to latitude as well as assumed relative contemporaneity. In the absence of other described cliff-face and tide-pool assemblages from Pacific Baja California, comparisons are limited to similar associations occurring in

[1] In proposing the Bay Point formation, Hertlein and Grant (1939, p. 72) specifically included fossiliferous deposits at Crown Point, Mission Bay (type locality), Spanish Bight, and Indian Point in San Diego Bay, all having predominately warm-water assemblages, and at Pacific Beach, a mixed association of southern and off-shore species. Other fossiliferous deposits on the Nestor terrace and its probable equivalents in this region appear to represent facies of this formation. These include the La Jolla terrace (Hanna, 1926, p. 194), Point Loma terrace (Webb, 1937; Berry, 1922), and the "Border locality" (Emerson and Addicott, 1953).

the terrace deposits (discussed above) of the San Pedro and San Diego areas. Of these, the faunal composition of the open-coast facies in the Point Loma terrace most closely approximates the Punta China fauna. Both assemblages lack extinct organisms, include but one locally extinct southern species, and possess several components of the cold-water element[1] (see table 1). Compared quantitatively, 55 per cent of the 90 identified species of mollusks recorded by Webb (1937) and Berry (1922) from the Point Loma terrace are common to the Punta China fauna. Although the cold-water element present in the Punta China fauna appears to require a somewhat cooler environment than needed to support the Point Loma fauna, both reflect colder water conditions than those faunules in the late Pleistocene deposits containing the conspicuous tropical element. Faunal composition of certain of the "older terrace" deposits of the Palos Verdes Hills is similar to the Punta China fauna. Some of these, including the Chaces' (1919) "Chiton Bed" locality, are devoid of the tropical element and extinct species[2] and contain a number of northern, shallow-water indicators (see table 1). As mentioned above, however, several of the Palos Verdes deposits carry a mixed association of both cold- and warm-water species at different depositional sites on the same terrace. These occurrences, together with other evidence cited, indicate the probable contemporaneous existence of warmer and colder water temperatures than now occur at these latitudes.

In the complete absence of contradiction, the Punta China deposits can be thus conclusively referred to the late Pleistocene on the basis of the totally modern faunal composition and the limited physiographic evidence. Two diverse interpretations are suggested by the available data to account for a depositional environment with water temperatures lower than those currently existing at this latitude:

1. Upwelling not present locally (or, if present, the influence is indeterminable) during a general southward shift of the surface isotherms, resulting presumably from the effects of glaciation. This conclusion, while theoretically sound, is not in harmony with the paleo-ecological interpretations of the late Pleistocene Pacific coast faunal history presented above.

2. Severe local upwelling present (rates of upwelling of considerably greater magnitude than existing at present in this region) during a northward shift of the surface isotherms, possibly when temperatures were warm enough to support the tropical elements in the Pleistocene San Quintín fauna to the south and the late Pleistocene faunas of the southern California district to the north. Admittedly, coldest temperatures should be expected in upwelling areas at times when regional surface temperatures were reduced. But temporal changes in coastal and submarine topography and the resulting alterations of regional oceanographic and climatic conditions undoubtedly greatly influenced local environments. Some aspects of the distribution of the modern west American marine biota admirably manifest this assumption.

It is obvious, however, that an "interglacial"[3] assignment to a predominantly cold-water assemblage from a deposit lacking stratigraphically demonstrated correlates of warm-water bio-facies is highly speculative. This interpretation must be considered tentative until the results of detailed ecological studies, including $O^{18}$ analyses, and inter-regional stratigraphic investigations of the numerous fossiliferous Baja California terrace deposits serve to corroborate or refute a conclusion based, of necessity, on a part rather than the whole.

[1] Although the "northern" stony coral, *Balanophyllia elegans*, is not known from the Point Loma deposits, Webb (1937, p. 345) records "coral fragments" that may represent this species. However, another species, *Astrangia lajollaensis*, now occurs intertidally in the San Diego area.

[2] Dr. S. S. Berry (*in litt.*) questionably refers two valves of *Callistochiton decoratus* from Punta China to *C. d. ferminicus*, a form originally described from the "Chiton Bed" locality (second terrace, Palos Verdes Hills) and not known to be living.

[3] It is of interest to note that Stokes (1955) postulates coolest and warmest ocean temperatures during the Pleistocene to have occurred in the stages of glacial retreat and glacial advance, respectively. Under this interpretation this assemblage, if correlative with the late Pleistocene terrace faunas of southern California, would appear to represent the phase intermediate between the stages of glacial advance and glacial maximum, the period when the warm near-shore waters were gradually cooling attendant with a probable increase in the influence of upwelling waters on the marine biota.

# FOSSIL LOCALITIES IN THE PUNTA CHINA TERRACE

FOSSILS WERE COLLECTED from six stations situated along the seashore in the vicinity of Puerto Santo Tomás, Baja California, Mexico. Map references are: United States Army Air Force Preliminary Base, Ensenada (472B), scale 1:500,000, April, 1946, and United States Navy Hydrographic Office, San Diego, to Bahía San Quintín, chart 1149, natural scale 1:290,000 at latitude 30° 15′ N., edition 45, November, 1948. Locality numbers refer to the collections of the University of California Museum of Paleontology, Berkeley. The collection stations are plotted, with the exception of locality A-9546a, on the location map (fig. 1).

A-9002: At latitude 31° 31′ 22″ N., longitude 116° 39′ W. Terrace deposit exposed on the south side of Punta China, about 500 yards east of the point. Fossils from basal 1–6-foot stratum, at about 25 feet above sea level, locally resting on rocks of either middle or upper Cretaceous age and overlain by approximately 25–30 feet of unfossiliferous gravel and conglomerate. Rock type: reddish brown weathering, sandy gravel; ranging in size from very fine sand to boulders 6 feet in diameter; average particle size, granules. Gravel largely unconsolidated, but locally cemented to form a coquina of coarse, poorly sorted sand and fossils. Collected by J. W. Durham and E. C. Allison, August, 1952; W. O. Addicott and W. K. Emerson, December, 1952.

A-9593: Terrace deposit exposed in sea cliff facing the small bay north of Punta China; north side of the southernmost of a series of faults along this beach. Fossils from basal 3–4-foot stratum, at an estimated elevation of from 20 to 25 feet above sea level, resting on upper Cretaceous rocks and overlain by unfossiliferous gravel and reddish soil. Rock type: reddish weathering, sandy gravel. Collected by J. W. Durham and W. K. Emerson, June, 1953.

A-9594: At latitude 31° 33′ 40″ N., longitude 116° 41′ 45″ W. Remnant exposed on south side of the northern tip of Punta Santo Tomás; accessible by trail leading north from end of road at Puerto Santo Tomás anchorage. Fossils from stratum about 5 feet in thickness, at an estimated 20 feet above sea level, overlying white, plutonic rock. Rock type: very well indurated, sandy conglomerate. Collected by W. O. Addicott, December, 1952.

A-9595: Remnant exposed south of Punta China, on first rocky cliff south of the two near-shore islets. Fossils from basal stratum, at about 25 feet above sea level, overlying Cretaceous rocks. Rock type: poorly sorted, sandy gravel, with cobbles up to 10 inches in diameter. Collected by W. O. Addicott, December, 1952.

A-9596: Remnant exposed in small cove on the west side of Punta China. Fossils from 1–3-foot stratum, resting unconformably on Cretaceous rocks, at about 12 to 15 feet in elevation above sea level, and overlain by 10 feet of poorly sorted, locally fossiliferous sands. Rock type: reddish brown weathering, poorly sorted, coarse-grained sand containing boulders up to 18 inches in diameter. Collected by W. K. Emerson and W. O. Addicott, December, 1952.

A-9546a: Remnant exposed in sea cliff south of Punta China, about half of the distance between Punta China and Punta San José. Fossils from thin stratum capping (?) upper Cretaceous rock, at an elevation of about 25 feet above sea level. Rock type: well sorted, pebbly sand, Fossils uncommon. Collected by W. K. Emerson, June, 1953.

# ALPHABETICAL LIST OF THE PUNTA CHINA FAUNA

METAZOAN FOSSILS from five localities in the Punta China terrace deposits are listed in table 2. The identified fossils total 105 species and recognized infraspecific forms, including 96 mollusks (66 gastropods, 19 pelecypods, 10 chitons, and one scaphopod), one brachiopod, one stony coral, three Bryozoa, one echinoid, and three barnacles. Of this number, 89 species were collected from the richly fossiliferous sand on the south side of Punta China, locality A-9002.

In addition to the species recorded below, S. Stillman Berry reports (*in litt.*) two species of mollusks collected by Carl L. Hubbs from the south side of Punta China, namely: a chiton, *Mopalia acuta* (Carpenter), 1855, and a gastropod, *Tegula marcida* (Gould), 1853 (=*Phorcus pulligo* Martyn, 1784).

TABLE 2

ALPHABETICAL CHECK LIST OF FOSSILS BY GROUPS

| | Locality Numbers in North-South Sequence | | | | | |
|---|---|---|---|---|---|---|
| | A-9594 | A-9593 | A-9596 | A-9002 | A-9595 | A-9546a |
| GASTROPODA | | | | | | |
| *Acanthina lugubris* (Sowerby), 1821 | — | — | — | x | — | x |
| *Acanthina spirata* (Blainville), 1832 | — | — | — | x | — | — |
| *Acmaea asmi* (Middendorff), 1847 | — | — | — | x | — | x |
| *Acmaea cassis* Eschscholtz, 1833 | — | — | — | x | — | — |
| *Acmaea digitalis* Eschscholtz, 1833 | — | x | — | x | — | — |
| *Acmaea insessa* (Hinds), 1842 | x | x | — | x | — | x |
| *Acmaea instabilis* (Gould), 1846 | — | — | — | x | — | — |
| *Acmaea mitra* Eschscholtz, 1833 | — | — | x | x | x | x |
| *Acmaea scabra* (Gould), 1846 | — | x | — | x | x | x |
| *Acmaea scutum* Eschscholtz, 1833 | — | — | — | x | — | x |
| *Aletes squamigerus* Carpenter, 1856 | — | — | x | x | — | — |
| *Amphissa versicolor* Dall, 1871 | x | — | x | x | — | — |
| *Astraea undosa* (Wood), 1828 | — | — | — | x | — | — |
| *Balcis thersites* (Carpenter), 1864 | — | — | — | x | — | — |
| *Bittium quadrifilatum* Carpenter, 1864 | — | — | — | x | — | — |
| *Calliostoma ligatum* Gould, 1853 (=*C. costatum* Martyn, 1784) | x | — | — | x | — | — |
| *Conus californicus* Hinds, 1844 | x | — | x | x | — | — |
| *Crepidula adunca* Sowerby, 1825 | — | — | x | x | — | — |
| *Crepidula lingulata* Gould, 1846 | x | — | — | x | — | — |
| *Crepidula norrisiarum* Williamson, 1905 | — | — | — | x | — | — |
| *Cypraeolina pyriformis* Carpenter, 1865 | — | — | — | x | — | — |
| *Diodora aspera* (Eschscholtz), 1833 | — | — | x | x | — | — |
| *Fissurella volcano* Reeve, 1849 | x | — | x | x | — | x |
| *Gadinia reticulata* (Sowerby), 1835 | — | — | — | x | — | — |
| *Haliotis corrugata* Gray, 1828 | x | — | — | — | — | — |
| *Haliotis cracherodi* Leach, 1814 | ? | — | — | x | x | x |
| *Haliotis rufescens* Swainson, 1822 | — | — | ? | x | x | — |
| *Halistylus subpupoideus* (Tryon), 1886 | — | — | — | x | — | — |
| *Hipponix antiquatus* (Linnaeus), 1767 | — | — | x | x | — | x |
| *Hipponix antiquatus* var. *cranioides* Carpenter, 1864 | — | — | — | x | — | x |
| *Hipponix tumens* Carpenter, 1864 | — | x | — | x | — | — |
| *Homalopoma bacula* (Carpenter), 1864 | — | — | — | x | ? | — |
| *Homalopoma carpenteri* (Pilsbry), 1888 | x | — | x | — | — | — |
| *Kellettia kelletti* (Forbes), 1850 | — | — | — | x | — | — |
| *Liotia fenestrata* Carpenter, 1864 | — | — | — | x | — | — |

TABLE 2—(*Continued*)

| | Locality Numbers in North-South Sequence | | | | | |
|---|---|---|---|---|---|---|
| | A-9594 | A-9593 | A-9596 | A-9002 | A-9595 | A-9546a |
| *Littorina planaxis* Philippi, 1847 | — | — | — | x | — | — |
| *Littorina scutulata* Gould, 1849 | — | x | — | x | x | — |
| *Lottia gigantea* Gray, 1834 | — | — | — | — | x | — |
| "*Mangelia*" *rhyssa* Dall, 1919 | — | — | — | x | — | — |
| *Megatebennus bimaculata* (Dall), 1871 | — | — | — | x | — | — |
| *Megathura crenulata* (Sowerby), 1825 | — | — | — | x | — | — |
| *Metaxia diadema* Bartsch, 1907 | — | — | — | x | — | — |
| *Mitra idae* Melville, 1893 | — | x | — | x | — | — |
| *Mitrella carinata* (Hinds), 1844 | — | — | — | x | — | x |
| *Mitrella carinata* forma *gausapata* (Gould), 1851 | — | — | — | x | — | — |
| *Mitrella tuberosa* Carpenter, 1864 | — | — | — | x | — | — |
| *Mitromorpha aspera* Carpenter, 1865 | — | — | — | x | — | — |
| *Mitromorpha gracilior* Hemphill, 1884 | — | — | — | x | — | — |
| *Nassarius fossatus* (Gould), 1849 | — | — | — | x | — | — |
| *Nassarius mendicus* forma *cooperi* Forbes, 1850 | — | — | — | x | — | — |
| *Norrisia norrisi* (Sowerby), 1838 | x | — | — | — | — | — |
| *Ocinebra lurida* (Eschscholtz), 1833 | — | — | — | x | — | — |
| *Olivella biplicata* (Sowerby), 1825 | — | x | x | x | — | — |
| *Opalia wroblewski chacei* Strong, 1937 | — | — | — | x | — | — |
| *Phasianella compta* Gould, 1855 | x | — | — | — | — | — |
| *Polinices* cf. *P. lewisi* (Gould), 1847 | — | — | — | x | — | — |
| *Pseudomelatoma* cf. *P. moesta* (Carpenter), 1864 | — | — | — | x | — | — |
| *Seila montereyensis* Bartsch, 1907 | — | — | — | x | — | — |
| *Tegula brunnea* (Philippi), 1848 | — | — | x | x | x | x |
| *Tegula brunnea* forma *fluctuata* (Dall), 1872 | — | — | — | x | — | — |
| *Tegula funebralis* (A. Adams), 1859 | — | x | — | x | x | x |
| "*Tegula*" *montereyi* (Kiener), 1856 | — | — | — | x | — | — |
| *Triphora pedroana* Bartsch, 1907 | — | — | — | x | — | — |
| *Turbonilla tenuicula* (Gould), 1853 | — | — | — | x | — | — |
| *Turritella* cf. *T. cooperi* Carpenter, 1864 | — | x | — | — | — | — |
| *Zonaria spadicea* (Swainson), 1823 | — | — | — | x | — | — |
| AMPHINEURA[a] | | | | | | |
| *Callistochiton crassicostatus* Pilsbry, 1893 | — | — | — | x | — | — |
| *Callistochiton* cf. *C. decoratus ferminicus* Berry, 1922 | — | — | — | x | — | — |
| *Callistochiton palmulatus* Carpenter, *in* Pilsbry, 1893 | — | — | — | x | — | — |
| *Callistochiton palmulatus* var. *mirabilis* Pilsbry, 1893 | — | — | — | x | — | — |
| *Cryptochiton stelleri* (Middendorff), 1846 | — | — | — | x | — | — |
| *Lepidozona cooperi* "Carpenter" (Pilsbry), 1892 | — | — | — | x | — | — |
| *Mopalia* cf. *M. lignosa* (Gould), 1846 | — | — | — | x | — | — |
| *Mopalia muscosa* (Gould), 1846 | — | — | — | x | — | — |
| *Stenoplax heathiana* Berry, 1911 | — | — | — | x | — | — |
| *Tonicella* cf. *T. lineata* (Wood), 1815 | — | — | — | x | — | — |

TABLE 2—(*Continued*)

| | Locality Numbers in North-South Sequence | | | | | |
|---|---|---|---|---|---|---|
| | A-9594 | A-9593 | A-9596 | A-9002 | A-9595 | A-9546a |
| SCAPHOPODA | | | | | | |
| *Dentalium neohexagonum* Sharp and Pilsbry, 1897 | — | — | — | x | — | — |
| PELECYPODA | | | | | | |
| *Acar bailyi* Bartsch, 1931 [=? *A. pernoides* (Carpenter), 1856] | — | — | — | x | — | — |
| *Chama pellucida* (Broderip), 1835 | x | — | — | x | — | — |
| *Clinocardium fucanum* Dall, 1907 | — | — | — | x | — | — |
| *Cumingia californica* Conrad, 1837 | — | x | — | x | — | — |
| *Glans carpenteri* (Lamy), 1922 | — | — | x | x | — | x |
| *Glycymeris (?)profunda* (Dall), 1879 | — | — | — | x | — | — |
| *Hinnites multirugosus* (Gale), 1928 | — | — | x | x | x | — |
| *Irus lamellifer* (Conrad), 1837 | — | — | — | x | — | — |
| *Lucina californica* (Conrad), 1837 | x | x | x | x | x | — |
| *Modiolus fornicatus* (Carpenter), 1864 | — | — | x | x | — | — |
| *Mytilus californianus* Conrad, 1837 | x | — | x | — | — | — |
| *Petricola carditoides* (Conrad), 1837 | — | — | — | x | — | — |
| *Pododesmus macroschismus* (Deshayes), 1839 | — | — | x | x | — | — |
| *Protothaca staminea* (Conrad), 1837 | — | — | x | x | x | — |
| *Saxicava arctica* (Linnaeus), 1767 | — | — | x | x | — | — |
| *Semele decisa* (Conrad), 1837 | — | — | — | x | — | — |
| *Septifer bifurcatus* (Conrad), 1837 | — | — | — | x | — | — |
| *Tellina buttoni* Dall, 1900 | — | — | — | x | — | — |
| *Transennella tantilla* (Gould), 1853 | — | — | — | x | — | — |
| BRACHIOPODA | | | | | | |
| *Terebratalia transversa* var. *lata* Dall, 1921 | — | — | — | x | — | — |
| COELENTERATA (HEXACORALLIA)[b] | | | | | | |
| *Balanophyllia elegans* Verrill, 1864 | — | — | — | x | — | — |
| ECHINODERMATA | | | | | | |
| *Strongylocentrotus* cf. *S. purpuratus* (Stimpson), 1857 | x | — | — | — | x | x |
| BRYOZOA[c] | | | | | | |
| *Antropora tincta* (Hastings), 1930 | — | — | — | x | — | — |
| *Lagenipora punctulata* (Gabb and Horn), 1862 | — | — | — | x | — | — |
| *Rhynchozoon tumulosum* (Hicks), 1882 | — | — | — | x | — | — |
| CIRRIPEDIA | | | | | | |
| *Balanus* cf. *B. nubilus* Darwin, 1854 | — | — | x | x | x | — |
| *Balanus* cf. *B. tintinnabulum californicus* Pilsbry, 1916 | x | — | — | x | — | — |
| *Tetraclita squamosa rubescens* Darwin, 1854 | x | — | — | x | — | — |

[a] Identifications contributed by S. S. Berry.
[b] Identification contributed by J. W. Durham.
[c] Identifications contributed by J. D. Soule.

# LITERATURE CITED


ALLISON, EDWIN C.
1955. Middle Cretaceous Gastropoda from Punta China, Baja California, Mexico. Jour. Paleont., vol. 29, pp. 400–432, 3 figs., 5 pls.

ARNOLD, RALPH
1903. The paleontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California. Mem. California Acad. Sci., vol. 3, pp. 1–420, 37 pls.

BEAL, CARL H.
1948. Reconnaissance of the geology and oil possibilities of Baja California, Mexico. Mem. Geol. Soc. America, no. 31, pp. i–ix, 1–138, 11 pls.

BERRY, S. STILLMAN
1922. Fossil chitons of western North America. Proc. California Acad. Sci., ser. 4, vol. 11, pp. 399–526, 11 figs., 16 pls.
1926. Fossil chitons from the Pleistocene of San Quintin Bay, Lower California. Amer. Jour. Sci., vol. 12, pp. 455–456.
1946. A re-examination of the chiton, *Stenoplax magdalenensis* (Hinds), with description of a new species. Proc. Malacol. Soc., London, vol. 26, pp. 161–166, 6 figs., 2 pls.

BERRY, S. STILLMAN, AND CARL L. HUBBS
1954. The distribution, past and present, of Cryptochiton. (Abstract.) Ann. Rept. Amer. Malacol. Union, p. 22.

BRUFF, STEPHEN C.
1946. The paleontology of the Pleistocene molluscan fauna of the Newport Bay area, California. Univ. California Publ., Bull. Dept. Geol. Sci., vol. 27, pp. 213–240, 12 figs.

BURCH, JOHN Q. (ED.)
1945–1946. Distributional list of the west American marine mollusks from San Diego, California to the Polar Sea. Los Angeles, Conchological Club of Southern California, pt. 1, pt. 2 (vols. 1, 2).

CHACE, E. P., AND E. M. CHACE
1919. An unreported exposure of the San Pedro Pleistocene. Lorquinia, California, vol. 2, pp. 41–44.

CRICKMAY, C. H.
1929. The anomalous stratigraphy of Deadman's Island, California. Jour. Geol., vol. 37, pp. 616–638, 1 table.

DALL, WILLIAM HEALEY
1918. Pleistocene fossils of Magdalena Bay, Lower California, collected by Charles Russell Orcutt. Nautilus, vol. 32, pp. 23–26.
1921a. New fossil invertebrates from San Quentin Bay, Lower California. West Amer. Scientist, vol. 19, no. 2, pp. 17–18.
1921b. New shells from the Pliocene or early Pleistocene of San Quentin Bay, Lower California. *Ibid.*, vol. 19, no. 3, pp. 21–23.
1921c. Summary of the marine shellbearing mollusks of the northwest coast of America, from San Diego, California, to the Polar Sea, mostly contained in the collection of the United States National Museum, with illustrations of hitherto unfigured species. Bull. U. S. Natl. Mus., no. 112, pp. 1–217, 22 pls.

DAWSON, E. YALE
1951. A further study of upwelling and associated vegetation along Pacific Baja California, Mexico. Jour. Marine Res., vol. 10, pp. 39–58, 6 figs.
1952. Circulation within Bahia Vizcaino, Baja California, and its effects on marine vegetation. Amer. Jour. Bot., vol. 39, pp. 425–432, 5 figs.

DELONG, JAMES H., JR.
1941. The paleontology and stratigraphy of the Pleistocene at Signal Hill, Long Beach, California. Trans. San Diego Soc. Nat. Hist., vol. 9, pp. 229–252, 4 figs., 1 chart.

DURHAM, J. WYATT
1950a. Cenozoic marine climates of the Pacific coast. Bull. Geol. Soc. Amer., vol. 61, pp. 1243–1264, 3 figs.
1950b. 1940 E. W. Scripps cruise to the Gulf of California. Pt. II. Megascopic paleontology and marine stratigraphy. Mem. Geol. Soc. Amer., no. 43, pp. 1–216, 48 pls.

DURHAM, J. WYATT, AND J. LAURENS BARNARD
1952. Stony corals of the eastern Pacific collected by the Velero III and Velero IV. Allan Hancock Pacific Expedition. Los Angeles, vol. 16, pp. 1–110, 16 pls.

ELLIS, ARTHUR J.
1919. Physiography. *In* Ellis, Arthur J., and Charles H. Lee, Geology and ground waters of the western part of San Diego county California. U. S. Geol. Surv., Water-Supply Paper, no. 446, pp. 20–50, 2 pls.

EMERSON, WILLIAM K.
1952. The influence of upwelling on the distribution of marine floras and faunas of the west coast of Baja California, Mexico. (Abstract.) Ann. Rept. Amer. Malacol. Union, pp. 32–33.
1953. Neo-ecology, paleontology and marine mollusks. (Abstract.) *Ibid.*, pp. 26–27.
1956. Upwelling and associated marine life along Pacific Baja California, Mexico. Jour. Paleont., vol. 30, pp. 393–397, 1 fig.

EMERSON, WILLIAM K., AND WARREN O. ADDICOTT
1953. A Pleistocene invertebrate fauna from the southwest corner of San Diego County, California. Trans. San Diego Soc. Nat. Hist., vol. 11, pp. 429–444, 1 map.

GARTH, JOHN S.
1955. The case for a warm-temperate marine fauna on the west coast of North America. Essays in the natural sciences in honor of Captain Allan Hancock on the occasion of his birthday July 26, 1955. Los Angeles, University of Southern California Press, pp. 19–27.

GRANT, U. S., IV, AND HOYT RODNEY GALE
1931. Catalogue of the marine Pliocene and Pleistocene Mollusca of California, and adjacent regions. Mem. San Diego Soc. Nat. Hist., vol. 1, pp. 1–1036, 32 pls.

HANNA, MARCUS A.
1926. Geology of the La Jolla Quadrangle, California. Univ. California Publ., Bull. Dept. Geol. Sci., vol. 16, pp. 187–246, 7 pls., 1 map.

HERTLEIN, LEO GEORGE
1931. Additional Pliocene and Pleistocene fossils from Lower California. Jour. Paleont., vol. 5, pp. 365–367.
1934. Pleistocene mollusks from the Tres Marias Islands, Cedros Island, and San Ignacio Lagoon, Mexico. Bull. Southern California Acad. Sci., vol. 33, pp. 59–73, 1 pl.

HERTLEIN, LEO GEORGE, AND WILLIAM K. EMERSON
1956. Marine Pleistocene invertebrates from near Puerto Peñasco, Sonora, Mexico. Trans. San Diego Soc. Nat. Hist., vol. 12, pp. 154–176, pl. 12, 2 maps.

HERTLEIN, LEO GEORGE, AND U. S. GRANT, IV
1939. Geology and oil possibilities of southwestern San Diego County. California Jour. Mines and Geol., vol. 35, pp. 57–78, 8 figs.
1944. The geology and paleontology of the marine Pliocene of San Diego, California. Part 1, Geology. Mem. San Diego Soc. Nat. Hist., vol. 2, pp. 1–72, 6 figs., 18 pls., 1 map.

HERTLEIN, LEO GEORGE, AND A. M. STRONG
1943. Eastern Pacific expeditions of the New York Zoological Society. XXXII. Mollusks from the west coast of Mexico and Central America. Part II. Zoologica, New York Zool. Soc., vol. 28, pp. 149–168, 1 pl.
1947. [Same title.] XXXVI. [Same title.] Part V. *Ibid.*, vol. 31, pt. 4, pp. 129–150, 1 pl.
1948. [Same title.] XXXIX. [Same title.] Part VI. *Ibid.*, vol. 33, pt. 4, pp. 163–198 2 pls.
1955. Marine mollusks collected during the "Askoy" expedition to Panama, Colombia, and Ecuador in 1941. Bull. Amer. Mus. Nat. Hist., vol. 107, pp. 159–318, 3 pls.

HEWATT, WILLIS G.
1946. Marine ecological studies on San Cruz Island, California. Ecol. Monogr., vol. 16, pp. 185–210, 2 figs.

HUBBS, CARL L.
1948. Changes in the fish fauna of western North America correlated with changes in ocean temperature. Jour. Marine Res., vol. 7, pp. 459–482, 6 figs.

JORDAN, ERIC KNIGHT
1924. Quaternary and Recent molluscan faunas of the west coast of Lower California. Bull. Southern California Acad. Sci., vol. 23, pp. 146–156.
1926. Molluscan fauna of the Pleistocene of San Quintin Bay, Lower California. Proc. California Acad. Sci., ser. 4, vol. 15, pp. 241–255, 1 fig., 1 pl.
1936. The Pleistocene fauna of Magdalena Bay, Lower California. Contrib. Dept. Geol. Stanford Univ., vol. 1, pp. 101–173, 3 pls. (With an introduction by Leo George Hertlein.)

KEEN, A. MYRA
1937. An abridged check list and bibliography of west North American marine Mollusca. Stanford, California, Stanford University Press, 84 pp., 3 figs.
1954. Five new species and a new subgenus in the pelecypod family Cardiidae. Bull. Amer. Paleont., vol. 35, no. 153, pp. 1–24, 1 pl.

LINDGREN, W.
1888. Notes on the geology of Baja California, Mexico. Proc. California Acad. Sci., ser. 2, vol. 1, pt. 2, pp. 173–196.

MCEWEN, GEORGE F.
1916. Summary and interpretation of the hydrographic observations made by the Scripps Institution for Biological Research of the University of California 1908–1915. Univ. California Publ. Zool., vol. 15, pp. 255–356, 38 pls.

MANAR, T. A., (ED.)
1953. Progress report, California cooperative oceanic fisheries investigations, 1 July 1952–30 June 1953. Terminal Island, California, California State Fisheries Laboratory, pp. 1–44, 31 figs.

MANGER, G. EDWARD
1929. Some Pleistocene mollusks of San Quintin Bay and other localities from Lower California. (Abstract.) Balti-

more, The Johns Hopkins University, May 1, 1929. (Summary of dissertation.)
1934. The geology of San Quintin Bay. Johns Hopkins Univ. Studies Geol., no. 11, pp. 273–303, 1 pl.

MASON, HERBERT L.
1934. Pleistocene flora of the Tomales formation. Publ. Carnegie Inst. Washington, no. 415, pp. 81–179, 1 fig., 11 pls.

MASSEY, WILLIAM C.
1947. Brief report on archaeological investigations in Baja California. Southwestern Jour. Anthrop., vol. 3, pp. 344–359, 2 figs.

ORCUTT, C. R.
1921a. Paradise lost. West Amer. Scientist, vol. 19, no. 2, pp. 18–20.
1921b. Pleistocene beds of San Quintin Bay, Lower California. *Ibid.*, vol. 19, no. 3, pp. 23–24.

ORCUTT, C. R., AND W. H. DALL
1885. Notes on the mollusks of the vicinity of San Diego, Cal., and Todos Santos Bay Lower California. Proc. U. S. Natl. Mus., vol. 8, pp. 534–552, 1 pl.

PALMER, ROBERT H., AND LEO GEORGE HERTLEIN
1936. Marine Pleistocene mollusks from Oaxaca, Mexico. Bull. Southern California Acad. Sci., vol. 35, pt. 2, pp. 65–80, 1 pl.

SANTILLÁN, MANUEL, AND TOMÁS BARRERA
1930. Las posibilidades petrolíferas en la costa occidental de la Baja California, entre los paralelos 30° y 32° de latitud norte. An. Inst. Geol. Mexico, vol. 5, pp. 1–37, 12 figs.

SMITH, ALLYN G.
1947. Chitons covering the families Lepidopleuridae and Lepidochitonidae. Minutes Conchol. Club Southern California, no. 66, pp. 3–16.

SMITH, JAMES PERRIN
1919. Climatic relations of the Tertiary and Quaternary faunas of the California region. Proc. California Acad. Sci., ser. 4, vol. 9, pp. 123–173, 1 pl.

STEPHENS, FRANK
1929. Notes on the marine Pleistocene deposits of San Diego County, California. Trans. San Diego Soc. Nat. Hist., vol. 5, pp. 245–256, 1 fig.

STOKES, WILLIAM LEE
1955. Another look at the ice age. Science, vol. 122, no. 3174, pp. 815–821, 1 fig.

SVERDRUP, H. U., AND W. E. ALLEN
1939. Distribution of diatoms in relation to the character of water masses and currents off southern California in 1938. Jour. Marine Res., vol. 2, pp. 131–144, 12 figs.

VALENTINE, JAMES W.
1955a. Ecologic requirements and depositional environments of Pleistocene molluscan faunas from southern and Baja California. (Abstract.) Jour. Paleont., vol. 28, no. 6, p. 881.
1955b. Upwelling and thermally anomalous Pacific coast Pleistocene molluscan faunas. Amer. Jour. Sci., vol. 253, pp. 462–474.
1956. Upper Pleistocene Mollusca from Potrero Canyon, Pacific Palisades, California. Trans. San Diego Soc. Nat. Hist., vol. 12, pp. 181–205, pl. 13, 1 map.

WALTON, WILLIAM R.
1955. Ecology of living benthonic Foraminifera, Todos Santos Bay, Baja California. Jour. Paleont., vol. 29, pp. 952–1018, 24 figs., 6 pls.

WEAVER, CHARLES
1949. Geology of the coast ranges immediately north of the San Francisco Bay region, California. Mem. Geol. Soc. Amer., no. 35, pp. i–ix, 1–242, 10 pls.

WEBB, ROBERT W.
1937. Paleontology of the Pleistocene of Point Loma, San Diego County, California. Trans. San Diego Soc. Nat. Hist., vol. 8, pp. 337–348.

WILLETT, GEORGE
1937. An upper Pleistocene fauna from the Baldwin Hills, Los Angeles County, California. Trans. San Diego Soc. Nat. Hist., vol. 8, pp. 379–406, 2 pls.

WILSON, IVAN F.
1948. Buried topography, initial structures, and sedimentation in Santa Rosalía area, Baja California, Mexico. Bull. Amer. Assoc. Petrol. Geol., vol. 32, pp. 1762–1807, 12 figs.

WOODRING, W. P.
1935. Fossils from the marine Pleistocene terraces of the San Pedro Hills, California. Amer. Jour. Sci., ser. 5, vol. 29, pp. 292–305, 1 fig.
1951. Basic assumption underlying paleoecology. Science, vol. 113, no. 2939, p. 482.

WOODRING, W. P., M. N. BRAMLETTE, AND W. S. W. KEW
1946. Geology and paleontology of Palos Verdes Hills, California. U. S. Geol. Surv. Prof. Paper, no. 207, pp. 1–145, 14 figs., 37 pls.