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LATE PLEISTOCENE INVERTEBRATES OF THE NEWPORT BAY AREA, CALIFORNIA

By George P. Kanakoff and William K. Emerson

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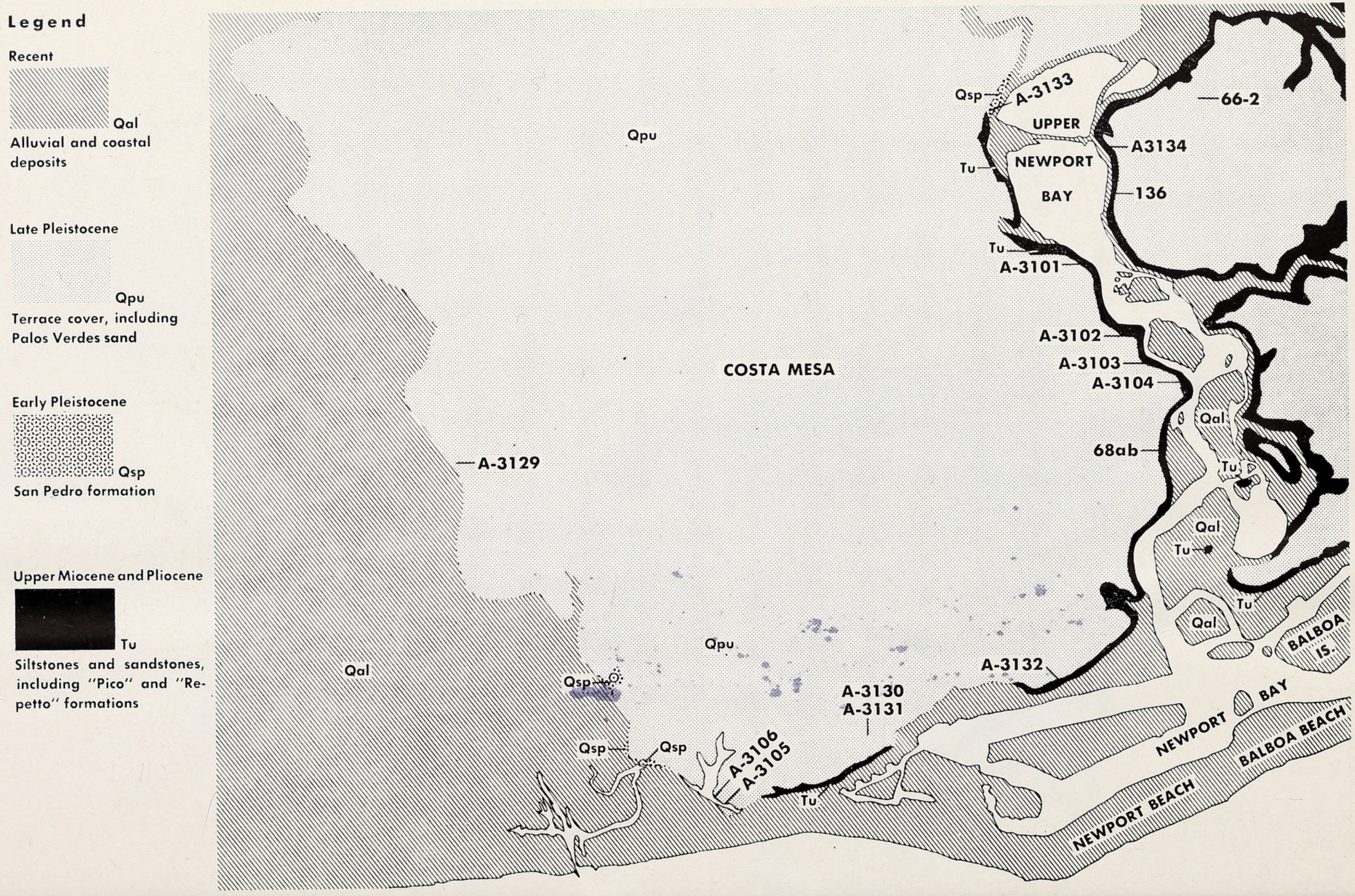
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LATE PLEISTOCENE INVERTEBRATES OF THE NEWPORT BAY AREA, CALIFORNIA

By George P. Kanakoff[1] and William K. Emerson[2]

INTRODUCTION

This paper records late Pleistocene metazoan invertebrates from three localities near Newport Bay, Orange County, California. The fauna is discussed in terms of the known Quaternary history of the southern California district, and paleoecological interpretations are undertaken based on a collected assemblage of 496 species, mostly mollusks, from the lowest exposed terrace of the San Joaquin Hills and the Newport Mesa. Vertebrates previously recorded from this area (see p. 8) number at least 40 species. The fauna is the largest assemblage of megafossils thus far reported from western America. The terrace fauna is considered to be essentially an equivalent of the fauna of the Palos Verdes sand, and the date of platform cutting and age of the associated marine deposits are inferred to be post-early Pleistocene, probably ad-Wisconsin stage.

This study was initiated in the spring of 1940 when Mr. and Mrs. F. L. Grouard of Santa Ana, California, brought to the attention of the senior author a small number of Pleistocene mollusks from the premises of the Irvine Estate, north of Newport Bay. A new record for the Pleistocene of California and a new species were contained in this collection. This prompted the senior author to visit the region the following year and make additional collections from several localities on the Newport Mesa and from the cliff across Newport Bay fringing the north side of the San Joaquin Hills. As these collections contained new records for the late Pleistocene faunas of the Los Angeles basin, including several new species, subsequent visits to the Newport area were made and several hundred pounds of screenings were obtained, sorted and identified. World War II interrupted the senior author's studies, but the late George Willett completed the sorting and identification of the collections from two of the collecting localities. From this material, Willett (1944) described two new pelecypods,[3] and four new gastropods[4] were later described in a posthumously published paper (Willett, 1948).

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[1]Los Angeles County Museum, Los Angeles 7, California.
[2]American Museum of Natural History, New York 24, New York.
[3]*Cardita hilli* and *Chione picta.*
[4]*Turbonilla* (*T.*) *grouardi, Odostomia* (*Menestho*) *effiae, O.* (*Chrysallida*) *elsiae,* and *Triphora kanakoffi.*

←

Fig. 1. Map of the Newport Bay area showing fossil collecting localities of Bruff (1946), those preceded by A, and the present report (base and geology after Poland and Piper, 1956, pl. 3). According to Vedder *et al.* (1957) the Tertiary rocks designated as "Tu" should include the middle Miocene "Monterey shale" or Puente formation.

Upon his return to the Museum in 1945, the senior author was encouraged by the late Dr. Chester Stock to make a series of weekly collecting trips to the area which resulted in the procuring of a large collection from more than 15 exposures in the terrace deposits. One particular site (Los Angeles County Museum Invertebrate Paleontology locality 66-2),[5] exposed in a gully cut into the terrace surface on the northwest side of the San Joaquin Hills, was found to be especially rich. Here a 21-foot thick pocket of sediments, overlying the conglomerate resting on the terrace platform, was entirely removed and the sediment screened (Fig. 4). This site yielded an abundance of vertebrate remains, including fish, bird and mammal bones, numerous invertebrates, and even plant remains. Several papers resulting from the study of the vertebrate elements of these collections have been published, see page 8. Additional studies of the large collection of mammal material are being continued by Dr. Theodore Downs, Curator of Vertebrate Paleontology of the Los Angeles County Museum. The only reptilian remains found were plastron fragments of a large turtle.

Owing to the vast number of invertebrates collected, only the material taken from two sites, one from each side of Newport Bay, are included in the present study. These include the one previously mentioned from the southeastern side of the bay, locality 66-2, and one from the northwestern part of the bay, localities 68-A and 68-B. In order to give an indication of the abundance of the molluscan elements of the fauna, the number of every constituent collected at each locality was carefully noted by the senior author and is recorded for each species in the faunal list below.

The senior author has briefly discussed the fauna (Kanakoff, 1948; 1950) and has described a new species of gastropod, (*Diodora constantiae*, Kanakoff, 1953).

Owing to the senior author's preoccupation with other duties, the junior author was invited to collaborate in the preparation of this paper. In 1958, he accompanied the senior author on a reconnaissance of the area and later visited the region in the company of Dr. Warren O. Addicott of the General Petroleum Company of Los Angeles. The junior author is largely responsible for preparing this paper for publication.

The project could have not been completed without the assistance of a number of people. We are greatly indebted to the following for various kinds of aid: Mr. and Mrs. F. L. Grouard, Mr. W. B. Willis, Mr. Edgerton B. Sprague, Miss Arminta Neal, Mr. and Mrs. David Packard, Mrs. Eleanor McLauchlan, Mr. and Mrs. Robert Zava and Mr. and Mrs. Harry R. Turver. In addition to the late George Willett, Drs. Leo George Hertlein, S. Stillman Berry, Mr. Allyn G. Smith, and the late A. M. Strong collaborated with the senior author in the identification of certain of the molluscan constituents of the fauna. Mr. Robert G. Thomas determined the elevations of the fossil localities by leveling. The Director of

[5]L.A.C.M.I.P. localities are hereafter referred to as localities 66-2, 68-A, and 68-B.

the Allan Hancock Foundation of the University of Southern California permitted us to use two line cuts (figures 2 and 3 of this report) from the Foundation's "Occasional Papers" series, Number 20 (Stevenson and Emery, 1958).

Dr. Warren O. Addicott, Dr. Hildegarde Howard, and Mr. John G. Vedder kindly read the manuscript and offered helpful suggestions. Any errors of commission or omission, however, remain the responsibility of the authors.

PREVIOUS PALEONTOLOGICAL STUDIES

Passing mention of the presence of late Pleistocene megascopic invertebrates in the Newport Bay area has been made by a number of writers, but faunal lists have appeared in only two previously published papers. Arnold (1903, p. 56) listed a total of 21 species of mollusks from the Newport Mesa (Costa Mesa) and considered the assemblage to be equivalent to the "Upper San Pedro series." These records, together with

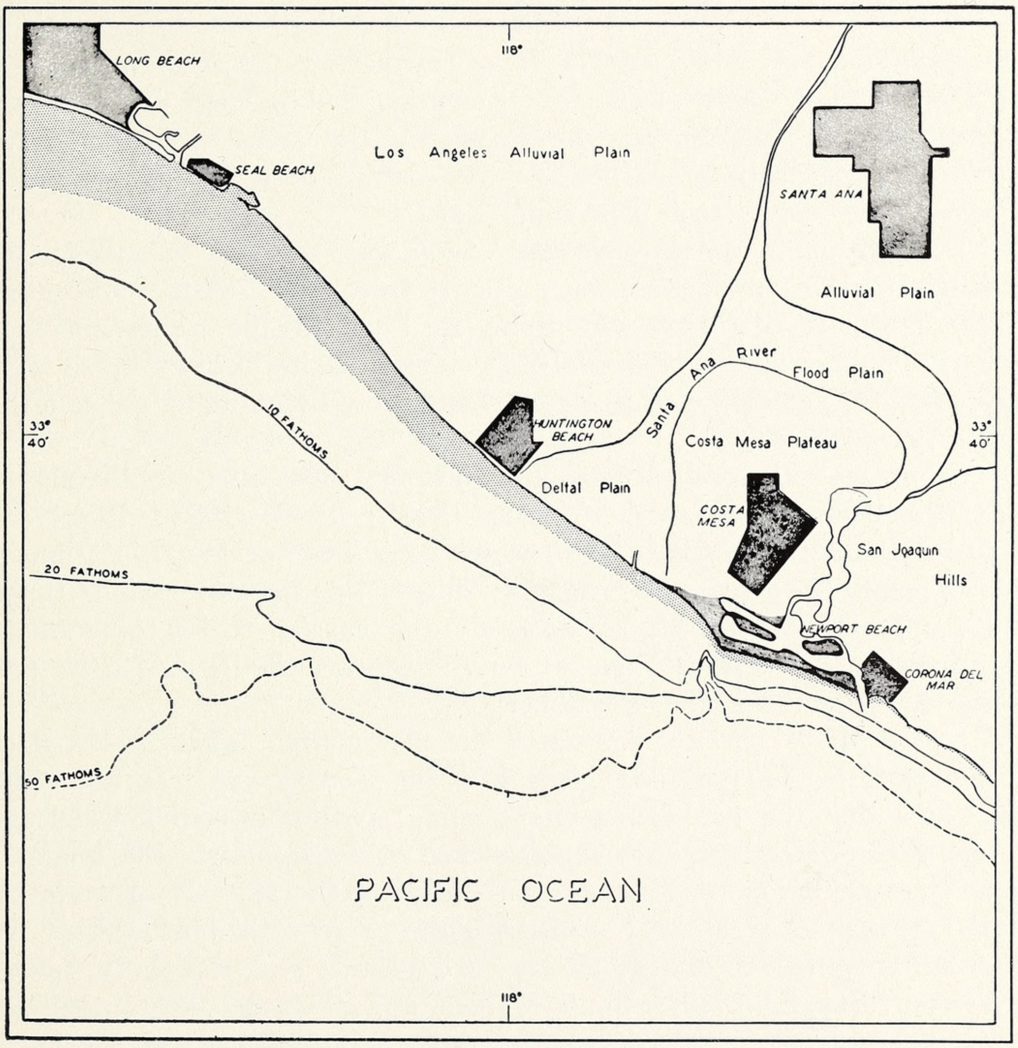

Fig. 2. A chart showing the coastal region of southern California from Long Beach to Corona Del Mar (after Stevenson and Emery, 1958, fig. 8).

additional species noted in various collections, were included in the valuable compilation of Grant and Gale (1931).

Bruff (1940) completed a study of the Pleistocene history of the Newport Bay area and shortly thereafter published an important contribution on the paleontology of this invertebrate fauna (Bruff, 1946). He recorded a total of 169 taxa, chiefly species of marine mollusks, from 10 localities on the Newport Mesa and one locality on the lowest terrace on the north side of the San Joaquin Hills. Bruff believed the deposits to be equivalent to the "Palos Verdes sands" of the San Pedro area. He concluded the Pleistocene hydroclimate to have been warmer by approximately 3.4° F. than that of the present littoral, near-shore waters of this latitude. Two predominant types of habitats were recognized: protected rocky shores and bay-estuaries with rocky, sandy and muddy bottoms. A depth of more than 60 feet was postulated over the western part of Newport Mesa area (Costa Mesa), becoming shallower with the deposition of marine sediments on the terrace platform.

Poland *et al.* (1956, p. 54), in a study of the ground-water geology of the region, cited Arnold's (1903) list of fossils from the area and reported the conclusion of George Willett, based on his study of part of the present collections, that this fauna was essentially the same age as the one previously described by Willett (1937) from "upper Pleistocene beds (Palos Verdes sand) near Playa del Rey."

In addition to the invertebrates, numerous remains of marine and terrestrial vertebrates have been reported from late Pleistocene deposits of the Newport Bay area. Mr. John E. Fitch of the California State Fisheries Laboratory recognized 16 species of marine fishes from locality 66-2 (Kanakoff, 1956). All are extant forms now living along the southern California coast.

From several localities in the Newport Bay area, including the present collections, Howard (1948a; 1948b; 1949; 1955; 1958) has recorded 18 species of birds, all of which could have occurred in a marine environment. Of these, two (possibly three) species are extinct forms, and the others are known to occur in the coastal region of southern California at the present time, or within geologically Recent time (two are known only from kitchen middens).

Lance (1948) briefly compared the mammalian fauna of the Palos Verdes sand of Newport Bay Mesa with the Rancho La Brea fauna and concluded that the two faunas have some species in common, but the former differs strikingly by: the presence of *Tanupolama*, the relatively better representation of *Tapirus* and the apparent absence of mylodont sloths.[6] Savage *et al.* (1954) mentioned the presence of land and marine birds and mammals in marine (Palos Verdes sand) and near-shore deposits at Newport Bay, San Pedro, Santa Monica, and Playa del Rey. In addition

[6]Dr. Theodore Downs reports (*in literis*) the previously unrecorded occurrence of *Nothrotherium, Megalonyx* and *Bison* from the Newport Bay deposits, locality 66-2.

to marine inhabitants, they record such land dwellers as ground sloths, horses, tapirs, camels, bisons, mammoths, and several terrestrial birds, and suggest that the presence of *Bison* indicates a Rancholabrean age for these faunas.

REGIONAL PLEISTOCENE SEDIMENTS

Newport Bay is bordered by the San Joaquin Hills to the southeast and Newport Mesa to the north and northwest (see Fig. 2). The fauna enumerated in this paper occurs in deposits on the lowest emergent, wave-cut terrace on the bay side of the San Joaquin Hills and from correlative sediments capping Newport Mesa on the northern side of the Bay. In order to discuss the Newport fauna in terms of the known Quaternary history of the western border of the Los Angeles basin, it is necessary to describe briefly the present topography and the post-Pliocene sediments of this region.

The Los Angeles basin is bordered by the Santa Monica mountains to the northwest and by a succession of hills and mountains to the north and east. The coastal plain is interrupted by several gaps, which divide the region into a series of low hills and mesas of irregular configuration, and by a high headland, the Palos Verdes hills, situated about mid-way along the coastal margin of the Basin. Tongues of the central plain extend to the coast through six prominent lowlands cut largely by streams through the mesas and between the hills of the Newport-Inglewood belt. Newport Mesa, separated by the Santa Ana Gap and Newport Bay, is the most southeasterly of these coastal mesas.

Off shore, five major submerged platforms have been recognized on the mainland shelf, the off-shore island shelves, and the bank tops of the continental borderland. These have been interpreted as erosional marine terraces cut during times of lower stands of the Pleistocene sea, possibly during Wisconsin time (Emery, 1958).

The low hills and coastal mesas along the Newport-Inglewood structural zone are capped by largely unconsolidated sediments, interfingering beds of sand, gravel, silt and clay of Pleistocene age, which underlie Recent deposits and overlie late Pliocene or older rocks. The Pleistocene beds attain a maximum thickness of about 1000 feet along the coast and of approximately 3000 feet inland beneath the Downey Plain. Three distinct units have been recognized: 1, Palos Verdes sand, late Pleistocene, 2, unnamed late Pleistocene deposits, and 3, San Pedro formation, early Pleistocene.

The basal San Pedro formation, the thickest unit of the three beds, outcrops on Newport Mesa only on the southwest edge of the mesa and near the head of Newport Bay. On the basis of subsurface data from core samples, it appears to underlie the mesa northward from these two exposures, and dips gently northward.

From logs of wells near Dominguez Hill and Wilmington, Poland *et al.* (1956, p. 55) recognized certain strata that occur between definite or probable correlatives of the Palos Verdes sand and the San Pedro formation and referred to them as "unnamed upper Pleistocene deposits." The contact, however, between this unnamed deposit and the overlying Palos Verdes sand has not been discovered in outcrop, and this deposit is not present at least on the southeastern part of Newport Mesa as the Palos Verdes sand bevels rock of Miocene and Pliocene age. Poland *et al.* (1956) consider the unnamed late Pleistocene beds to be, at least in part, correlative with deposits on the twelve older terraces of the Palos Verdes hills. This suggests a possible correlation of these beds with the deposits on older terraces of the San Joaquin Hills and with some of the older terrace deposits occurring elsewhere along the coast.

A thin layer of locally fossiliferous gray sand and gravel outcrops beneath the surface at various places on the hills, mesas and plains along the Newport-Inglewood belt. These sediments were originally described in part by Arnold and Arnold (1902) and designated the "Upper San Pedro Series" with the type locality at the "lumber yard" exposure at San Pedro (Arnold, 1903). Woodring *et al.* (1946) formally defined the unit and restricted the name "Palos Verdes sand" to the marine deposits on the lowest terrace of Arnold's "Upper San Pedro Series." In addition to the type area, similar terrace deposits in the Los Angeles basin, ranging from Santa Monica in the north to Newport Bay in the south, were presumed to be essential equivalents of the Palos Verdes sand. The apparent correlation of these beds was largely based on the presence of a warm-water fauna deposited on the lowest emergent terrace platform which bevels formations ranging in age from early Pleistocene to Miocene. In the type area the formation ranges in thickness from a few inches to about 15 feet. Exposures elsewhere in the basin, in regions which have undergone strong structural deformation, attain a maximum thickness of nearly 90 feet.

A characteristically reddish-brown colored, non-fossiliferous sand caps the highlands and plains of the Newport-Inglewood structural belt. The terrace cover generally overlies the Palos Verdes sand or locally rests directly on the terrace platform to form the present land surface. Although the cover appears to be largely alluvial or slope wash, the thinner coastal veneer locally is composed of weathered wind-blown beach sand and coastal dune and bay-lagoon deposits.

NEWPORT BAY AREA

Topography

The Newport "valley" forms a deeply incised canyon between Newport Mesa and the base of the San Joaquin Hills (fig. 3). As this trench cuts through the mesa and separates it from the lowest terrace on the San Joaquin Hills, it is the seventh and most southerly situated coastal gap in the Newport-Inglewood structural belt. According to Poland *et al.* (1956, p. 28) the canyon extends approximately 6 miles inland, is 0.2 to 0.8 miles wide, about 115 feet in greatest depth near the coast, but shallows to 20 feet at its head. The inland arm of the present bay occupies the southwestern part of the canyon.

Newport Mesa is approximately 100 feet in elevation near the present sea cliff and dips about 20 feet in a mile to pass beneath the central Downey Plain at an altitude of about 30 feet above sea level (Poland, *et al.*, 1956). The mesa faces the Santa Ana River to the northwest, the

Fig. 3. Aerial photo-mosaic showing the Newport Bay area, from Costa Mesa to Corona Del Mar (after Stevenson and Emery, 1958, fig. 1).

inner Newport Bay on the southeast and the barrier beach of Newport Beach on the southwest. The mesa terminates in river-cut bluffs approximately 100 feet in elevation facing the Santa Ana Gap and the present channel of inner Newport Bay, but a sea-cut cliff borders the lagoon and the oceanfront on the west side.

The San Joaquin Hills, viewed from the northwest, rise in a series of five marine terraces with elevations of about 100, 200, 300, 600, and 900 feet above present sea level (Poland *et al.*, 1956). The two lower terraces are the broadest and best preserved. The older terraces have been largely destroyed by erosion. The lowest terrace, which contains fossiliferous deposits and is at about the same elevation as the Newport Mesa, extends inland and is covered by the coastal margin of the central Downey Plain.

Pleistocene Geology

Sand, gravel and conglomerate referable to the Palos Verdes sand cover the peneplained-surface of the Newport Mesa and veneer the platform of the lowest terrace on the bordering San Joaquin Hills. This formation is in turn largely capped with brownish-red silty sand and a thin surface layer of reddish colored soil.

The formation is thinnest along the end of the mesa facing the western part of the Inner Bay Channel, where the sediments average 10 to 15 feet thick and rest with a marked angular unconformity on Miocene rocks of the Monterey shale.[7] The underlying rocks that crop out along the upper bay channel are apparently of Pliocene age and have been referred, in part, to the Capistrano and an unnamed formation. Miocene and Pliocene rock are exposed near the base of the cliff inside the entrance of the Inner Bay and along the southwestern face of the mesa, respectively. Along most of the ocean front Tertiary strata are not exposed in the sea cliff and the Pleistocene sediments attain a maximum exposed thickness of 90 feet.

The essentially flat-lying Pleistocene beds parallel the irregular surface bevelled off the folded Tertiary rocks which have a 4 to 5 degree northwest dip. As the overlying Pleistocene beds dip approximately 3 degrees northwesterly, the difference in dips at the contact explains the thickening of the covering sediments toward the northwest (Bruff, 1946, p. 217). Also, the central part of the Los Angeles basin presumably filled rapidly with sediments causing depression in that region with subsequent thickening of sediments basinward (Woodford *et al.*, 1954, p. 74).

Newport Mesa extends across the upper end of the Inner Bay, interrupted locally by the drainage system, and continues as the cover on the lowest terrace platform of the San Joaquin Hills. The surfaces of the wave-cut terrace and of the Mesa are at approximately the same 100-

[7]The formational names of the Tertiary sediments follow the nomenclature of Vedder *et al.* (1957).

foot elevation. The thin veneer of Palos Verdes sediments covering the terrace platform, however, is about 12 to 20 feet thick in places (localities 66-2, 66-10). The Pleistocene sediments rest on the terrace platform cut into the Miocene and Pliocene rocks, the contact being at an elevation of 60 to 65 feet near the base of the old sea cliff of the terrace.

Although the fossiliferous sediments are mostly gray, fine to coarse sands, the largely non-fossiliferous, buff-colored, silty sands are more abundant. Some sandy lenses show cross-bedding. Fossils occur chiefly in beds of poorly sorted, largely unconsolidated sands resting on basal conglomerates or directly on the platform in the absence of the conglomerates. The lenticular conglomeratatic beds, composed of pebbles and cobbles, are, however, not limited in distribution to the surface of the terrace platform and the fossils are scattered irregularly throughout most of the beds (Bruff, 1946).

Bruff (1946, p. 219) believed the 1 to 10 feet of brownish-red sandy clay, capping the marine deposits on the Mesa platform and the lowest terrace, to be part of the Palos Verdes formation. He states that fossils occur occasionally throughout this "member" as the result of a minor change in facies. The cover, however, has not been demonstrated to be entirely of marine origin and the fossils may have been reworked from previously deposited beds. The presence in this area of numerous Recent invertebrates from kitchen midden sites further confuses the problem. Inasmuch as Woodring *et al.* (1956, p. 56) restricted the Palos Verdes sand to include only marine deposits, it is convenient, for the present time, to consider the uppermost beds as non-marine cover. These, at least in part, probably date from Wisconsin time to present.

PLEISTOCENE HISTORY

The late Pleistocene history of this area was discussed in some detail by Bruff (1946). As was characteristic of the views held at the time of his investigation, Bruff ascribed the emergence of the Mesa to its present height to tectonic uplift rather than to eustatic change in sea level, or to a combination of these phenomena. The evolution of Newport Bay was more recently interpreted by Stevenson and Emery (1958, p. 10).

Bruff postulated that the antecedent Santa Ana River carved the Newport Bay "valley" before the Palos Verdes sand was deposited. He believed that Palos Verdes sediments completely filled the "valley" and were subsequently removed by erosive action of the river. His conclusions were largely based on the local thickening of deposits along the face of the present cliffs of the bay channel (Bruff, 1946, figs. 8, 10, 12).

Stevenson and Emery (1958, p. 10, fig. 16) ascribed the cutting of the bay channel to the erosive action of the Santa Ana River and other streams during the "middle of the Pleistocene," at a time when "sea level was more than 100 feet lower than today." They suggested that the upper portion of the Newport Submarine Canyon (see Fig. 2) may have been carved during this period of emergence, but admitted that it could have been cut during a prior or subsequent emergence. From data obtained from drill holes, they recorded the bottom of the Santa Ana River bed to be a maximum of 123 feet below present sea level.

The available geologic evidence, however, does not conclusively date the inner bay channel as a pre-Palos Verdes feature. As John G. Vedder has pointed out (*in literis*), some of Bruff's supposedly isolated deposits of Palos Verdes sand in the cliff face of the present bay channel are displaced slump-blocks and, moreover, there is no evidence that these sediments are present in the channel below present sea level. Furthermore, the "valley" more likely originated as a submarine canyon during early Palos Verdes time and the cutting of the inner channel to a depth of more than 100 feet below the present sea level probably occurred in Wisconsin time. Although this interpretation is only one of several possibilities, it would appear to be a more plausible explanation for the origin of the "valley" and the incised channel.

Regardless of the phenomena involved in the evolution of the "valley," a rise in sea level is indicated in Palos Verdes time by the occurrence of marine fossils in the sediments veneering the Mesa platform and in the correlative deposits on the lowest terrace of the San Joaquin Hills.[8] On the basis of the composition of these fossil assemblages, Stevenson and Emery (1958, fig. 17) believed the Mesa to have been an island during "Upper-most Pleistocene" time and the marine inundation to have extended seven to ten miles inland. The existence of a large mesa-island in late Palos Verdes time is not corroborated by the geologic evidence. Although small islands may have resulted from the inundation of the subaerially eroded surface of the coastal region during early Palos Verdes time, the entire Newport Mesa area was eventually covered by the marine sediments as indicated by the subsurface data (Poland *et al.*, 1956). Therefore, by the close of Palos Verdes time, the Mesa was covered by shallow water, and the lowest terrace was cut into the exposed slopes of the San Joaquin Hills. This terrace apparently extended as a continuous coastal plain northeastward to include the presently interrupted Huntington Beach and Bolsa Chica Mesas (Poland *et al.*, 1956). The terrace also extended southward along the coast for some distance. It was mapped by Vedder *et al.* (1957) as a correlative unit as far south as San Clemente, and continues nearly uninterruptedly to the vicinity of Encinitas, north of Escondido Creek.

At the close of Palos Verdes time, the now very shallow embayment apparently became locally confined by the accumulation of marine and continental sediments and the development of temporary bars and spits that produced large back-bay lagoons. With the advent of the Wisconsin epoch, the emergent mesa was mantled with alluvial and eolian cover and extensively eroded. The channel of the Inner Bay was largely cleared of bay-fill, presumably by the erosive action of the Santa Ana River or

[8]An eustaticly controlled rise in sea level is assumed, but in a tectonicly active area such as the Los Angeles Basin, tectonic uplift of some degree also may be involved.

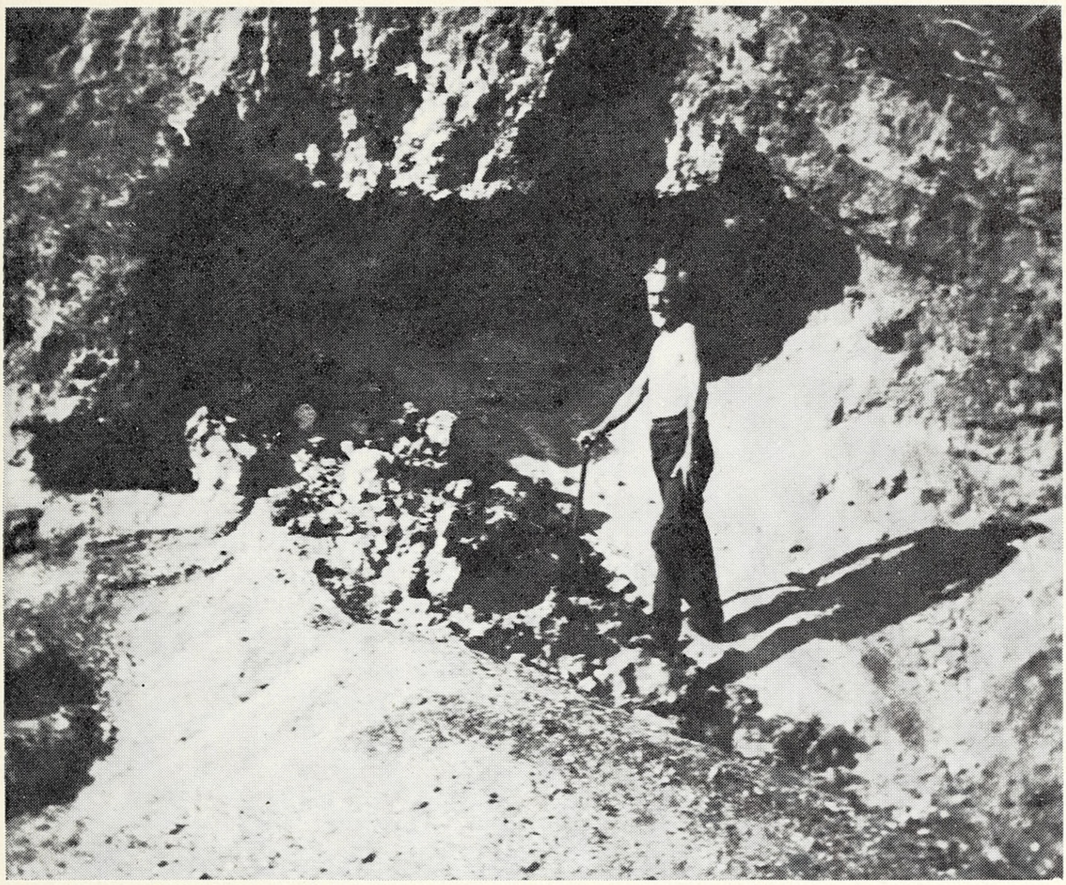

Fig. 4. Excavation site at locality 66-2; senior author removing overburden from the exposure after a minor land slide (photograph by Arminta Neal).

other streams. The subsequent rise in sea level in late Wisconsin and Recent time, together with subaerial forces of erosion, has largely produced the present topography of this area (Fig. 3).

COLLECTING LOCALITIES

Invertebrates were collected by the senior author from more than fifteen exposures in the area. This study is limited to three especially rich collections, two from localities on the southwestern edge of Newport Mesa (68-A and 68-B) and one from the terrace deposits on the opposite side of the Inner Bay, near the air field (66-2). Reference is also made to the faunal lists of Bruff (1956, pp. 232-334) representing 10 localities on the Mesa and one on the terrace.[9] The collecting stations are indicated on the locality map, Fig. 1.

The following descriptions are taken from the senior author's field notes: Locality 66-2 (Latitude 33° 38′ 37″ N., Longitude 117° 52′ 37″ W.). The exposure occurs in a north-facing erosion channel cut into the surface of the terrace a short distance from the base of the next terrace (Figs. 4 and 5). Fossils were excavated from a rich horizon immediately

[9]Bruff's locality A-3133 from the northeastern edge of the Mesa is not considered, for it appears to be from an exposure of sediments older than Palos Verdes sand.

above a 1 to 2-foot basal conglomerate overlying Pliocene rocks. In this area, the Palos Verdes sand was estimated to be 20-36 feet thick and to be covered by 8 to 15 feet of alluvium.

The stratigraphic section exposed at locality 66-2 above the angular unconformity between the Palos Verdes sand and the Pliocene rock is:

Age	Thickness	Description
Late Pleistocene (?) and Recent	8-15′	Alluvium, brownish-red.
Late Pleistocene (Palos Verdes sand)		
Upper part	10-20′	Gray, fine grained sand; fossils rare.
Basal part	9-11′	Rust-colored, fine to coarse, very fossiliferous sand, becoming coarser with depth and grading into a basal 1-2 foot thick conglomerate of well rounded boulders composed of shale and sandstone.
	[Angular unconformity]	
Late Pliocene "Unnamed sandstone" of Vedder *et al.*, 1957	? (only erosional surface exposed)	Light gray, fine grained sandstone.

Fig. 5. Locality 66-2 exposed in gulley in the lowest emergent terrace of the San Joaquin Hills with the third terrace in the background (photograph by Arminta Neal).

The plane table survey of Mr. R. G. Thomas shows the Pleistocene-Pliocene contact to be at an elevation of 65 feet (±1 foot), and the top of the richly fossiliferous sand member to be 77 feet (±1 foot), or about 12 feet thick. At a nearby exposure(L.A.C.M.I.P. 66-10) the top and base of the fossiliferous stratum were determined to be 80 feet (±2 feet) and 60 feet (±2) feet, respectively.

The two other collecting localities recorded herein, are from an exposure in the cliff face of the Mesa on the opposite side of the Inner Bay channel. These are from the same exposure, but one station (locality 68-A) is about 8 to 10 feet lower in the section than the other (locality 68-B). The lower stratum is richly fossiliferous and near the Pliocene-Miocene contact. The sediments consist of fine grain sand near the top of the section and show a gradation from fine to coarse-grained sand towards the base. The Pleistocene sediments are only 12 to 18 feet thick at this exposure. The base level is reported by Mr. Thomas to be 82 feet (±1 foot).

The measured base level corresponds well with elevations determined for the lower level of Bruff's fossil localities from along the Mesa side of the channel and the corresponding elevation on the edge of the terrace across the channel (see Fig. 5 for the location of these collecting stations). These range from 78 to 82 feet, but considering the irregular surface of the terrace platform and possble errors in surveying, the differences in elevations are minor.

The apparent lower elevation of the terrace platform, 13 to 22 feet, near the fore-edge of the second terrace (localities 66-2 and 66-10) requires brief comment. If these figures are correct, this "pocket" in the terrace shelf could be explained as the result of local deformation or erosion occurring prior to the deposition of the Palos Verdes sand. More likely, the platform was channelled by currents or by some other means before or during deposition of the sediments.

NEWPORT BAY FAUNA

This section enumerates the largest assemblage of metazoan invertebrates known from the marine Pleistocene deposits of western North America. The identified species number 3 stony corals, 32 bryozoans, 2 brachipods, 436 mollusks, 5 echinoids, 14 crabs, and 4 barnacles for a total of 496 species. In addition to these the collections include species representing 5 genera of annelid worms. The remaining unidentified species of varous phyla account for a collected fauna of more than 500 species.

Bruff (1946) reported 169 species, chiefly mollusks, from 11 collecting stations in the Palos Verdes sand of the Newport Bay area. All but 29 of the species cited by Bruff were previously recorded in Arnold's (1903) list of 305 species from the "Upper San Pedro Series" of the San Pedro area. Willett (1937) recorded 326 taxa from the Palos Verdes sand at Playa del Rey.

The largest Pleistocene fauna previously reported from western North America is that recorded by Jordan (1936). He listed 441 taxa of larger invertebrates, mostly mollusks, from terrace deposits on the leeward side of Magdalena and Margarita islands in Magdalena Bay, Baja California, Mexico.

FAUNAL CONSTITUENTS

Annelida

Dr. Olga Hartman of the Allan Hancock Foundation, University of Southern California, identified the following genera of marine annelids from locality 66-2: *Protula, Spiochaetopterus, Spirorbis, Dodecaceria,* and *Salmacina.* The specimens could not be identified to species, for the opercula were not found.

Brachiopoda

Only two species representing this phylum were encountered among the vast amount of material examined from the three stations. These are *Glottidia albida* (Hinds) and *Terebratalia transversa* (Sowerby) from locality 66-2. The former is reported to range at the present time from Monterey Bay, California to Acapulco Bay, Mexico, and the latter from Alaska to Ensenada, Baja California (Hertlein and Grant, 1944b).

Bryozoa

The bryozoan material was identified by the late Dr. Raymond C. Osburn and by Dr. John D. Soule of the Allan Hancock Foundation of the University of Southern California. A total of 31 species of ectoprocts were recognized from localities 68-B and 66-2. Of this number, 23 were previously recorded from these localities by Soule and Duff (1957). The remaining eight species were subsequently identified by Dr. Soule and are indicated in the list below by an asterisk preceding the names. Another species collected in the same terrace deposit as 66-2, but across the road, brings the total to 32. All are extant species.

	68-B	66-2
Antropora tincta (Hastings)	—	x
Callopora circumclathrata (Hincks)	—	x
Cauloramphus spiniferum (Johnston)	—	x
**Cellaria diffusa* Robertson	x	—
Cellaria mandibulata Hincks	—	x
Celletosia radiata (Moll)	—	x
Conopeum commensale Kirkpatrick and Metzelaar	—	x
Costazia costazi (Audouin)	—	x
**Diaperoecia californica* (Orbigny)	x	—
**Diaperoecia rugosa* Osburn = ? *floridana* Osburn	x	x
Discoporella umbellata (Defrance)	—	x
**Heteropora magna* O'Donoghue	—	x
Hippopodina feegeensis (Busk)	—	x

Hipporporella gorgonensis Hastings	—	x
Hippoporidra edax (Busk)	—	x
**Hippothoa hyalina* (Linné)	—	x
Holoporella brunnea (Hincks)	—	x
Lagenipora punctulata (Gabb and Horn)	—	x
Membranipora savarti (Aubouin)	—	x
Membranipora tenuis Desor	x	—
Membranipora tuberculata (Bosc)	—	x
**Microporella californica* (Busk)	—	x[10]
Microporella ciliata (Pallas)	—	x
Microporina borealis (Busk)	x	—
Mucronella microstoma (Norman)	—	x
**Porella concinna* (Busk)	—	x
Porella porifera (Hincks)	—	x
**Rhynchozoon rostratum* (Busk)	—	x
Rhynchozoon tumulosum (Hincks)	—	x
Thalamoporella californica (Levinsen)	—	x
**Tubulipora tuba* (Gabb and Horn)	—	x
Tubulipora tuba fasciculifera (Hincks)	—	x

On the basis of the available distributional data (Osburn, 1950; 1952; 1953), all but three of the bryozoan constituents of the fauna are known to live at the present time in the southern California region in habitats ranging from intertidal to shallow infratidal. Several species appear to be cosmopolitan, and many others are known to range from British Columbia to Panama. Of the three locally extinct species, one (*Conopeum commensale*) ranges from Baja California to Peru. The other two (*Heteropora magna* and *Mucronella microstoma*) are not known to occur south of Puget Sound, Washington and British Columbia, respectively, in the Eastern Pacific.

Cnidaria

According to Dr. J. Wyatt Durham of the University of California Museum of Paleontology four species of stony corals are represented in the present collections, as follows:

Balanophyllia elegans Verrill
Dendrophyllia oldroydi Faustino
Paracyathus stearnsii Verrill (= *P. pedroensis* Vaughn, *fide* Durham and Barnard, 1952)
? *Sphenotrochus* sp. (juveniles)

All of the species occur at the present time in infratidal depths off the southern California coast. The corals are rare in the collections, and several of the specimens are badly worn.

[10]Not known from L.A.C.M.I.P. localities 68-B or 66-2, but recorded from locality 136, Newport Bay Road, Newport, California, the same terrace deposit as locality 66-2.

The three identified species have been reported previously from the Pleistocene of the southern California-Baja California district (Durham, 1947; Emerson, 1956).

Crustacea

Crabs

The large collecton of cheliped propods and actyls of decapod crabs is largely unidentified. Menzies (1951), however, identified four extant species of the brachyuran genus *Cancer* in material from the terrace deposit, locality 66-2. These are: *Cancer branneri* Rathbun, *Cancer gracilis* Dana, *Cancer jordani* Rathbun, *Cancer magister* Dana. These species live in shallow water, in bays or near shore. With one exception, they are known to occur along the southern California coast at the present time. *Cancer branneri* has been taken from some of the Channel Islands and at several localities along the Baja California coast, but is not reported from the southern California mainland (John S. Garth, *in literis*).

The following additional species also have been identified by Dr. Robert J. Menzies, Columbia University, from the designated localities:

	68-A	68-B	66-2
Callianassa californiensis Dana	—	—	x
Callinectes arcuatus Ordway	—	x	—
Callinectes bellicosus (Stimpson)	x	—	—
Cancer productus Randall	—	—	x
Cycloxanthops novemdentatus (Lockington)	—	—	x
Hemigrapsus nudus Dana	—	—	x
Hemigrapsus oregonensis Dana	—	—	x
Portunus xantusi (Stimpson)	—	x	—
Pugettia producta (Randall)	—	—	x
Speocarcinus californiensis Lockington	—	—	x

Although these species live at the present time along the southern California coast, the two species of *Callinectes* are southern ranging forms commonly found in warmer waters. *Callianassa* and *Speocarcinus* are mudflat inhabitants of protected bays.

Additional records of crabs from the Pleistocene deposits of the Los Angeles basin have been reported by Rathbun (1926), Willett (1937), and Menzies (1951).

Cirripedia

Barnacle remains, representing 7 or 8 species, are not uncommon from 66-2. Specimens apparently referable to *Balanus tintinnabulum californicus* Pilsbry, *Tetraclita squamosa* (Brugrière), and *Coronula diadema* (Linnaeus) comprise about 90 per cent of the barnacle collection. The present range of at least one species, *Coronula reginae* Darwin, may be extra-limital. Species of *Coronula*, "whale barnacles," however, are widely distributed by their cetacean hosts.

Echinodermata

The echinoids from locality 66-2 were identified by Dr. J. Wyatt Durham of the University of California Museum of Paleontology as follows:

Dendraster excentricus (Eschscholtz)
Dendraster vizcainoensis Grant and Hertlein
Dendraster vizcainoensis similaris Grant and Hertlein
Dendraster sp. (juveniles)
Lytechinus sp.
Mellita new sp. (=*M. longifissa* Kew, not Michelin)
Strongylocentrotus franciscanus (A. Agassiz)
Strongylocentrotus purpuratus (Stimpson)

According to Dr. Durham this previously unrecognized species of *Mellita* is known to be living off the Central American coast at the present time.

Dendraster vizcainoensis was described from "Quaternary beach" deposits at Punta Santa Rosalia and Puerto de Santo Domingo, Baja California, Mexico, and the form *D. v. similaris* is known from late Pleistocene (Palos Verdes sand or equivalent) deposits near Signal Hill and Playa del Rey in the Los Angeles area (Grant and Hertlein, 1938). This species was believed to be extinct, but living specimens of the typical form were recently collected along the open coast of Vizcaino Bay in the vicinity of Miller's Landing by E. C. Allison and F. H. Kilmer of the University of California Museum of Paleontology. The remaining identified species occur in the modern fauna at the latitude of Newport Bay.

Mollusca

The mollusks are the predominant element of the collected fauna. The inferred ecological requirements and climatic significance of the Newport fauna, therefore, are largely based on the mollusks. The 436 recognized taxa are enumerated in the check list and the numbers of taxa and specimens are tabulated below by class and collecting locality.

	68-A		68-B		66-2		Total No. of	Total No. of
	Taxa	Specim.	Taxa	Specim.	Taxa	Specim.	Taxa	Specim.
Pelecypoda	68	3,260	56	3,858	128	31,647	128	38,765
Gastropoda	101	1,441	143	4,483	281	33,314	289	39,238
Scaphopoda	1	120	3	388	7	1,628	7	2,136
Amphineura	4	161	5	171	11	830	12	1,162
Totals	174	4,982	207	8,900	427	67,419	436	81,301

Of the 436 identified species and varieties, 427 are represented in the collections from locality 66-2. This rich locality also yielded 67,419 specimens of the 81,301 specimens collected from the three localities.

The taxa are listed alphabetically in the following check list. The nomenclature largely follows the usage of Keen (1937). For each locality, the number of specimens of each species is recorded; the number of recognizable fragments is indicated by numerals enclosed in parentheses.

Pelecypoda	68-A	68-B	66-2
Aligena cerritensis Arnold	5	10	5
Americardia biangulata (Broderip and Sowerby)	1	—	4
Amiantis callosa (Conrad)	4(1)	8(2)	678
Anatina undulata (Gould)	(3)	—	3(113)
Anomia peruviana Orbigny	35	33	1,253
Apolymetis biangulata (Carpenter)	(2)	1	176
Arca perlabiata Grant and Gale	5	1	81
Barbatia bailyi (Bartsch) = ? *B. pernoides* (Carpenter)	1	—	41
Barnea pacifica Stearns	—	—	12
Brachidontes adamsianus (Dunker)	—	—	239
Cardita hilli Willett	5	—	421
Cardita ventricosa Gould	—	—	57
Chama pellucida Broderip	2	—	211
Chione californiensis (Broderip)	67	16	237
Chione cortezi (Carpenter) = *Venus gibbosula* Deshayes MS., not Reeve	—	—	48
Chione fluctifraga (Sowerby)	21	—	123
Chione gnidia (Broderip and Sowerby)	3	3	173
"*Chione*" *picta* "Dall" Willett	62	31	453
Chione undatella (Sowerby)	—	—	512
Cooperella subdiaphana (Carpenter)	—	—	3
Corbula luteola Carpenter	338	226	1,115
Crassinella branneri (Arnold)	616	309	209
Crassinella nuculiformis Berry	600	543	1,600
Cryptomya californica (Conrad)	16	(3)	98
Cumingia californica Conrad	—	—	19
Cyathodonta undulata Conrad	—	17	10
Cyclinella singleyi Dall	—	—	6
Cyclinella subquadrata (Hanley)	—	—	5
Diplodonta orbellus (Gould)	—	—	7
Diplodonta sericata (Reeve)	78	29(2)	1,065
Donax californicus Conrad	81	114	1,922
Donax gouldi Dall	107	72	2,949
Dosinia ponderosa (Gray)	1	—	17
Gari californica (Conrad)	—	—	7
Gari edentula (Gabb)	—	—	5
Glans carpenteri (Lamy)	2	—	18
Glycymeris subobsoleta (Carpenter)	2	—	1,668
Heterodonax bimaculata (Linnaeus)	—	—	1

Pelecypoda (cont.)	68-A	68-B	66-2
Hiatella arctica (Linnaeus)	—	—	4
Hinnites multirugosus Gale	(2)	—	48
Kellia laperousi (Deshayes)	—	—	2
Laevicardium elatum (Sowerby)	—	—	14
Laevicardium substriatum (Conrad)	11	2	259
Lima hemphilli Hertlein and Strong = *L. dehiscens* auct., not Conrad, 1837	1	—	14
Lithophaga plumula kelseyi Hertlein and Strong (1946)	—	—	7
Lucina approximata (Dall)	—	48	101
Lucina californica Conrad	2	1	33
Lucina excavata Carpenter	2	—	9
Lucina nuttalli Conrad	9	110	665
Macoma elongata (Hanley)	—	—	7
Macoma indentata tenuirostris Dall	(3)	1(3)	7
Macoma irus Hanley = *M. inquinata* (Deshayes)	—	—	6
Macoma nasuta (Conrad)	7(2)	(2)	510
Macoma pacis Pilsbry and Lowe	—	—	145
Macoma secta (Conrad)	2(1)	1	61
"*Macrocallista*" *squalida* Sowerby	—	—	15
Mactra californica Conrad	(2)	(5)	4(14)
Mactra nasuta Gould	—	—	(2)
Miodontiscus prolongatus Carpenter	—	—	2
Modiolus capax (Conrad)	1	—	65
Modiolus modiolus (Linnaeus)	—	2	1
Modiolus rectus (Conrad)	2	—	7
Mulinia pallida modesta Dall	2	9(4)	10(48)
Mytilus californianus Conrad	5	2	171
Nucula exigua Sowerby	727	873	3,456
Nuculana taphria (Dall)	3	873	5
Ostrea laticaudata Carpenter	2	—	15
Ostrea lurida Carpenter	89	25	949
Ostrea megodon Hanley	—	—	3
Pandora punctata Conrad	—	43	11
Panope generosa Gould	—	(5)	10(12)
Parapholas californica (Conrad)	—	—	3
Pecten bergingianus Middendorff	—	—	1
Pecten caurinus Gould	3	2	4
Pecten circularis aequisulcatus Carpenter	14	6	746
Pecten diegensis Dall	1	—	6
Pecten hericius Gould	—	—	1
Pecten latiauratus Conrad	48	186	1,145
Pecten monotimeris Conrad	2	—	26

Pelecypoda (cont.)	68-A	68-B	66-2
Pecten rubidus rubidus Hinds = *hindsi* Carpenter	—	—	5
Pecten rubidus venturaensis Waterfall	—	—	1
Pecten vogdesi Arnold	—	—	6
Periploma planuiscula Sowerby	7	10	395
Petricola californiensis Pilsbry and Lowe	4	1(2)	9
Petricola gracilis parallela Pilsbry and Lowe	(36)	(11)	1,560
Petricola tellimyalis (Carpenter)	—	—	13
Philobrya setosa (Carpenter)	—	—	2
Pholadidea ovoidea (Gould)	4	—	12
Pitar newcombianus (Gabb)	1	—	2
Pitar vulnerata (Broderip)	—	—	10
Platyodon cancellatus Conrad	(2)	(13)	31(16)
Protothaca grata Say	—	—	12
Protothaca staminea (Conrad)	—	(5)	190
Protothaca staminea forma *laciniata* (Carpenter)	—	1	16
Protothaca ternerrima (Carpenter)	—	—	21
Pseudochama exogyra (Conrad)	—	—	803
Rochefortia aleutica Dall	—	3	2
Rochefortia reyana Willett	—	3	2
Sanguinolaria nuttalli Conrad	1	—	76
Sanguinolaria nuttalli forma *orcutti* Dall	—	—	18
Saxidomus nuttalli (Conrad)	—	3	115
Schizothaerus nuttalli (Conrad)	(2)	—	29(19)
Semele decisa (Conrad)	—	—	118
Semele pulchra (Sowerby)	48	34(2)	53
Semele striosa (C. B. Adams)	—	—	5
Septifer bifurcatus (Conrad)	12	—	563
Siliqua lucida (Conrad)	(2)	(13)	(32)
Solen rosaceus Carpenter	(37)	(2)	1(8)
Solen sicarius Gould	—	(40)	(66)
Spisula californica Carpenter	—	—	20(11)
Spisula falcata (Gould)	29(4)	6(8)	367
Spisula hemphilli (Dall)	4	—	686
Spisula planulata Conrad	—	—	64
Tagelus californicus (Conrad)	(12)	2(8)	26
Tagelus subteres (Conrad)	(4)	—	40(18)
Tellina bodegensis Hinds	—	—	6
Tellina idae Dall	—	1(21)	3
Tellina meropsis Dall	5	3	21
Tellina rubescens Hanley	—	—	20

Pelecypoda (cont.)	68-A	68-B	66-2
Tellina santarosae Dall	—	—	2
Tivela stultorum (Mawe)	1	27	203
Tivela stultorum forma *scarificata* Berry	—	—	9
Trachycardium procerum (Sowerby)	40	12	1,138
Trachycardium quadragenarium (Conrad)	2	3	217
Ventricola fordi (Yates)	—	—	2(21)
Verticordia ornata (Orbigny)	—	—	2
Yoldia cooperi Gabb	—	1	108
Zirfaea pilsbryi Lowe	(2)	—	49(225)
Gastropoda			
Acanthina lugubris (Sowerby)	—	—	5
Acanthina spirata (Blainville)	1	3	157
Acmaea asmi (Middendorff)	—	—	3
Acmaea depicta (Hinds)	5	—	22
Acmaea insessa (Hinds)	—	1	183
Acmaea limatula Carpenter	—	—	19
Acmaea paleacea Gould	1	1	36
Acmaea pelta Eschscholtz	—	—	2
Acmaea persona Eschscholtz	—	—	1
Acmaea scabra (Gould)	1	1	126
Acteocina culcitella (Gould)	49	176	232
Acteocina inculta (Gould)	11	52	6
Acteocina smirna Dall	—	—	14
Acteon punctocaelatus (Carpenter)	6	3	33
Acteon traski Stearns	(1)	1	51(21)
Admete gracilior (Carpenter)	—	4	12
Aesopus chrysalloideus (Carpenter)	36	14	822
Aesopus sanctus Dall	5	2	32
Alabina californica (Dall and Bartsch)	—	—	7
Alabina tenuisculpta (Carpenter)	12	36	52
Alabina tenuisculpta forma *phalacra* Bartsch	—	—	48
Alabina turrita (Carpenter)	—	8	5
Aletes squamigerus Carpenter	35	(21)	13
Alvania acutilirata (Carpenter)	—	—	1
Alvania fossilis Bartsch	—	—	5
Amphissa reticulata Dall	—	—	2
Amphissa versicolor Dall	—	—	18
Anachis penicillata Carpenter	—	3	145
Antiplanes perversa (Gabb)	—	4	—
Antiplanes santarosana Dall	—	—	1
Assiminea translucens (Carpenter)	—	—	4
Astraea gibberosa (Dillwyn) = *A. inaequalis* (Martyn)	—	—	(1)
Astraea undosa (Wood)	(1)	1	98

Gastropoda (cont.)	68-A	68-B	66-2
Atys casta Carpenter	—	1	6
Balcis compacta (Carpenter)	—	—	1
Balcis micans (Carpenter)	40	82	22
Balcis monicensis (Bartsch)	—	—	14
Balcis oldroydi (Bartsch)	—	—	30
Balcis rutila (Carpenter)	—	30	60
Balcis thersites (Carpenter)	—	—	10
Barbarofusus kobleti (Dall)	—	—	2
"*Barleeia*" *acuta* (Carpenter)	—	—	1
Barleeia marmorea (Carpenter)	—	—	4
Barleeia subtenuis var. *rimata* (Carpenter)	—	—	158
Bellaspira grippii Dall	—	—	2
Bittium interfossa Carpenter	—	—	2
Bittium quadrifilatum Carpenter	9	1	93
Bittium rugatum Carpenter	1	502	650
Bivonia compacta Carpenter	—	—	1
Borsonella bartschi (Arnold)	—	—	1
Bursa californica (Hinds)	—	4(10)	132
Caecum californicum Dall	6	250	88
Calliostoma dolarius (Holten) = *C. canaliculatum* (Martyn)	46	18	9
Calliostoma eximium (Reeve)	3	—	12
Calliostoma ligatus (Gould)	—	—	6
Calliostoma gemmulatum Carpenter	36	24	164
Calliostoma supragramosum Carpenter	—	—	3
Calliostoma tricolor Gabb	10	35	21
Calyptraea contorta Carpenter	1	37	10
Cancellaria bullata Sowerby	—	—	1
Cancellaria tritonidea Gabb	—	—	39
"*Cantharus*" *lugubris* (C. B. Adams)	—	—	3
Cavolina trispinosa Lessor	—	—	1
"*Centrifuga*" *leeana* (Dall)	—	—	3(11)
Cerithidea albonodosa Gould and Carpenter	—	—	54
Cerithidea californica (Haldeman)	10	5	529
Cerithiopsis alcima Bartsch	—	4	9
Cerithiopsis antefilosa Bartsch	2	10	10
Cerithiopsis antemunda Bartsch	1	—	8
Cerithiopsis carpenteri Bartsch	—	—	2
Cerithiopsis cesta Bartsch	—	1	1
Cerithiopsis cosmia Bartsch	2	—	18
Cerithiopsis diegensis Bartsch	—	—	1
Cerithiopsis fossilis Bartsch	—	—	20
Cerithiopsis oxys Bartsch	1	10	15
Cerithiopsis pedroana Bartsch	—	—	1

Gastropoda (cont.)	68-A	68-B	66-2
Clathrodrillia fancherae Dall	—	42	67
Clathrodrillia ophioderma Dall	2	2	4
"*Clathurella*" *conradiana* Gabb	—	—	3
Coleophysis carinata (Carpenter)	—	75	222
Coleophysis harpa (Dall)	—	—	2
Conus californicus Hinds	4	57	456
Crassispira montereyensis (Stearns)	—	—	5
Crepidula arenata (Broderip)	90	88	1,218
Crepidula norrissiarum Williamson	—	—	176
Crepidula nummaria Gould	3	11	28
Crepidula onyx Sowerby	24	25	595
Crepidula princeps Conrad	—	1	4
Crepipatella lingulata (Gould)	1	1	54
Crucibulum spinosum (Sowerby)	121	114	737
Cylichna attonsa Carpenter	—	91	20
Cystiscus regularis (Carpenter)	—	—	91
Cytharella hexagona (Gabb)	1	—	4
Cytharella merita (Hinds)	—	—	3
Cytharella merita var. *painei* (Arnold)	—	—	40
Diodora aspera (Eschscholtz)	—	—	3
Diodora constantiae Kanakoff	16	4	25
Diodora densiclathrata (Reeve)	(1)	—	6
Diodora inaequalis (Sowerby)	4	2	80
Diodora murina (Dall)	—	—	3
Elaeocyma empyrosia (Dall)	—	—	3
Elaeocyma hemphilli (Stearns)	40	11	242
Epitonium acrostephanum Dall	—	3	2
Epitonium bellastriatum (Carpenter)	—	17	5
Epitonium californicum (Dall)	—	—	2
Epitonium clarki T. S. Oldroyd	—	36	22
Epitonium cooperi Strong	53	29	19
Epitonium indianorum (Carpenter)	—	—	19
Epitonium rectilaminatum (Dall)	1	—	6
Epitonium tinctium (Carpenter)	25	19	14
Erato columbella Menke	—	—	15
Eupleura muriciformis Broderip	(1)	2	23
Fartulum occidentale (Bartsch)	—	10	34
Fissurella volcano Reeve	11	5	258
Forreria belcheri (Hinds)	—	5(5)	101
Glyphostoma adana Dall	—	—	4
Haliotis corrugata Gray	—	—	3
Haliotis cracherodi Leach	—	—	4
Haliotis fulgens Philippi	—	—	1
Haliotis rufescens Swainson	—	(1)	4

Gastropoda (cont.)	68-A	68-B	66-2
Halistylus subpupoideus (Tryon)	—	—	91
Haminoea virescens (Sowerby)	—	—	30
Hipponix antiquatus (Linné)	2	12	113
Hipponix tumens (Carpenter)	—	1	42
Homalopoma carpenteri (Pilsbry)	—	—	1
Homalopoma paucicostatum (Dall)	—	—	2
"*Hyalina*" *californica* (Tomlin)	2	—	66
Iselina fenestrata (Carpenter)	1	—	27
Jaton festivus (Hinds)	—	—	20(56)
Kellettia kelletti (Forbes)	20	3	32
Kurtzia gordoni Bartsch	—	—	15
Kurtzia roperi (Dall)	—	1	—
Lacuna marmorata Dall	—	72	2
Lacuna unifasciata Carpenter	—	18	140
Lamellaria stearnsi Dall	—	—	2
Liota acuticostata Carpenter	—	1	9
Littorina planaxis Philippi	—	—	6
Littorina scutulata (Gould)	3	3	530
"*Lora*" *fidicula* (Gould)	—	—	1
Lottia gigantea Sowerby	—	—	3
Lucapinella callomarginata (Dall)	19	3	108
Macron lividus (A. Adams)	—	—	3
"*Mangelia*" *cetolaca* Dall	6	61	370
"*Mangelia*" *hooveri* Arnold	—	—	3
"*Mangelia*" *interlirata* Stearns	—	—	5
"*Mangelia*" *variegata* Carpenter	42	251	634
Margarites optabilis (Carpenter)	—	—	3
Margarites parcipictus (Carpenter)	10	9	482
Maxwellia gemma (Sowerby)	—	—	(12)
Maxwellia santarosana (Dall)	—	—	(1)
Megasurcula carpenteriana (Gabb)	—	2	10
Megatebennus bimaculatus (Dall)	(1)	—	9
Megathura crenulata (Sowerby)	3	2	5
Melampus olivaceus Carpenter	36	—	239
Metaxia convexa (Carpenter)	—	—	10
Metaxia diadema Bartsch	6	1	13
Micranellum crebricinctum (Carpenter)	6	36	17
Mitra catalinae (Dall)	1	1	2
Mitra fultoni E. A. Smith	—	—	5
Mitra idae Melville	—	—	6
Mitrella carinata (Hinds)	98	208	7,548
Mitrella carinata forma *gausapata* (Gould)	42	98	2,000
Mitrella tuberosa (Carpenter)	1	14	163
Mitromorpha filosa (Carpenter)	—	—	13

Gastropoda (cont.)	68-A	68-B	66-2
Mitromorpha gracilior Hemphill	—	2	4
Nassarius cerritensis (Arnold)	7(5)	4	130
Nassarius delosi (Woodring)	(1)	48	47
Nassarius fossatus (Gould)	(1)	3	41
Nassarius mendicus (Gould)	—	—	8
Nassarius mendicus forma *cooperi* (Forbes)	—	—	6
Nassarius perpinguis (Hinds)	38	143	60
Nassarius tegulus (Reeve)	6(5)	3	33
Neptunea tabulata (Baird)	—	—	66
Norrisia norrisi (Sowerby)	1	—	37
Ocenebra barbarensis (Gabb)	—	—	1
Ocenebra foveolata (Hinds)	—	—	11
Ocenebra interfossa Carpenter	—	—	10
Ocenebra lurida (Middendorff)	1	(1)	3
Ocenebra poulsoni Carpenter	3	7	12
Odostomia acrybia Dall and Bartsch	—	—	2
Odostomia aepynota Dall and Bartsch	—	—	7
Odostomia amianta Dall and Bartsch	—	—	1
Odostomia atossa Dall	—	5	5
Odostomia donilla Dall and Bartsch	3	—	99
Odostomia effiae Willett	2	—	6
Odostomia elsiae Willett	3	2	4
Odostomia fetella Dall and Bartsch	—	—	3
Odostomia helena Bartsch	—	9	30
Odostomia helga Dall and Bartsch	—	—	5
Odostomia io Dall and Bartsch	—	—	3
Odostomia navisa Dall and Bartsch	—	1	1
Odostomia nemo Dall and Bartsch	—	32	105
Odostomia pulcia Dall and Bartsch	—	—	2
Odostomia talama Dall and Bartsch	1	2	2
Odostomia tenuisculpta Carpenter	—	—	5
Odostomia terricula Dall and Bartsch	—	—	3
Odostomia virginalis Dall and Bartsch	—	—	2
Olivella baetica Carpenter	12	476	2,908
Olivella biplicata (Sowerby)	2	37	129
Olivella pedroana (Conrad)	93	27	2,313
Opalia insculpta Carpenter	—	—	17
Opalia wroblewskyi chacei Strong	—	—(1)	1
Petaloconchus complicatus Dall	—	—	15
Phasianella compta Gould	105	183	1,151
Phasianella pulloides Carpenter	—	—	18
Phasianella substriata (Carpenter)	—	10	14
"*Phyllonotus*" *radix nigritus* (Philippi)	—	—	67
Pleurtomella herminea Dall	—	—	1

Gastropoda (cont.)	68-A	68-B	66-2
Polinices altus Arnold	—	41	66
Polinices draconis (Dall)	—	—	5
Polinices lewisi (Gould)	1	—	9
Polinices reclusianus (Deshayes)	8	85	171
Pseudomelatoma penicillata var. *semiinflata* Grant and Gale	—	—	4
"*Pterorytis*" *monoceros* (Sowerby)	—	—	52
"*Pterorytis*" *nuttalli* (Conrad)	1	—(2)	38(15)
Pusula californianus (Gray)	—	—	12
Pusula radians (Lamarck)	—	—	4(1)
Pusula solandri (Sowerby)	—	—	16
Pyramidella mazatlanica Dall and Bartsch	—	—	2
"*Pyramidella*" *pedroana* Dall and Bartsch	—	—	1
Rissoina californica Bartsch	—	—	5
Rissonia cf. *R. nereina* Bartsch	—	1	1
Rissoina pleistocena Bartsch	—	10	36
Seila montereyensis Bartsch	4	5	112
Sinum scopulosum (Conrad)	2	10	13
Skenea coronadoensis (Arnold)	—	1	42
Spiroglyphus lituellus (Mörch)	3	2	12
Tachyrhynchus lacteolus (Carpenter)	—	—	18
Tegula aureotincta (Forbes)	—	—	49
Tegula funebralis (A. Adams)	—	1	—
Tegula gallina (Forbes)	—	—	21(112)
Tegula gallina forma *multifilosa* Stearns	11	21	133(31)
Tegula ligulata (Menke)	12	26	698
"*Tegula*" *montereyi* (Kiener)	2	1	—
Terebra pedroana Dall	22	71	275
Terebra specillata Hinds	—	—	418
Thais haemastoma biserialis (Blainville)	—	—	69
Trimusculus reticulatus (Sowerby)	—	—	5
Triphora hemphilli (Bartsch)	1	—	1
Triphora pedroana Bartsch	1	—	8
Triphora kanakoffi Willett	—	—	1(1)
Turbonilla almo Dall and Bartsch	—	14	25
Turbonilla antemunda Dall and Bartsch	1	—	—
Turbonilla antestriata Dall and Bartsch	—	16	16
Turbonilla arnoldi Dall and Bartsch	—	87	44
Turbonilla asser Dall and Bartsch	1	31	15
Turbonilla attrita Dall and Bartsch	12	—	27
Turbonilla buttoni Dall and Bartsch	1	16	91
Turbonilla callimene Bartsch	—	—	3
Turbonilla canfieldi Dall and Bartsch	—	4	33
Turbonilla castanea (Keep)	—	—	1

Gastropoda (cont.)	68-A	68-B	66-2
Turbonilla grouardi Willett	—	—	3
Turbonilla halia Dall and Bartsch	—	1	—
Turbonilla halistrepta Dall and Bartsch	—	—	111
Turbonilla hypolispa Dall and Bartsch	—	1	—
Turbonilla idae T. S. Oldroyd	—	6	—
Turbonilla jewetti Dall and Bartsch	—	—	3
Turbonilla laminata Carpenter	2	4	18
Turbonilla latifundia Dall and Bartsch	—	—	3
Turbonilla lowei Dall and Bartsch	4	16	84
Turbonilla pecora T. S. Oldroyd	—	—	10
Turbonilla pedroana Dall and Bartsch	—	—	204
Turbonilla pentalopha Dall and Bartsch	—	3	14
Turbonilla ralphi Dall and Bartsch	—	4	6
Turbonilla simpsoni Dall and Bartsch	—	—	1
Turbonilla stylina Carpenter	—	3	21
Turbonilla tenuicula (Gould)	22	12	397
Turbonilla torquata Dall and Bartsch	—	—	5
Turbonilla tridentata (Carpenter)	—	84	192
Turbonilla weldi Dall and Bartsch	—	3	2
Turritella cooperi Carpenter	—	3	3
Turritella goniostoma Valenciennes	—	—	5
Vermicularia eburnea (Reeve)	—	—	1
Vermicularia pellucida Broderip and Sowerby	—	13	68
"*Vesica*" *punctulata* (A. Adams)	(4)	1	38
Vitrinella oldroydi Bartsch	—	—	1
Volvulella cylindrica (Carpenter)	—	18	5
Williamia peltoides (Carpenter)	—	1	1
Zonaria spadicea (Swainson)	—	(1)	29
Fresh Water Species			
Gyraulus similaris Baker	—	9	66
Helisoma cf. *H. trivolvis* (Say)	2	2	6(1)
"*Paludestrina*" *curta* Arnold	—	2	1
"*Paludestrina*" *protea* Gould	—	—	11
Physa osculans Haldeman	6	2	2
Valvata humeralis Say	—	2	3
Rangia lecontei Conrad	—	—	4(5)
Terrestrial Species			
Glyptostoma newberrianum (W. G. Binney)	—	—	5
Helmithoglypta sp. indet.	—	—	2
Quickella cf. *Q. rehderi* Pilsbry	1	—	2
Scaphopoda			
Cadulus fusiformis Pilsbry and Sharp	—	45	12
Dentalium agassizi Pilsbry and Sharp	—	—	1(1)

Scaphopoda (cont.)	68-A	68-B	66-2
Dentalium neohexagonum Sharp and Pilsbry	120	338	1,544
Dentalium numerosum Pilsbry and Sharp	—	—	2
Dentalium pretiosum Sowerby	—	—	32
Dentalium semipolitum Broderip and Sowerby	—	5	27
Siphonodentalium quardifissatum (Dall)	—	—	9
Amphineura[11]			
Acanthochitona avicula Carpenter	—	—	2
Callistochiton crassicostatus Pilsbry	—	—	16
Callistochiton palmulatus Carpenter	2	37	15
Cyanoplax hartwegi (Carpenter)	1	—	1
Ischnochiton conspicuus "Carpenter" Pilsbry	—	—	4
Ischnochiton acrior "Carpenter" Pilsbry	157	117	583
Ischnochiton magdalenensis (Hinds)	1	12	177
Lepidochitona keepiana Berry	—	—	2
Lepidopleurus nexus (Carpenter)	—	1	—
Lepidozona brunnea (Dall)	—	—	17
Mopalia acuta (Carpenter)	—	—	7
Mopalia muscosa (Gould)	—	4	6

HABITAT REQUIREMENTS

Inasmuch as Bruff (1946, pp. 299-331) has made a detailed analysis of the habitat requirements of the previously known constituents of the fauna, only brief comment is needed on this subject. Most of the species live at the present time in mud, sand, or rocky rubble of semi-protected embayments or in similar substrates of exposed coasts in shallow depths below strong wave action. Minor elements in the fauna include back-bay tidal flat inhabitants, sandy beach dwellers of the open coast, rock and rocky rubble inhabitants of both open and protected coasts, species restricted bathymetrically to depths greater than 10 fathoms, freshwater inhabitants from adjacent streams and pools, and land dwellers from nearby marsh lands.

At the present time most of the faunal components live in depths of ten fathoms or less. Species representing constituents of the minor, deep-water element are largely fragmental or worn and were apparently carried shoreward by storm waves and mixed with the shallow water deposits.

In addition to the intermittent development of isolated bays and estuaries, behind temporary barrier bars, the entire embayment was afforded partial shelter from northwestern weather by the Palos Verdes island-headland and other large highlands bordering the coast to the north, and by the Channel Islands off shore.

The great diversity of habitats represented in these collections and the

[11]Identifications by S. S. Berry.

large number of species and specimens comprising the samples suggest that a major part of the fauna was carried by southeastward flowing currents from different environments of the local embayment and deposited in the shallower water along the shore bordering the sea cliff of the San Joaquin Hills. A contributing cause of this ecological diversity undoubtedly was temporal change in local substrate composition produced by regional alterations of physiographic and hydrographic factors, such as the temporary development of bars and spits, the shoaling of the embayment, and influx of fresh water from migrating mouths of ancestral Santa Ana and San Gabriel rivers.

The abundance of protected shore inhabitants, especially shallow water rock and rubble dwellers, in the collection from locality 66-2, apparently reflects the presence of a semi-protected shore along the base of the sea cliff. This locality obviously was protected from the southwest by the San Joaquin highlands. Most of the rocky shore associates are lacking in the present collections from localities along the northern side of the Inner Bay, but, as Bruff (1946) has pointed out, these assemblages contain a small protected-shore element mixed with the predominant bay-estuarine element.

The presence of protected-shore forms in Bruff's collections apparently prompted Stevenson and Emery (1958, p. 10, fig. 17) to conclude that Newport Mesa stood during part of Palos Verdes time as a low island with protected shore assemblages occurring on the leeward shore. As suggested above, however, this faunal element apparently lived along the semi-protected bay shore of the San Joaquin highland and was eventually deposited with other assemblages in the local embayment. Moreover, geologic evidence for the existence of a large island-mesa is lacking (see p. 14).

TEMPERATURE REQUIREMENTS

A thermal diversity greater than that now existing at this latitude is indicated for the paleohydroclimate by the number of locally extinct species in the fauna. Many of the faunal components are limited in range, at the present time, to points north or south of the Newport Bay area. Of considerable ecological significance is the large number of thermophilic (warm-limited) species, (see Table 1). These are mostly Panamic Province faunal constituents that are now restricted in their northern distribution to the large lagoons along the southern west coast of Baja California or to the Gulf of California. This tropical element of locally extinct species comprises about 12 per cent of the Newport fauna. In addition to these, the fauna contains a large group of locally extant species with their present northern end-point of range terminating in the southern California area. Most significant of these sub-tropical species are: *Americardia biangulata, Anatina undulata, Diplodonta sericata, Laevicardum elatum, Laevicardium substraitum, Semele striosa, Tellina meropsis, Morula lugubris* and *Pusula solandri.* (cont. on p. 42)

Table 1

Locally Extinct "Southern" Indicators in the Newport Bay Fauna with Present Range and Occurrences in other West American Pleistocene Faunas
(asterisk indicates first record of the species for the Palos Verdes sand)

Species List	Present Range	Los Angeles area San Pedro Sand	Los Angeles area Palos Verdes sand or equivalents	San Diego area	San Quintín Bay	Magdalena Bay
Mollusca Pelecypoda						
Aligena cerritensis	La Jolla, California to Magdalena Bay, Baja California (Dall, 1921)	—	x	x	x	x
Arca perlabiata	Magdalena Bay, Baja California to Tumbez, Peru (Hertlein and Strong, 1943)	—	x	—	—	x
**Chione cortezi*	Magdalena Bay, Baja California to Guaymas (Keen, 1958a)	—	—	—	—	—
Chione gnidia	Cedros Island, Baja California to Paita, Peru (Hertlein and Strong, 1948)	—	x	x	—	x
"Chione" picta	Magdalena Bay, Baja California to Panama (Hertlein and Strong, 1948)	—	x	—	—	x
Crassinella branneri	Scammon Lagoon, Baja California (Woodring *et al.*, 1946) to Panama (Jordan, 1936)	—	x	x	x	x
Crassinella nuculiformis	Cape San Lucus, Baja California (Woodring *et al.*, 1946)	—	x	x	—	—
Cyathodonta undulata	Gulf of California to Peru (Hertlein and Strong, 1946)	—	x	—	—	x
Cyclinella singleyi	Scammon Lagoon, Baja California to Panama (Keen, 1958b)	—	x	—	—	—

**Cyclinella subquadrata*	Guaymas, Mexico to Paita, Peru (Hertlein and Strong, 1948)	—	—	—	—	—
Dosinia ponderosa	Scammon Lagoon, Baja California to Paita, Peru (Hertlein and Strong, 1948)	—	x	x	x	x
**Macoma elongata* Hanley	Baja California to Panama (Hertlein and Strong, 1949)	—	—	—	—	—
**Macoma pacis*	Gulf of California to Golfito, Costa Rica (Hertlein and Strong, 1949)	—	—	—	—	—
"Macrocallista" squalida	Scammon Lagoon, Baja California to Mancora, Peru (Hertlein and Strong, 1948)	—	x	—	x	x
Mulinia pallida modesta	Magdalena Bay, Baja California to Gulf of California (Hertlein and Strong, 1950)	x	x	x	—	?
**Ostrea megadon*	Scammon Lagoon, Baja California to Paita, Peru (Hertlein and Strong, 1946)	x	—	—	x	—
Pecten vogdesi	Magdalena Bay, Baja California to Paita, Peru (Hertlein and Strong, 1946)	—	x	x	x	—
Petricola gracilis parallela	Scammon Lagoon, Baja California to Corinto, Nicaragua (Hertlein and Strong, 1948)	—	x	—	—	—
**Pitar vulneratus*	Magdalena Bay, Baja California to the Bay of Panama (Hertlein and Strong, 1948)	—	—	—	—	—
**Protothaca grata*	Cape Colnett, Baja California to Antofogasta, Chile (Hertlein and Strong, 1948)	—	—	—	—	x
Tellina rubescens	Tenacatita Bay, Mexico to Tumbez, Peru (Hertlein and Strong, 1949)	—	x	—	—	?
Trachycardium procerum	Lagoon Head, Baja California to Lobos Island, Peru (Hertlein and Strong, 1947)	x	x	x	x	x
Gastropoda						
Acanthina lugubris	Todos Santos Bay, Baja California to Panama (Burch, 1945)	—	x	x	?	x
**Acteocina smirna*	San Diego, Calif. to El Salvador (Dall, 1921)	—	—	—	—	—

Table 1 (Continued)

Species List Mollusca Gastropoda	Present Range	Los Angeles area San Pedro Sand	Los Angeles area Palos Verdes sand or equivalents	San Diego area	San Quintín Bay	Magdalena Bay
Acteon traski	San Diego, California to Panama (Dall, 1921)	—	x	x	x	—
Cancellaria (Trigonostoma) bullata	Cedros Island, Baja California to Panama (Burch, 1945)	—	x	—	—	—
"Centrifuga" leeana	Guadalupe Island to Cedros Island, Baja California Mexico (Burch, 1945)	—	x	—	—	—
**Cerithiopsis cesta*	San Diego, California (Bartsch, 1911)	—	—	—	—	—
**Crepidula arenata*	Scammon Lagoon, Baja California to Santa Elena, Ecuador (Berry, 1950)	—	—	—	—	—
**Diodora constantiae*	Puertocita, Baja California, and Puerto Peñasco, Sonora, Mexico (Faye Howard, collector)	—	—	—	—	—
Eupleura muriciformis	Cedros Island, Baja California, Mexico, to Lobitos, Peru (Hertlein and Strong 1955)	x	x	x	—	x
**Glyphostoma adana*	Concepcíon Bay, Baja California Mexico (Dall, 1919)	—	—	—	—	—
"Mangelia" cetolaca	Baja California, to Salina Cruz, Mexico (Dall, 1921)	x	x	x	—	—
Mitra fultoni	San Diego, California to Point Abreojos, Baja California, Mexico (Burch, 1945)	—	x	—	—	—

**Odostomia acrybia*	Point Abreojos, Baja California, Mexico (Dall and Bartsch, 1909)	—	—	—	—	—
**Odostomia talama*	Scammon Lagoon, Baja California, Mexico (Dall and Bartsch, 1909)	—	—	—	—	—
**Phyllonotus radix nigritus*	Scammon Lagoon (Jordan, 1924) and Magdalena Bay, Baja California (Cooke, n.d.) and Gulf of California, Mexico (Keen, 1958b)	—	—	x	—	x
"*Pterorytis*" *monoceros*	Baja California, Mexico (Grant and Gale, 1931)	—	x	—	—	—
**Pusula radians*	Magdalena Bay, Baja California to Ecuador (Keen, 1958b)	—	—	—	—	x
**Rissoina nereina*	Point Abreojos to Cape San Lucas, Baja California (Burch, 1946)	—	—	—	—	x
Skenea coronadoensis	Todos Santos Bay, Baja California (Burch, 1946)	—	x	x	—	—
**Terebra specillata*	Concepcíon Bay, Baja California to Piñas Bay, Panama (Hertlein and Strong, 1955)	—	—	—	—	?
Thais haemastoma biserialis	Cedros Island, Baja California, to Peru (Woodring *et al.*, 1946)	—	x	—	—	x
**Triphora hemphilli*	Point Abreojos, Baja California (Bartsch, 1907)	—	—	—	—	x
**Turritella goniostoma*	La Paz, Baja California to Ecuador (Keen, 1958b)	—	—	x	—	?
**Vermicularia pellucida*	"Panama" (Keen, 1958b)	—	—	—	—	—
"*Vesica*" *punctulata*	Magadalena Bay, Baja California to Peru (Keen, 1958b)	—	x	?	—	x

Table 2

Locally Extinct, and Certain Extant Species in the Newport Bay Fauna having Northern Implications, with Present Range and Occurrences in other West American Pleistocene Faunas Indicated

(asterisk indicates first record of the species for the Palos Verdes sand)

Species List	Present Range	Los Angeles area San Pedro Sand	Los Angeles area Palos Verdes Sand or equivalents	San Diego area	San Quintín Bay	Magdalena Bay
Mollusca Pelecypoda						
Cardita ventricosa	Belkoffski Bay, Alaska to off San Diego, California (Dall, 1921)	x	x	x	—	—
Gari californica	Japan, Kamchatka, Aleutian Il. and south to San Diego, California (Grant and Gale, 1931)	x	x	x	—	—
Glycymeris subobsoleta	Aleutian Islands to Puget Sound, Washington (Dall, 1921)	x	x	x	—	—
Macoma irus	Japan, Bering Strait and south to Monterey Bay, California (Dall, 1921)	x	x	x	—	—

Pecten caurinus	Channel Il., Orca Inlet, Cordova, Alaska to Point Reyes, California (Hertlein, 1940)	x	x	—	—	—
Pecten hericius	Port Athorp, Alaska to San Diego, California (Dall, 1921)	x	x	—	—	—
Pecten rubidus	Bering Sea to San Diego (Dall, 1921)	x	x	—	—	—
Rochefortia aleutica	Bering Sea to Coronado Isl., Baja California, Mexico (Dall, 1921)	—	x	—	—	—
Modiolus modiolus	Japan, Arctic Ocean south to Monterey, California also Atlantic Ocean (Soot-Ryen, 1955)	—	x	—	x	—
Gastropoda						
**Amphissa reticulata*	Port Althorp, Alaska to off San Diego, California (Dall, 1921)	—	—	—	—	—
Antiplanes perversa	Forrester Island, Alaska to off San Diego, California (Dall, 1921)	x	x	—	—	—
Calliostoma doliarium	Afognak Island, Alaska to San Diego, California (Burch, 1946)	x	x	x	x	—
Calliostoma ligatum	Prince William Sound, Alaska to San Luis Obispo Co., California (Burch, 1946)	x	x	x	—	—
"*Lora*" *fidicula*	Aleutian Islands, Alaska to Puget Sound, Washington (Dall, 1921)	?	x	—	—	—
Polinices draconis	Port Althorp, Alaska to Catalina Island, California (Dall, 1921)	—	x	—	—	—

Table 3

Extinct Molluscan Species in the Newport Fauna, with Other Occurrences and Known Living Allied Forms Noted.

Species	Reported Occurrences and Allied Living Forms
Pelecypoda	
Cardita hilli	Newport fauna only; said by Willett (1944) to resemble some forms of *C. crebricostata* Krauss, Recent, Point Barrow, Alaska to Monterey, California.
Pecten venturaensis	"Upper Pico," early Pleistocene, Ventura Co., California; a form of *P. hindsi,* Recent, Bering Sea to San Diego, California.
Rochefortia reyana	Palos Verdes sand, late Pleistocene, Baldwin Hills, Los Angeles basin; closely allied to *R. pedroana* Dall, Recent, Morro Bay to San Pedro, California.
Tivela scarificata	"Pleistocene of San Pedro," no definite locality given; biological validity questionable, probably an ecophenotypic variety of *T. stultorum* Mawe.
Gastropoda	
Alvania fossilis	Pleistocene, "sand rock, San Pedro California."
Balcis monicensis	Palos Verdes sand, Late Pleistocene, Santa Monica, Los Angeles basin.
"Cancellaria" tritonidea	Pliocene and Pleistocene of California; occurs in the Pleistocene San Pedro sand and Palos Verdes sand of the Los Angeles basin; no closely related living species is known, but genus has southern implications.
Cerithiopsis fossilis	Pleistocene, Los Angeles basin; probably a variety of *C. arnoldi,* ? Recent, San Pedro, California.
Crepidula princeps	Miocene to Pleistocene of western North America; occurs in the Pleistocene Timms Point silt and Palos Verdes sand of the Los Angeles basin; possibly related to the Recent boreal species, *C. grandis* Middendorff, but more likely has southern implications.
Epitonium clarki	Palos Verdes sand, late Pleistocene, Santa Monica, Los Angeles basin; closely allied to *E. bellastriatum* (Carpenter), Recent, Monterey, California to Todos Santos Bay, Baja California.

Odostomia effiae	Newport fauna only; similar to *O. grammatospira* Dall and Bartsch, Recent, Cape San Lucas, Baja California and Pleistocene of San Diego, California.
Odostomia elsiae	Newport fauna only; similar to *O. talama* Dall and Bartsch, Recent, Scammon Lagoon, Baja California.
Opalia insculpta	Santa Barbara formation, early Pleistocene, Santa Barbara and Palos Verdes sand, late Pleistocene; Los Angeles basin; closely allied to, if not conspecific with, *O. crenimarginata* (Dall), Recent, Santa Monica, California to Puerto Libertad, Mexico (Burch, 1945).
Pseudomelatoma penicillata var. *semiinflata*	Palos Verdes sand, late Pleistocene, Los Angeles basin; apparently a variety of *P. penicillata* (Carpenter).
Rissoina pleistocena	Palos Verdes sand, late Pleistocene, Playa del Rey, California; Bay Point formation, late Pleistocene, San Diego, California; related to species now living south of Newport (Woodring *et al.*, 1946).
Triphora kanakoffi	Newport fauna only; similar to *T. pedroana* (Bartsch), Recent, Redondo Beach, California to South Coronado Island, Baja California, Mexico (Dall, 1921).
Turbonilla arnoldi	Pleistocene of Los Angeles basin, California; Bay Point formation, late Pleistocene, San Diego, California.
Turbonilla grouardi	Newport fauna only; similar to *T. calvini* Dall and Bartsch, Recent, off La Paz, Baja California, Mexico.
Turbonilla idae	San Pedro sand, early Pleistocene, Nob Hill, Los Angeles Co. and Santa Barbara formation, early Pleistocene, Ventura Co., California; similar to *T. taylori* Dall and Bartsch, Recent, British Columbia to Puget Sound, Washington.
Turbonilla latifundia	San Pedro Sand, early Pleistocene, and Palos Verdes sand, late Pleistocene, of San Pedro, California.
Turbonilla pecora	San Pedro sand, early Pleistocene, Nob Hill, Los Angeles Co.; related to *T. dinora* Bartsch, Recent, San Diego, California.
Turbonilla ralphi	Pleistocene of Los Angeles basin and San Diego, California; closely allied to *T. torquata* (Gould), Recent, Monterey, California to Todos Santos Bay, Baja California

The presence of a tropical element in the fauna suggests the hydroclimate to have been warmer, at least in local areas, than at the present time. The mean annual surface water temperature today is recorded to be 57.8°F. off Newport Beach (Bruff, 1946) and about 61°F. off San Pedro (Hertlein and Grant, 1944a). It seems probable that the hydroclimate of the back-bay habitats within the Los Angeles basin during Palos Verdes time was comparable to similar environments of the present day lagoons along the west coast of Baja California from Scammon Lagoon to Magdalena Bay. Most of the species of the tropical element are now living in these shallow, warm-water lagoons. The present mean annual surface temperature of San Ignacio Lagoon, which is located in about the center of this series of protected embayments, is about 65°F. (Hertlein and Grant, 1944a). It would appear, therefore, that the hydroclimate of similar protected habitats within the Newport embayment was at least 4°F. warmer than at the present time.

The northern element in the fauna comprises many species that now range from higher latitudes southward in progressively greater depths, but only 2 per cent of the fauna is composed of northern ranging species which are not known at the present time to live at this latitude. These include six mollusks (see Table 2) and two bryozoans. The presence of this boreal element may reflect the former existence of coastal water masses cooler than now exist in this region. Some of these species, which may be living undetected off the present coast in deeper waters, may have lived during Palos Verdes time near shore in coastal areas of intense upwelling. On the basis of the present collections alone, however, it is not possible to determine the possible influence of upwelling on the composition of the local faunas.

In order to determine the regional hydroclimate, a knowledge of the composition of late Pleistocene fossil assemblages from sites of possible upwelling along the open coast south of San Joaquin highlands is required. Through the courtesy of John G. Vedder, information on the composition of the large collections made by the U. S. Geological Survey when mapping this area was made available to the writers. Assemblages from deposits on the lowest emergent terrace approximately seven miles south of Newport Bay, in the Laguna Beach area, are a mixture of subtropical and transition elements, including: *Crassinella branneri, Thais biserialis, "Chione" picta, Amercardia biangulata, Pusula solandri, Nassarius delosi,* and *Acmaea mitra* (U.S.G.S. F586, F587). Farther south, in the Capistrano Beach-San Clemente region, the assemblages appear to have fewer of the subtropical species represented and several cold water indicators appear, such as *"Cryptochiton" stelleri, Tegula brunnea, "Tegula" montereyi* and *Clinocardium nuttalli* (U.S.G.S. F592). Willett (1938) recorded a cool water assemblage, including *Clinocardium nuttalli, Placiphorella velata* and *Calliostoma ligatum,* from undesignated deposits at Capistrano Beach.

Although Willett's locality no longer exists, about 100 of the molluscan species from the San Clemente exposure (U.S.G.S. F592) are common to Willett's Capistrano Beach assemblage (Vedder, *in literis*).

The apparent absence of the Panamic tropical element in the coastal terrace deposits indicates the open coast hydroclimate to have been cooler than the hydroclimate of the semi-protected bay environment. The occurrence of cold water indicators in the Capistrano Beach deposits may reflect the former presence of locally severe upwelling in the region south of Dana Point.

The regional composition of the late Pleistocene faunas of southern California and northwestern Baja California requires the contemporaneous existence of a cooler hydroclimate along parts of the open coast and a warmer hydroclimate in the protected embayments than exist in this region at the present time. It has been previously suggested that the present distributional pattern of water temperatures along the southern part of Pacific Baja California may approximate the marine environment of the Los Angeles basin during Palos Verdes time. Along this part of Baja California, tropical species are now largely confined to the lagoons and protected bays,[12] warm-temperate elements occur in adjacent coastal waters, and "northern" species appear in local sites of seasonal upwelling along the open coast (Emerson, 1956).

AGE AND CORRELATION

Although the Newport Mesa invertebrate fauna is essentially modern in composition, about 5 per cent of the constituents (22 mollusks and 1 echinoid) are not known to be living. Many of the apparently extinct molluscan species are closely allied to modern forms. Several of them (see Table 3) may prove to be conspecific with Recent species when the range of specific variation of the forms is better known. Others may eventually be found living off the North American west coast. Of the 22 molluscan forms not known to be living, only two lack close relatives in the modern Eastern Pacific faunas. "*Cancellaria*" *tritonidea* occurs in the Pliocene and Pleistocene of California, but does not appear to be closely related to any known Recent species. *Crepidula princeps* commonly occurs in Miocene and Pliocene deposits of western North America, but is rarely found in Pleistocene deposits of southern California. It does not appear to be closely related with similar Recent forms.

Most of the species representing the previously mentioned locally extinct northern and southern elements of the fauna are reported, respectively, from the early Pleistocene of the Los Angeles embayment and the

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[12]Some tropical species of invertebrates have been reported from the southern half of Vizcaino Bay, where Dawson (1952) demonstrated the presence of both relatively warm and cold water algal associations living in near proximity in the well-circulated coastal waters. Additional collections must be made along the open coast of Vizcaino Bay in order to determine if the thermophiles that appear to be largely restricted to the protected lagoons and bays also occur in this exposed bay.

late Pleistocene embayments at lower latitudes (see Tables 2, 3). The presence of these elements and of the extinct species would seemingly be sufficient faunal evidence alone to preclude assigning a post-Wisconsin age to the fauna. The limited available radiocarbon evidence corroborates this conclusion. Carbon-14 age determinations for fossil deposits on the lowest emergent terraces at San Pedro (Kulp *et al.*, 1952) and Santa Cruz, California (Bradley, 1956) indicate ages greater than 30,000 years B. P.

The physiographic evidence also attests to the antiquity of these deposits. The emergent terrace has been considerably modified since Palos Verdes time by the deposition of continental sediments and by erosion. Streams and rivers have incised channels in the terrace to depths greater than 100 feet below the present sea level, and the modern sea has truncated the western margin of the terrace plane. On the other hand, the occurrence of the fossiliferous sediments on the platform of the lowest (youngest) emergent terrace of the region, together with the faunal composition, requires a post-early Pleistocene age. Correlation of the deposits with the Palos Verdes sand of late Pleistocene age is indicated by faunal comparison with the Pacific coast Cenozoic stages based on the metazoan chronology (Weaver *et al.*, 1944). The fauna contains the warm water element that characterizes the fauna of the regional type section at San Pedro (Woodring *et al.*, 1946). Most of these thermophilic (warm-limited) species have been reported from deposits on the lowest emergent terrace elsewhere in the Los Angeles basin and are known to occur locally in similar deposits along the southern California and western Baja California coast (see Table 1). Subaerial erosion and regional deformation have reduced this terrace to discontinuous remnants that defy correlation by conventional methods. All of the available data, however, suggest the fossiliferous Newport Mesa terrace deposits to be a temporal equivalent of the Palos Verdes sand. Moreover, deposition of the sediments near the close of the third inter-glacial stage may be postulated, but is not demonstrable. The possibility of a glacial age (presumably *ad*-Wisconsin) for the fauna is conceivable if the theory of thermal lag of the Pleistocene marine hydroclimates is considered. Under this interpretation (Stokes, 1955), highest ocean temperatures are postulated during phases of glacial advance, the period when the warm near-shore waters gradually cooled attendant with an increase in rates of oceanic and coastal upwelling (Emerson, 1956).

Our present state of knowledge does not permit recognition of marine deposits in terms of the glacial-interglacial sequence. Consequently, a definite age classification of the Newport Mesa fauna and associated sediments is not possible, and the deposits must be referred with discernment to a time interval later than early Pleistocene and prior to the deglacial phase of the Wisconsin stage.

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