FOSSILS FROM THE MARINE PLEISTOCENE TERRACES OF THE SAN PEDRO HILLS, CALIFORNIA.[1]

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The San Pedro Hills, which reach an altitude of 1,480 feet above sea level, constitute an upland peninsula along part of the southwest side of the Los Angeles Plain (Fig. 1). It has been known since Lawson's reconnaissance of coastal Southern California 40 years ago[2] that an unusually fine set of marine terraces is found in this peninsula, but the fossils so far recorded from them are all from the lowest one.

These terraces and the deposits lying on them were examined during the course of geologic mapping undertaken for the Geological Survey in collaboration with W. S. W. Kew and M. N. Bramlette, though not as much time was devoted to them as they deserve. The report on the geology of this area may be delayed for some time, and it is the purpose of this preliminary account to put on record the discovery of fossils on many of the terraces and to discuss their chronologic and climatic significance. So far, the extensive collections of fossils have been examined only in a preliminary fashion.

In this discussion Pleistocene time is accepted as the period intervening between the advance of the first continental ice sheet in northern United States and the retreat of the last one in the same region. This definition is rather vague, but it is still more vague when applied to coastal Southern California, where the advance and retreat were not directly recorded, and where physical indirect effects of them have not been recognized with any reasonable degree of assurance. In the light of this failure an attempt is made to define Pleistocene time in terms of paleontologic data elsewhere correlated more or less satisfactorily with glacial chronology. Deposits in coastal Southern California that carry horses of the genus *Equus* and elephant-like proboscideans, or beds carrying marine faunas that on a basis of reasonably complete representation have no extinct genera and a low per-

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] Lawson, Andrew C.: The post-Pliocene diastrophism of the coast of Southern California: California Univ. Dept. Geol. Bull., vol. 1, pp. 122-128, 1893.

centage of extinct species—not more than about 5 per cent—are referred to the Pleistocene, whether they are undeformed or deformed. On the basis of this definition, which is admittedly unsatisfactory, the terraces of the San Pedro Hills are Pleistocene, for most of them clearly are later than beds carrying such fossils, and perhaps all of them are. The early terraces may be contemporaneous with the deposition of early Pleistocene sediments, but this matter need not be considered here.

MARINE TERRACES.

Lawson identified 11 terraces in the San Pedro Hills. As a result of the work recently undertaken, 13 main terraces are now tentatively recognized. Five other minor terraces seem to be represented at scattered localities, but their relations are uncertain. The number and correlation of even the main terraces is rather dubious. As may be seen on the 1:24,000 maps of the San Pedro Hills, Torrance, and Wilmington quadrangles, which cover the San Pedro Hills, there are great gaps in the upper and intermediate terraces on the windward side of the hills, where for the most part the terraces are wider and more clearly defined than on the leeward side, and on much of the leeward side they have been destroyed with the exception of isolated remnants. Some of the lower terraces are exceptionally wide on the leeward side in San Pedro and northwest of the town, as there the lower slopes of the hills are made up of soft rocks—diatomite and mudstone—whereas on the upper slopes and on all of the windward side the prevailing rock is cherty, siliceous shale. A further, and virtually insuperable, difficulty in determining the altitude of the base of the sea cliff at the rear of the terraces, and thereby in attempting to trace them across gaps, is presented by the thick cover of débris that was rapidly shed on the emerged platforms by the high cliff that backs platforms on a mountainous coast, such as this one. This feature was clearly described by Professor Davis in his observations on the terraces of the Santa Monica Mountains, the next highland up the coast from the San Pedro Hills.[3] The subaerial platform cover, as Professor Davis called it, is thickest at the rear of a terrace, the very place where the altitude of the plat-

[3] Davis, W. M.: Glacial epochs of the Santa Monica Mountains, California: Geol. Soc. America Bull., vol. 44, pp. 1041-1133, pls. 40-56, 26 figs., 1933.

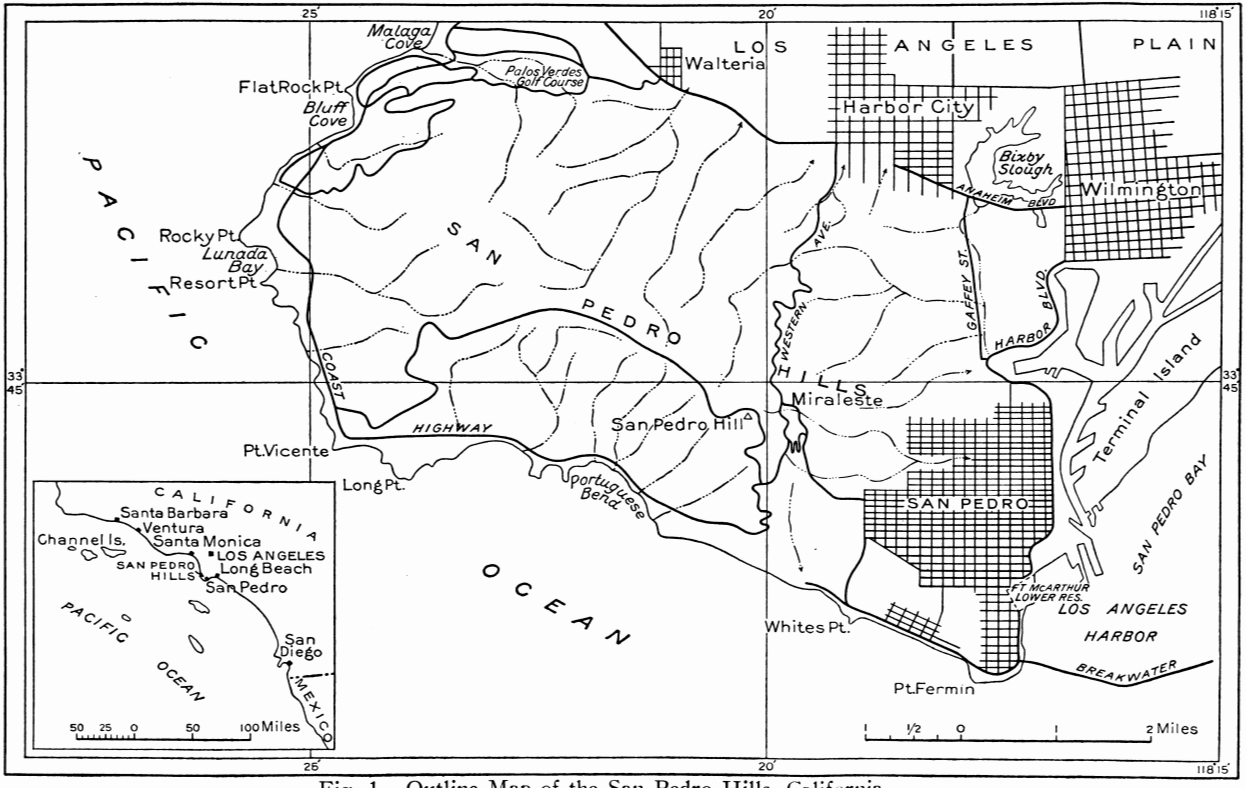

Fig. 1. Outline Map of the San Pedro Hills, California.

Terraces, fossil localities, and faunal facies.

Terrace number	Region where terrace is well-developed	Altitude in feet of change in slope at rear in region where terrace is well-developed	Altitude in feet designated by Lawson (probable equivalents)	Fossil localities	Altitude in feet of fossil localities	Faunal facies
13	South slope of San Pedro Hill	1,325				
12	Southeast slope of San Pedro Hill	1,225	1,240	Highway, southeast slope of San Pedro Hill	1,214	Tide pool
11	South slope of San Pedro Hill	1,150				
10	West slope, inland from Lunada Bay ...	1,050	1,040			
9	Southeast slope of San Pedro Hill	925	960	Western Ave., southeast slope of San Pedro Hill	925	Tide pool
8	West slope, northwest of Pt. Vicente ...	850	860			
7	West slope, inland from Lunada Bay ...	750	700	Western Ave., west of Miraleste School	765	Tide pool
6	West slope, northeast of Lunada Bay ...	600	550	Del Monte Road, near La Venta Inn	550	Tide pool
				Colinta Road, Miraleste	560	Tide pool
5	West slope, northeast of Lunada Bay ...	450	400	Coast Highway, northeast of Pt. Vicente	400	Tide pool
4	West coast, east of Flat Rock Pt.	375		Campesina Road, west of Palos Verdes Golf Club	375	Tide pool
				Montemar Road, southeast of Flat Rock Pt.	360	Tide pool
3	West coast, inland from Rocky Pt.	300	300	Bluff Cove	260	Tide pool and protected bay
				Coast Highway, southeast of Resort Pt.	250	Tide pool
				Coast Highway, northwest of Long Pt.	250	Tide pool
				Peck St., San Pedro	240	Tide pool
2	West coast, inland from Rocky Pt.	225	240	Corta Road, Malaga Cove	190	Protected bay and tide pool
				Peck Park, San Pedro	210	Protected bay and tide pool
				South of Standard Tank Farm	220	Protected bay
1	South coast, west of Pt. Fermin	150	160[a]	9 localities on windward side of hills		Tide pool
			120[a]	32 localities on leeward side of hills..		Protected bay and tide pool; protected bay and offshore; protected bay; beach

[a] These two terraces, separated by a minor interval, generally less than 40 feet, are grouped as one terrace for the purpose of this account. The lower one is exceptionally wide in San Pedro, but is almost entirely consumed on the windward side. The upper one is the wide lowest terrace on the windward side, but is represented only at scattered localities on the leeward side.

form itself should be determined. On the east side of Portuguese Bend, on the south coast of the hills, the platform cover toward the rear of the first terrace has a thickness of 80 to 110 feet, and the smooth slope inland to the 325-foot level seems to represent a compound cover that conceals one or two terrace profiles. A highway cut east of Point Vicente reveals a continuous cover extending from the third to the first terrace, though the second is consumed along this part of the south coast. At places the altitude of the change in slope at the rear of a terrace differs as much as 50 feet on adjoining spurs, but this difference doubtless is a measure of the difference in thickness of the cover and not a measure of deformation. The covers are thickest on the youngest terraces and probably have been almost entirely, or quite entirely, removed on many remnants of the highest ones. The lack of a concealing cover on the highest ones is offset, however, by their greater destruction. Actual exposures of platforms beneath the covers are generally available only on the present sea cliff, which has retreated as far as the third terrace at only one locality—Bluff Cove—and in fortunately located highway cuts. With few exceptions, they are not exposed on the slopes of arroyos and canyons at any distance from the coast.

On account of these difficulties and their attendant uncertainties, the results of an attempt to trace the terraces around the hills are far from satisfactory. The tentative scheme adopted, the probable relation of the terraces recognized to those designated by Lawson, the fossil localities, and the faunal facies represented are shown in the table on page 295. The altitudes at the rear of the terraces represent the change in slope, which may nearly coincide with the altitude of the platform there, or may be far above it.

FOSSILS.

All the fossil localities on terraces above the first represent highway cuts or other artificial excavations, except the one for the third at Bluff Cove, where the present sea cliff has retreated to it. It is expected that other localities will be found during the course of further residential development in the Palos Verdes Estates and other parts of the hills. The fossil locality on the twelfth terrace at an altitude of 1,214 feet, the highest altitude at which fossils were found, is in a cut on the new highway across the top of the hills, where the following section is exposed:

Section of Deposits on Twelfth Terrace in Highway Cut on Southeast Slope of San Pedro Hill.

	Feet
5. Reddish brown soil	1-7
4. Cliff rubble	4-5
3. Cliff rubble carrying many abalones (*Haliotis cracherodii*) and a few turban shells (*Tegula funebralis*) wedged between stones	2
2. Coarse sand composed principally of shell fragments and shells; also carries pebbles	1-2
1. Mixture of cliff rubble, and pebbles and cobbles, many of which are bored	1½-2
Platform of siliceous shale, surface bored at many places.	

Most of the marine constituents in the beds in this section probably represent material swept up by high waves during violent storms, perhaps during one storm of exceptional violence. They may not have been worked over again by the sea after they were mixed with the rubble that had already begun to accumulate against the cliff backing the platform.

The fossils from the first (lowest) terrace on the windward side of the hills and all from the third to twelfth, with the exception of those from one locality on the third, represent a tide pool facies. This facies, represented at each locality by an average of about 30 species, constitutes an animal community that closely, though not quite exactly, corresponds to the community living in tide pools at the foot of the present sea cliff. It includes rock-clinging shells, some of which live near the upper edge of spray, others between tides, and others on algae-covered rocks in pools that generally are not laid bare; shells and sea urchins that live in rock crevices and holes; shells that live on kelp and eel grass, and among the algae and bryozoa growing on abalones; others that live under stones; and others that burrow in the sand filling rock crevices and holes. A few species, as noted later, are not found in tide pools at this latitude, but in deeper water. The tide pool facies on the first terrace was first discovered and recognized by Mr. and Mrs. E. P. Chace,[4] of San Pedro, at a locality near Point Fermin where chitons are, or rather were, unusually abundant. I am indebted to Mr. Chace for guiding me to this place, which is rapidly disappearing as a fossil locality due to park improvements.

The mixed tide pool and protected bay facies represented on the third terrace at Bluff Cove, on the west coast of the

[4] Chace, E. P., and E. M.: An unreported exposure of the San Pedro Pleistocene: Lorquinia, vol. 2, No. 6, pp. 41-43, 1919.

hills, includes most of the abundant tide pool shells and also many others that live in protected bays and inlets, and are abundant on the first terrace on the leeward side of the hills. These protected bay shells are regarded as storm-driven shells swept up from stations to the northeast on the leeward side of the hills. At this locality the fossils are embedded, not in sand or gravel, as they generally are, but in reddish brown fine-grained rubble interpreted as débris that accumulated against the cliff backing the platform.

The mixed protected bay and tide pool facies on the second terrace in the Malaga Cove residential district, also on the west coast but closer to the leeward side of the hills, virtually duplicates many collections from the protected bay facies on the first terrace on the leeward side, aside from the greater proportion of tide pool species. At this locality the shells were swept up by waves and trapped in a niche, later sealed by pebbles and cobbles. This is the only place where the sea urchin *Strongylocentrotus* is represented by tests. At two other localities on the second terrace on the leeward side of the hills species of protected bay facies, or of mixed protected bay and tide pool facies, were collected.

The fossils from the first terrace on the leeward side of the hills in the town of San Pedro were first recorded by geologists of the early transcontinental railroad surveys[5] and were described in Arnold's great monograph.[6] The deposits on the first terrace in this region constitute Arnold's upper San Pedro, now known as the Palos Verdes sand.[7] These fossils represent a much greater ecologic range than those from any terrace on the windward side, embracing a mixed protected bay and tide pool facies, a mixed protected bay and offshore facies, a beach facies, and in particular a protected bay and inlet facies containing a considerable admixture of fresh-water snails, and also of isolated bones of land mammals and birds. The protected bay facies yielded most of the 305 species of invertebrates, mainly mollusks, recorded by Arnold. On the leeward side the tide pool facies is best represented

[5] Antisell, Thomas: Geological report: U. S. Pacific R.R. Expl., vol. 7, pt. 2, p. 118, 1856. Blake, W. P.: Geological report: U. S. Pacific R.R. Expl., vol. 5, pt. 2, p. 186, 1857.

[6] Arnold, Ralph: The paleontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California: California Acad. Sci. Mem., vol. 3, 420 pp., 37 pls., 1903.

[7] See Woodring, W. P.: San Pedro Hills: Sixteenth Internat. Geol. Cong. Guidebook 15, p. 36, 1932.

near the breakwater, though even here protected bay shells are abundant. The mixed protected bay and offshore facies was found at a locality on the north edge of the Fort McArthur Lower Reservation—Arnold's "Crawfish George's" locality—and at one other place nearby. From this place northward and northwestward around the hills the protected bay and inlet facies is represented. The beach facies was found at only one place in San Pedro. A total of 32 collections was obtained on the leeward side at localities extending from the breakwater northward to Anaheim Boulevard and westward along or near the north edge of the hills to Walteria.

CHRONOLOGIC SIGNIFICANCE.

The abundant species in the tide pool facies, regardless of the terrace, are living species, and it is expected that virtually all the rare ones will be found to represent living species. These fossils, therefore, have no value in fixing the age of the terraces other than to indicate that they are Recent or presumably Pleistocene. The mixed tide pool and protected bay facies on the second and third terraces also includes no species that clearly is extinct.

Arnold considered as extinct 28 of the 300 species and varieties of mollusks recorded from the first terrace on the leeward side of the hills, but all except a few have since been eliminated as extinct by the later discovery of living representatives and by changes in identifications. The percentage of extinct species even in this relatively large and reasonably complete fauna probably is not more than two per cent. Some of the extinct species, such as *Turritella jewettii*,[8] may be represented only by detrital material derived from early Pleistocene fossiliferous beds across which the platform of the first terrace in parts of San Pedro and elsewhere was cut, but the recognition of detrital shells in these deposits by any unequivocal criteria is dubious. At all events, the low percentage of extinct species indicates the later part of Pleistocene time. The long series of events that intervened between the deposition of the early Pleistocene beds, which have a considerably greater percentage of extinct species in faunas of comparable size, also points

[8] Though this species was listed by Arnold as extinct (op. cit., p. 46), it generally is regarded as still living (Dall, W. H., U. S. Nat. Mus. Bull. 112, p. 151, 1921; Grant, U. S., IV, and Gale, H. R., San Diego Soc. Nat. Hist. Mem., vol. 1, p. 770, 1931). There are no records of living animals and no authentic records of fresh empty shells.

to the later part of Pleistocene time. On the other hand, the considerable history that followed the emergence of the lowest terrace indicates a greater age than very late Pleistocene, as Davis[9] emphasized for the lowest terrace on the coast of the Santa Monica Mountains. A compromise age determination for the first terrace on the basis of these inexact data is late middle or early upper Pleistocene.

CLIMATIC SIGNIFICANCE.

The discussion as to climatic significance that follows is based on the assumption that during the time when the terraces were cut the living species found on them as fossils had the same adjustment to their environment that they now have. It should be recognized that this is pure assumption, no matter how reasonable it may appear in view of the close approximation in time.

Nearly all the fossils in the tide pool facies are now living in pools at the base of the present sea cliff on the windward side of the hills. *Acanthina lugubris*, collected at a tide pool locality on the third terrace, is considerably north of its present range, the northern limit of which is San Diego. On the contrary, a few species (*Acmaea mitra, Tegula brunnea, Crepidula excavata, Bittium armillatum, Bittium eschrichtii montereyense*) that are not found in tide pools in the latitude of San Pedro, but live at a greater depth offshore, have been recognized in the tide pool facies, and others probably will fall in the same class when the collections are fully identified. The specimens representing these species are regarded as storm-swept shells carried in from the offshore part of the platform. Evidence pointing to storm waves as a transporting agent at several localities has already been presented. Further evidence is afforded by the finding at the rear of the first terrace near Point Fermin of several specimens of small tide pool species in fine-grained cliff rubble lying on an artificially exposed face of the ancient sea cliff that has a slope of 60°. The altitude of the platform at the base of the cliff here could not be determined, but the shells clearly are at a considerable distance above it. This admixture of storm-carried shells probably accounts for the more northern aspect of the chitons at the locality on the first terrace near Point Fermin discovered by Mr. and Mrs. Chace, on the basis

[9] Davis, W. M.: op. cit., pp. 1072-1073.

of which the conclusion was drawn that the temperature of the water when the fossils lived was a little lower than it now is.[10]

The mixed tide pool and protected bay facies on the third and second terraces embrace species that are within their present range, with the exception of the following, all of which are southern or of southern aspect:

Species of Southern Aspect in Mixed Tide Pool and Protected Bay Facies on Third and Second Terraces.

Terrace	Species	Present range[a]
3	Gouldia branneri (Arnold)	"San Diego to Panama"[b]
	Fragum biangulatum (Broderip and Sowerby)[c]	Catalina Island to Colombia
2	Acanthina lugubris Sowerby[c]	San Diego to Magdalena Bay, Lower Calif.
	Pecten vogdesi Arnold	Generally considered identical with Gulf of California species known as *P. cataractes* Dall
	Gouldia aff. varians (Carpenter)[c]	Perhaps identical with *G. varians*, which ranges from Gulf of California to "Panama"

[a] Present range in this table and succeeding one taken from Dall (op. cit.), and Grant and Gale (op. cit.).

[b] A small living race of this species is represented in collections from Scammon Lagoon, Lower California, at the Academy of Natural Sciences of Philadelphia and in collections from Magdalena Bay and nearby localities at the U. S. National Museum. A few bleached larger shells in the collections of the U. S. National Museum, dredged in shallow water at San Diego, may represent fossils eroded from Pleistocene beds bordering San Diego Bay, where *branneri* is known to occur.

[c] Not heretofore recorded as a fossil in this region.

Conflicting claims have been made for the climatic significance of the fossils on the first terrace on the leeward side of the hills. Arnold[11] observed that some species are not found in shallow coastal waters as far south as San Pedro, but that more are confined to regions south of San Pedro, and reached the conclusion that during the time when the deposits on this terrace were laid down the climate was warmer than it now is. This conclusion was further emphasized by J. P.

[10] Berry, S. Stillman: Fossil chitons of western North America: California Acad. Sci. Proc., 4th ser., vol. 11, pp. 408-409, 417-418, 1922.

[11] Arnold, Ralph: op. cit., pp. 66-67, 1903.

Smith,[12] who estimated that the temperature was about 4° F. above the present temperature, and by H. R. Gale,[13] who placed these deposits in the last interglacial period. At a date preceding Arnold's work, however, one worker came to the conclusion that the fossils at one locality—Arnold's "Crawfish George's" locality, already mentioned—represent a period when the temperature was lower than it now is.[14] The species of northern and southern aspect in the deposits on the first terrace on the leeward side of the hills are as follows:

Species of Northern and Southern Aspect in Deposits on First Terrace on Leeward Side of Hills.

Northern species	Present range
Fusitriton oregonensis (Redfield)	Bering Sea to San Diego in deeper water
Boreotrophon pacificus (Dall)[a]	Arctic Ocean to Acapulco, Mexico, in deeper water
Boreotrophon cf. multicostatus (Eschscholtz)	Bering Sea to San Pedro (*B. multicostatus*)
Amphissa columbiana Dall	Alaska to San Pedro
Neptunea tabulata (Baird)[b]	British Columbia to San Diego in deeper water
Exilioidea rectrirostris (Carpenter)	Alaska to Cape San Quintin, Lower California
Acila castrensis (Hinds)[b]	Bering Sea to San Diego
"Pecten" caurinus Gould[a]	Alaska to Siletz Bay, Oregon
Cerastoderma nuttallii (Conrad)	Bering Sea to San Diego; Lower California?

Southern species	Present range
Purpura monoceros (Sowerby)[a]	Lower California
Centrifuga leeana (Dall)[a]	Guadalupe Island to Cedros Island, Lower California
Eupleura muriciformis (Broderip)[a]	Gulf of California to Colombia
Macron aethiops kellettii (Adams)	Catalina Island?; Lower California and Gulf of California
Anadara perlabiata (Grant and Gale)	San Diego?; Lower California to Panama
Pecten vogdesi Arnold[a]	Generally considered identical with Gulf of California species known as *P. cataractes* Dall

[12] Smith, J. P.: Climatic relations of the Tertiary and Quarternary faunas of the California region: Calif. Acad. Sci. Proc., 4th ser., vol. 9, p. 137, 1919.

[13] Gale, H. R.: in Grant, U. S., IV, and Gale, H. R., San Diego Soc. Nat. Hist. Mem., vol. 1, p. 73, 1931.

[14] Ashley, G. H.: The Neocene stratigraphy of the Santa Cruz Mountains of California: California Acad. Sci. Proc., 2d ser., vol. 5, pp. 339-346, 1895.

Gouldia branneri (Arnold)[c]	"San Diego to Panama"
Gouldia aff. varians (Carpenter)[d]	Perhaps identical with *G. varians*, which ranges from Gulf of California to "Panama"
Taras sericatus (Reeve)	San Diego to Panama
Laevicardium elatum (Sowerby)	San Pedro to Panama
Trachycardium procerum (Sowerby)	Scammon Lagoon, Lower California to Peru
Fragum biangulatum (Broderip and Sowerby)[d]	Catalina Island to Colombia
Chione gnidia (Broderip and Sowerby)	Cedros Island, Lower California to Peru
Dosinia ponderosa (Gray)[d]	San Diego to Peru
Tellina rubescens Hanley[a]	Scammon Lagoon, Lower California to Peru
Mulinia modesta Dall[a]	Lower California and Gulf of California

[a] Based on Arnold's record.
[b] Based on Ashley's record. It is not clear whether all the fossils listed by Ashley are from the "point where a short drain has cut into the cliff" (Arnold's "Crawfish George's" locality).
[c] See note c, p. 301.
[d] Not heretofore recorded as a fossil in this region.

It will be observed that only one of the northern species—"*Pecten*" *caurinus*—is actually outside its present range, whereas all except two or three of the southern ones are, some as much as 400 miles.

The southern species point to warmer coastal water than at the present time. The simplest explanation for the northward extension of their range is the one that has been proposed: that it took place during an interglacial period when the temperature of coastal waters was higher than it is now. This view ignores, however, the species of northern aspect. Most of these northern species are known only from Arnold's "Crawfish George's" locality. This is the only place where I collected *Fusitriton oregonensis*, *Amphissa columbiana*, and *Exilioidea rectirostris*, as well as the only one at which foraminifera were found. *Borcotrophon* cf. *multicostatus* was collected here and at one other locality farther south. Moreover, none of the southern species was found in this region. If the apparent climatic implication of the fossils is to be translated into terms of glacial-interglacial chronology, the fossils in this region are glacial, as Ashley's claim implies. As it is manifestly incongruous to attribute deposits on the same terrace to interglacial and glacial periods at different localities, it is evident that the fossils have some other significance. The northern species are confined to the part of

the leeward side of the hills that faced the open ocean when the terraces were formed. None was found at the northeast end and on the north side of the hills, which faced a shallow bay, where the southern species are most abundant. This distribution strongly suggests that the specimens representing the northern shells are storm-driven shells, though storms of exceptional severity would be required to move them from the depth at which they now live in this latitude. This view fails to account, however, for "*Pecten*" *caurinus*, which is entirely outside its present range. The absence of any of these northern species at tide pool localities on the windward side, where storm waves were most powerful, probably is to be attributed to the steeper offshore slope there. Some of the northern shells, notably "*Pecten*" *caurinus*, recorded only by Arnold, may represent detrital material derived from the early Pleistocene beds, but again no satisfactory criteria for recognizing such material are apparent.

The southern species are not open to the same suspicion. Their presence so far north implies warmer coastal waters at this latitude. The distribution of terrace fossils of different climatic facies along the coast of Southern California throws some doubt, however, on the ready translation of the climatic implication of the southern species into terms of glacial-interglacial chronology. Southern species are found as fossils on the lowest terrace from San Diego northward to Santa Monica. They are absent farther north in Southern California and it has been suggested that fossils from the lowest terrace near Santa Barbara indicate a glacial period.[15] If southern species continue to be found as terrace fossils from San Diego to Santa Monica, particularly if they are found on more than one terrace in successive series, as in the San Pedro Hills, and if collecting continues to reveal only terrace fossils of glacial aspect, again particularly on more than one terrace, northward from Ventura, still further doubt will be thrown on the glacial-interglacial value of the southern species, as it is altogether improbable that the terraces south of Santa Monica are interglacial, whereas those in Southern California northward from Ventura are glacial. The geographic frame-

[15] Grant, U. S., and Strong, A. M.: Fossil mollusks from the vertebrate-bearing asphalt deposits at Carpenteria, California: Southern California Acad. Sci. Bull., vol. 33, pp. 7-11, 1934. Fossils of similar climatic implication from the lowest terrace west of Santa Barbara are recorded by Oldroyd and Grant. Nautilus, vol. 44, pp. 91-94, 1931.

work of the coast may have some bearing on the distribution of the southern species. During a still undated part of Pleistocene time, doubtless during at least part of the time when the terraces of the San Pedro Hills were being formed, the Channel Islands, which lie northwest of the hills, were joined to the present seaward end of the Santa Monica Mountains, forming a peninsula that extended far out into the ocean. Evidence for this seaward extension of the Santa Monica Mountains is afforded by the Pleistocene elephants found in terrace deposits on two of the islands—Santa Rosa[16] and Santa Cruz.[17] This peninsula protected the area to the south, in which the San Pedro Hills lie, from southward-drifting cold coastal water, a matter that was considered by H. R. Gale[18] and by Davis.[19] The northern limit of the southern species coincides with the base of the peninsula, but it is not known whether the relation is a causal one.

If the lowest terrace in the San Pedro Hills is interglacial, it follows that the second and third also are, as they carry southern species and, so far as now known, are free of the embarrassment of northern species. The tide pool fossils on terraces above the third have no climatic implication. If new localities are found on these terraces on the leeward side of the hills they may reveal protected bay species that have some climatic implication. A discrete assignment of all the terraces to the recognized interglacial periods with appropriate uplifts needs strong supporting evidence to be convincing.

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[16] Stock, Chester, and Furlong, E. L.: The Pleistocene elephants of Santa Rosa Island, California: Science, vol. 68, pp. 140-141, 1928.
[17] Chaney, R. W., and Mason, H. L.: A Pleistocene flora from Santa Cruz Island, California: Carnegie Inst., Washington, Pub. 415, p. 20, 1930.
[18] Gale, H. R.: op. cit., pp. 39, 64.
[19] Davis, W. M.: op. cit., p. 1110.