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**PLEISTOCENE INVERTEBRATES FROM  
NORTHWESTERN BAJA CALIFORNIA  
DEL NORTE, MEXICO**

By

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ABSTRACT: Six fossil localities on marine terraces between the Tijuana Playas and Rosarito Beach have yielded 83 identified species of mollusks together with a few other invertebrate forms. The assemblages are small (43 molluscan species at the most diverse locality) but represent several distinctive environments: an exposed sandy shore or nearshore association; gravel shore or nearshore associations; and quiet-water lagoon or marine pond associations. Assemblages from elevations below about 100 feet include southern species and probably represent the Late Pleistocene Verdean Province. Assemblages from higher elevations, between 120 and 130 feet, do not include species that are sensitive biostratigraphic indicators within the Pleistocene.

**INTRODUCTION**

Road cuts and quarries associated with the construction of new roads between the International Boundary and Rosarito Beach, northwestern Baja California, contain exposures of fossiliferous marine Pleistocene strata (fig. 1). The fossils are largely mollusks and represent chiefly sandy-bottom associations not previously reported from this region. In this paper these invertebrate fossil associations are described, evidence is presented to support an interpretation of their environmental backgrounds, and their place in the Pleistocene of southern California and Pacific Baja California is discussed.

**PREVIOUS WORK**

Pleistocene marine fossil assemblages from the coastal region of Baja California at Rosarito Beach and northward have been reported previously (Valen-



tine, 1957), but these contain large proportions of rocky-shore species and are not similar to those recorded herein. To the north, in southwestern San Diego County, subtidal sandy and silty-bottom assemblages have been described from near the International Boundary (Emerson and Addicott, 1953; Valentine, 1961). Farther north in and near San Diego, numbers of relatively quiet-water, sand-to mud-bottom associations are recorded from the Pleistocene (especially by Arnold, 1903; Stephens, 1929; Grant and Gale, 1931; and Hertlein and Grant, 1944). To the south of Rosarito Beach, assemblages dominated by rocky-shore species are known from around Punta Descanso (Valentine, 1957), Punta China (Emerson, 1956), and other localities. The nearest quiet-water, sandy- or muddy-bottom Pleistocene associations known to the south are from Bahía San Quintín (Jordan, 1926; Manger, 1934; Valentine and Meade, 1961), but these are about 120 miles from Rosarito Beach.

#### PRESENT WORK AND ACKNOWLEDGMENTS

The localities described here were discovered by one of us (Rowland) during work on the fauna of the San Diego Formation in northwestern Baja California. They were collected by the authors during 1966. We are much indebted to Mr. John Minch for making available to us the results of his geological mapping in this region, and to Dr. Edwin C. Allison, Department of Geology, San Diego State College, for various courtesies. Mr. Douglas Bolstad helped calculate sediment curves. Figures were drafted by Mrs. Ruth Darden. Field work has been partially supported by a grant from the Research Committee, University of California, Davis.

#### STRATIGRAPHY AND GEOLOGICAL SETTING

The fossils are from marine terrace deposits which overlie platforms eroded on rocks of the San Diego Formation in the north at the Tijuana Playas and on Miocene volcanics (Minch, 1967) in the south near Rosarito Beach. Numerous terrace levels are present, rising in flights from the present beaches. They surely correspond in part to the terrace sequence described by Ellis (in Ellis and Lee, 1919) in San Diego County. However, even in the San Diego region field work has disclosed that the terraces are more complicated than depicted by Ellis (E. C. Allison, personal communication). We have not attempted to trace the fossiliferous terrace deposits beyond the region of the fossil localities.

The elevation of each locality was estimated by aneroid barometers. Base stations were established on the beaches, and local tidal data were utilized to establish the heights of the stations above mean sea level. Mean sea level is the datum for our elevations, which are probably accurate to within  $\pm 10$  feet.

The base of the fossil locality at the Tijuana Playa, A-236, has an elevation of about 51 feet (fig. 1). The fossils are exposed in a gully and cut adjacent to



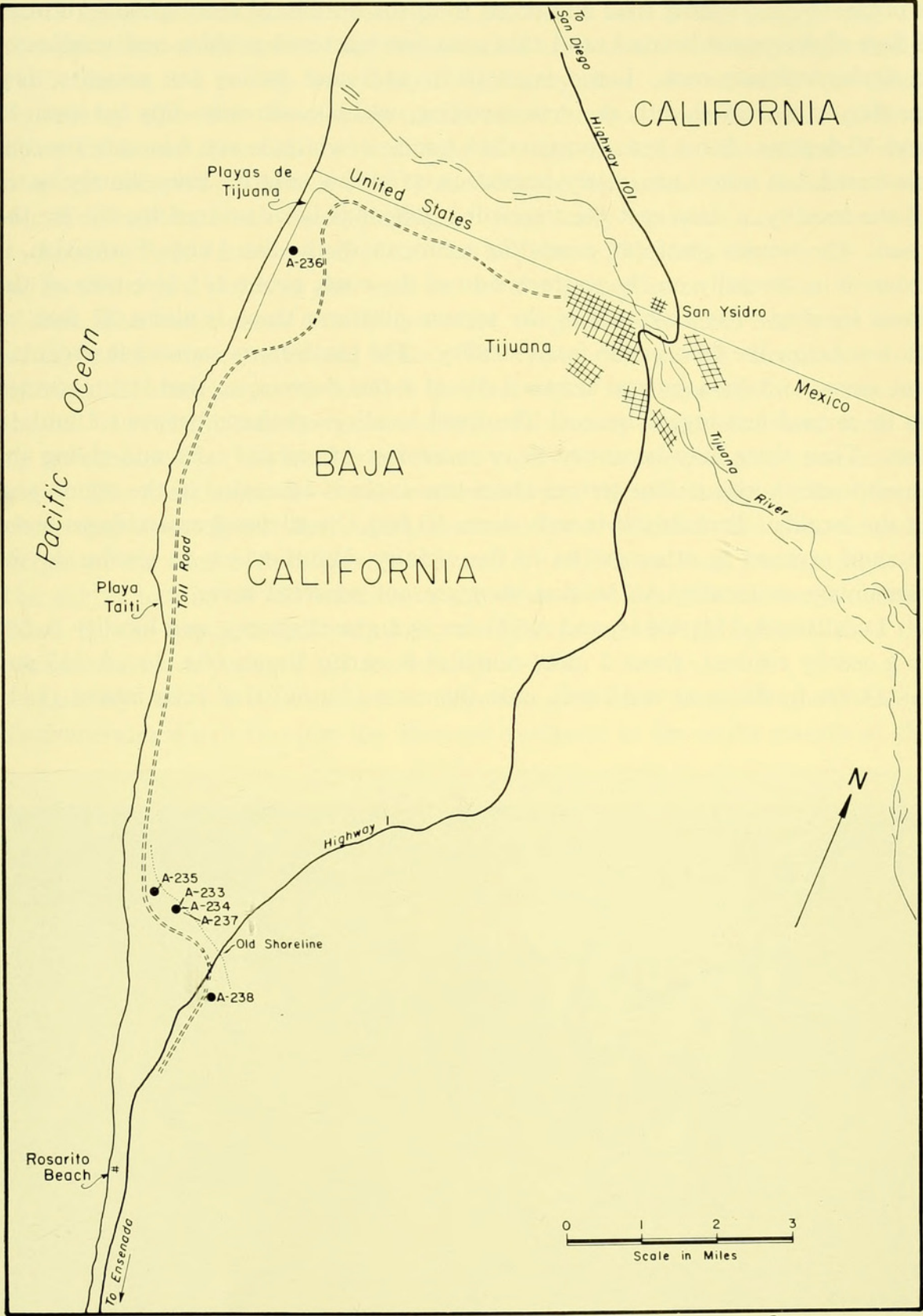


FIGURE 1. Index map of Baja California del Norte between Rosarito Beach and the International Boundary, showing the localities that yielded the fossil collections recorded herein.



a north-south trending road and occur from the bottom of the exposure through 6 feet of fine cross-bedded sand that contains scattered pebbles and cobbles of vesicular volcanic rock. Large fossil shells and sand dollars are present; they lie flat or are tilted with the cross-bedding, which commonly dips between 20 and 30 degrees. Some beds contain dark bands in which heavy minerals are concentrated, but others are nearly homogeneous in this regard. Immediately north of the locality, a deep east-west trending gully has been bridged by fill for the road. The terrace platform, eroded in sediments of the San Diego Formation, is exposed in the gully on the western side of the road, about 145 feet west of the fossil locality. The elevation of the terrace platform there is about 32 feet, or 19 feet below the base of the fossil locality. The platform is somewhat irregular, but seems to have a general seaward dip of a few degrees, so that it is expected to be several feet higher beneath the fossil locality—perhaps between 5 and 10 feet. Thus there may be about 10 or more feet of terrace sand underlying the fossiliferous horizon. The terrace shore line angle is concealed in the region east of the locality. Probably it is well above 60 feet. Small fossil assemblages occur in sand exposed in other gullies in the vicinity, but they are so similar to the assemblage at locality A-236 that they are not reported here.

Localities A-233, A-234, and A-237 are in a gravel quarry, and locality A-235 in a nearby roadcut, about 3 miles north of Rosarito Beach (fig. 1). A-233 and A-234 are in the same sand unit, near the crest of a hill that rises inland (east-



FIGURE 2. Northern (south-facing) wall of gravel quarry; locality A-233 is in white sands overlying the volcanics which make up dark wall face. Sands are overlapped by gravels which rest on the volcanics at the left. The quarry face is about 25 feet high at the left.



ward) from the road, and at the top of the north face of the quarry (fig. 2). The elevations of the lowest fossiliferous sands are 127 and 129 feet, respectively. The sediment is a poorly consolidated, light-gray, fine sand about 5 feet thick, overlain by alluvium. Fossils are concentrated in several shelly lenses about 6 inches thick and also scattered sparingly through the sand. The sediment rests on a unit mapped by Minch (1967) as Miocene volcanics. The surface of the volcanics exhibits much relief, sloping off irregularly westward and southward.

Locality A-235 is in a road cut in the hill about 250 yards west of the previous localities just north of the west end of the quarry at an elevation of about 98 feet. The fossils are in a medium to fine, conglomeratic sand, which has moderately and poorly consolidated lenses. The clasts are volcanic. Fossils are concentrated in lenses near the base of the cut, which was exposed in the summer and fall of 1966 but had been concealed by fill during subsequent road work by the spring of 1967. The sand is overlain by gravels interpreted as of non-marine origin. The gravels can be traced eastward along the north face of the quarry where they abut against the sloping surface of the volcanics and the westward margin of the sand of localities A-233 and A-234, which they overlap (fig. 2). The age of locality A-235 relative to the other two localities cannot be established by the exposed field relations, though we are of the opinion that the evidence favors a younger age for locality A-235.

Locality A-237 is at a still lower elevation of 80 feet in cobble and boulder conglomerates which lie upon the Miocene volcanics at the south margin of the



FIGURE 3. Southern margin of the gravel quarry; locality A-237. Note uneven surface of volcanics.



quarry (fig. 3). The surface of the volcanics is about 50 feet lower than atop the north quarry face beneath localities A-233 and A-234. Its temporal relation to the other nearby localities is not certainly established. The conglomerate may, for instance, be stratigraphically as well as topographically beneath the unit containing locality A-233, or may represent a later terrace. We favor the view that it is later and possibly related to the “non-marine gravels” that overlie localities on the north side of the quarry, but the field relations are equivocal.

Locality A-238 is exposed in a cut for an overpass foundation; the overpass crosses the Tijuana–Ensenada toll road about 2 miles north of Rosarito Beach and 1 mile southeast of the quarry (fig. 1). The elevation is about 122 feet, near the elevation of localities A-233 and A-234. Fossils are in a coarse to medium grained, poorly consolidated sand, the base of which is not exposed.

The general trend of raised terrace shore lines in the vicinity of locality A-236 at the Tijuana Playas is north–south, parallel with the present coast. In fact, the shallow-water habitats along the terraces were probably much like those of today, with exposed sandy beaches and rocky shores and slightly protected coves. However, north of Rosarito Beach the trend of the old shore lines turns inland, and when the sea stood between 80 and 125 or more feet higher than at present, the shore line trended southeastward from about 3½ miles north of Rosarito Beach for over a mile before turning southward again (fig. 1). Habitats in the lee of rocky points or other barriers could have been rather well-protected from waves along this southeasterly coastal stretch. The general trend of the terrace shore line is indicated on figure 1.

FAUNA

ASSOCIATIONS

Identified macrofossils are summarized by class or appropriate higher taxa in table 1 and listed by species in table 2. Microfossils are rare and were not

TABLE 1. *Summary of species diversity of fossil invertebrates, exclusive of microfossils, in collections from six localities in Northwestern Baja California, by classes or other high taxa.*

Taxa	Number of species						All collections
	A-236	A-233	A-234	A-235	A-237	A-238	
Bivalvia	17	19	23	18	6	20	45
Scaphopoda	1	0	0	0	0	0	1
Gastropoda	7	16	20	10	1	9	37
TOTAL MOLLUSCA	25	35	43	28	7	29	83
Cirripedia	0	2+	2+	0	0	1	2+
Echinoidea	1	0	1	0	0	1	1
TOTAL SPECIES	26	37+	46+	28	7	31	86+



TABLE 2. *Species from Pleistocene localities, Northwestern Baja California.*

Symbols: X, present; V, 1 specimen; R, 2-4 specimens; C, 4-8 specimens; A, 9-16 specimens; and S, 17 or more specimens; all per 100 specimens on sample.

Abundances based on mollusks only; other phyla judged subjectively using molluscan abundance scale.

Species	U. C. Davis localities					
	A-233	A-234	A-238	A-235	A-236	A-237
BIVALVIA						
<i>Glycymeris</i> cf. <i>G. subobsoleta</i> (Carpenter)	V	V	C		V	X
<i>Mytilus californianus</i> Conrad	R	R	V		V	
<i>Modiolus</i> cf. <i>M. modiolus</i> (Linnaeus)				V		
<i>Gregariella chenui</i> (Récluz)				R		
<i>Ostrea lurida</i> Carpenter	R	R	C	S		
<i>Pecten</i> cf. <i>P. vogdesi</i> Arnold				V		
<i>Plagioctenium circularis</i> (Sowerby)		V	V <sup>1</sup>	R		
<i>Leptopecten latiauratus</i> (Conrad)	R	V		V		
<i>Hinnites giganteus</i> (Gray)		V			V	
<i>Lima hemphilli</i> Hertlein and Strong				V		
<i>Anomia peruviana</i> d'Orbigny		V	V	R		
<i>Pododesmus cepio</i> (Gray)					V	
<i>Glans subquadrata</i> (Carpenter)	V					
<i>Luciniscia nuttalli</i> (Conrad)	V				V	X
<i>Diplodonta orbella</i> (Gould)				V		
<i>Kellia laperousii</i> (Deshayes)				V <sup>2</sup>		
<i>Mysella</i> cf. <i>M. aleutica</i> (Dall)		V				
<i>Pseudochama exogyra</i> (Conrad)				C <sup>2</sup>		
<i>Trachycardium?</i> cf. <i>T. quadragenarium</i> (Conrad)			V			
<i>Clinocardium?</i> species		V <sup>3</sup>				
<i>Tivela stultorum</i> (Mawe)	V	V	V		S <sup>2</sup>	
<i>Transenella tantilla</i> (Gould)	R	C	V	V		
<i>Saxidomus nuttalli</i> (Conrad)		V	V	V <sup>2</sup>	V	
<i>Chione fluctifraga</i> (Sowerby)	R	V	R			
<i>Chione gnidia</i> (Broderip and Sowerby)					V	
<i>Chione undatella simillima</i> (Sowerby)	A <sup>2</sup>	A <sup>2</sup>	C			
<i>Protothaca staminea</i> (Conrad)			V		R	V
<i>Petricola carditoides</i> (Conrad)					V	
<i>Spisula catilliformis</i> Conrad	V				V	
<i>Tresus nuttallii</i> (Conrad)		V	V	V	V	X
<i>Tellina bodegensis</i> Hinds	V				V	
<i>Tellina meropsis</i> Dall	A	R	R			
<i>Psammotreta biangulata</i> (Carpenter)		V		V		
<i>Macoma nasuta</i> (Conrad)	C <sup>2</sup>	C	C			X <sup>1</sup>
<i>Macoma secta</i> (Conrad)	V		V			
<i>Donax gouldii</i> Dall	C	R	A		C <sup>2</sup>	
<i>Sanguinolaria nuttallii</i> (Conrad)	R	C	R			X <sup>2</sup>
<i>Tagelus californianus</i> (Conrad)	C	R <sup>2</sup>	C			

<sup>1</sup> cf.<sup>2</sup> Some valves paired.<sup>3</sup> Found 20 yds. N. of main locality.



TABLE 2. (Continued)

Species	U. C. Davis localities					
	A-233	A-234	A-238	A-235	A-236	A-237
<i>Siliqua lucida</i> (Conrad)					V	
<i>Semele decisa</i> (Conrad)				R <sup>2</sup>		
<i>Semele rubropicta</i> Dall					V	
<i>Cumingia californica</i> Conrad		V		V		
<i>Cryptomya californica</i> (Conrad)	C	C	R		V	
<i>Corbula luteola</i> Carpenter		V				
<i>Hiatella arctica</i> (Linnaeus)				V		
SCAPHOPODA						
<i>Dentalium neohexagonum</i> Sharp and Pilsbry					C	
GASTROPODA						
<i>Acmaea digitalis</i> Eschscholtz	R			V <sup>1</sup>		
<i>Acmaea insessa</i> (Hinds)					V <sup>3</sup>	
<i>Acmaea mitra</i> Eschscholtz					R	
<i>Calliostoma doliarium</i> (Holton)	V	V				
<i>Tegula marcida</i> (Gould)					V	
<i>Pupillaria</i> aff. <i>P. parcipicta</i> (Carpenter)	S	S				
<i>Homalopoma carpenteri</i> (Pilsbry)					V	
<i>Epitonium cooperi</i> Strong		V				
<i>Littorina scutulata</i> Gould	R	V		R		
<i>Teinostoma supravallata</i> (Carpenter)	V					
<i>Caecum californicum</i> Dall				R		
<i>Aletes squamigerus</i> Carpenter		V				
<i>Bittium rugatum subplanatum</i> Bartsch	C	R	R			
<i>Seila montereyensis</i> Bartsch		V		V		
<i>Cerithidea californica</i> (Haldeman)	V	V	V	V		
<i>Crepidula adunca</i> Sowerby					V	
<i>Crepidula onyx</i> Sowerby	V		R	V		
<i>Crepidula princeps</i> Conrad						X
<i>Crepidatella lingulata</i> (Gould)		V		V		
<i>Neverita reclusiana</i> (Deshayes)	V <sup>1</sup>	V	V <sup>1</sup>			
<i>Mitrella carinata</i> (Hinds)	R	R	C			
<i>Mitrella tuberosa</i> (Carpenter)	R <sup>1</sup>	V				
<i>Nassarius fossatus</i> (Gould)					V	
<i>Nassarius mendicus cooperi</i> (Forbes)		R	R			
<i>Nassarius tegulus</i> (Reeve)			V			
<i>Olivella biplicata</i> (Sowerby)	V	R	R		R	
" <i>Cancellaria</i> " <i>tritonidea</i> Gabb		V				
" <i>Mangelia</i> " <i>variegata</i> Carpenter				V		
<i>Conus californicus</i> Hinds	V	C	R			
<i>Acteocina</i> cf. <i>A. inculta</i> (Gould)	R					
<i>Cylichna</i> ? species		V				
<i>Coleophysis carinata</i> (Carpenter)		V				
<i>Coleophysis harpa</i> (Dall)				V		
<i>Odostomia</i> cf. <i>O. helga</i> Dall and Bartsch				V		



TABLE 2. (Continued)

Species	U. C. Davis localities					
	A-233	A-234	A-238	A-235	A-236	A-237
<i>Odostomia</i> species		V				
<i>Turbonilla mörchi</i> Dall and Bartsch				V		
" <i>Paludestrina</i> " species?	R					
ECHINOIDEA						
<i>Dendraster excentricus</i> Eschscholtz	R	V	R		C	
CIRRIPEDIA						
<i>Balanus</i> species	A	A	C			
<i>Tetraclita</i> species	C	C				

identified. Unless stated to the contrary, the following discussion is based solely upon the mollusks. The assemblages range in molluscan diversity from seven species at locality A-237 to 43 at locality A-234. Bivalves considerably outnumber gastropods except at localities A-233 and A-234, where they slightly outnumber them.

In figure 4, all the pairs of collections from all localities except A-237 are compared to each other by Jaccard's coefficient. This coefficient measures the similarity between two collections by dividing the number of species common to the collections by the number of different species present in both collections. The properties of this coefficient are discussed by Sokal and Sneath (1963) and Fager (1963). One of its properties is to place much weight on differences in the number of species in the collections. For this reason the collection of only seven species from locality A-237 was not studied by Jaccard's coefficient, as no more than seven species could ever be common to A-237 and one of the other localities. From the similarity pattern among the other five localities (fig. 4),

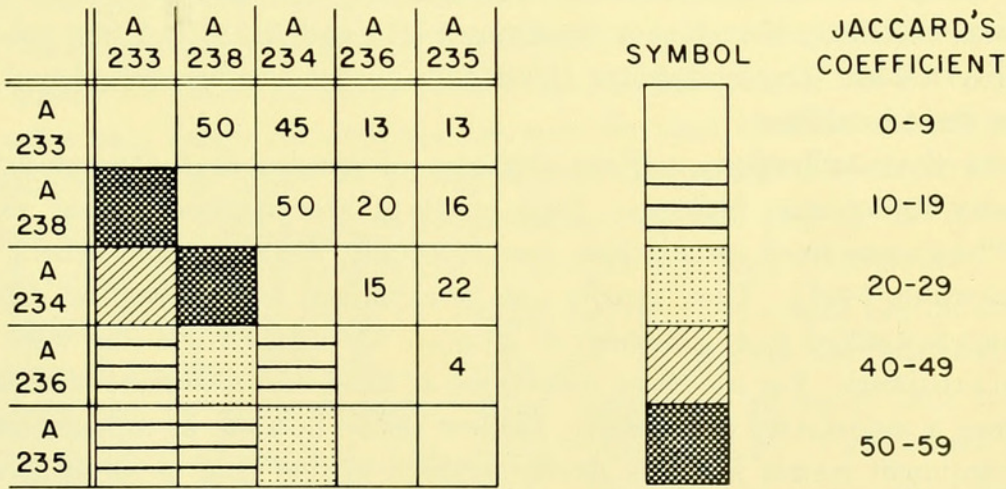


FIGURE 4. Trellis diagram showing pattern of similarity among the fossil collections, evaluated by Jaccard's coefficient.



TABLE 3. *Mollusks common to localities A-233, A-234, and A-238. Those that do not occur in other collections are indicated by an asterisk.*

BIVALVIA	BIVALVIA (continued)
<i>Glycymeris</i> cf. <i>G. subobsoleta</i> (Carpenter)	<i>Sanguinolaria nuttallii</i> Conrad
<i>Mytilus californianus</i> Conrad	<i>Tagelus californianus</i> (Conrad)*
<i>Ostrea lurida</i> Carpenter	<i>Cryptomya californica</i> (Conrad)
<i>Tivela stultorum</i> (Mawe)	
<i>Transennella tantilla</i> (Gould)	GASTROPODA
<i>Chione fluctifraga</i> (Sowerby)*	<i>Bittium rugatum subplanatum</i> Bartsch*
<i>Chione undatella simillima</i> (Sowerby)*	<i>Cerithidea californica</i> (Haldeman)
<i>Tellina meropsis</i> Dall*	<i>Neverita reclusiana</i> (Deshayes)*
<i>Macoma nasuta</i> (Conrad)	<i>Mitrella carinata</i> (Hinds)*
<i>Donax gouldii</i> Dall	<i>Olivella biplicata</i> (Sowerby)
	<i>Conus californicus</i> Hinds*

it can be seen that the diversity differences among the collections have not affected the clustering in ways that interfere with the interpretations. Only marine molluscan species were included in the calculations.

Collections from localities A-233, A-234, and A-238 exhibit high coefficients with each other and may represent approximately the same species associations. Coefficients of 45 to 50 such as present among these collections are nearly as high as experience indicates can be expected from small independent samples of the same moderately diverse shallow-water fossil assemblage (Valentine, in preparation). Relative species abundances are quite similar among these collections. Furthermore, these collections share 18 species (19 if *Neverita* is included), a high number considering their modest total diversities. The species in common are listed in table 3. Seven of them (probably eight), indicated by asterisks in the table, were not found in the other three collections. The species that are common to all three similar collections include the more abundant forms represented, except for the small trochid identified as *Pupillaria* aff. *P. parcipicta*, which was extremely abundant at localities A-233 and A-234 but was not found at locality A-238. The sand dollar *Dendraster excentricus* was also found at all three of these localities.

These three collections contain mixtures of species that characteristically live today in separate biotopes. Such mixtures are common among shallow-water Pleistocene fossil associations (see especially Woodring and others, 1946, and Valentine, 1961). They usually can be explained as representing death associations assembled from a number of separate life associations that were living in close proximity. For the three collections at hand, the dominant biotope may have been a moderately quiet-water, shallow sandy bottom, as represented now by the sediment matrix which is chiefly medium to fine sand at localities A-233 and A-234 and coarse to medium sand at A-238. According to collecting reports, many of the species prefer or tolerate substrates of this type, especially the bi-



valves, including *Chione fluctifraga*, *C. undatella*, *Tellina meropsis*, *Tresus nuttallii*, *Sanguinolaria nuttallii*, *Tagelus californianus*, and *Cryptomya californica*. Among the gastropods, *Neverita reclusiana*, *Olivella biplicata*, and *Conus californicus* are common in such habitats. *Dendraster excentricus* is also found chiefly on sandy substrates in moderately quiet to moderately turbulent water.

Some of the species suggest the presence of larger plants, perhaps eel-grass and marine marsh plants. *Cerithidea californica* is common on tidal marshes. *Pupillaria* aff. *P. parcipicta*, *Mitrella carinata*, and others of the small herbivorous gastropods frequent algal or cryptogam stands, as does *Leptopecten latiauratus*.

*Macoma nasuta* is a common species at these localities, but this form is recorded as living only on muddy or mixed sandy and muddy bottoms. It is a deposit feeder and evidently requires a large supply of fine detritus. Turbulent water will prevent deposits of fine detritus from accumulating, and since finer organic material ordinarily settles with the clay-sized sediment particles, the virtual absence of clay in a matrix with common *Macoma nasuta* (fig. 5) is puzzling. It is possible that the sediment was formerly more clayey and has been winnowed, though there is no special evidence of this. It has been suggested by Dr. Charles Stasek (personal communication) that in areas where abundant organic detritus is persistently supplied by tidal currents, *Macoma nasuta* might be able to live in sand. Certainly in regions where tidal waters are nearly free of mud, there would be little sedimentary evidence of organic tidal deposits, which would be ephemeral geologically. It is also possible that *M. nasuta* was formerly able to feed in part or entirely as a suspension feeder, as do numbers of the tellinaceans (see Pohlo, 1966; Maurer, 1967). Or it may simply be that shells of *Macoma nasuta* were washed onto these ancient sandy substrates from muddy areas nearby that were normally more protected from currents. In this case, some of the shells of other forms that tolerate muddy bottoms, such as *Tagelus californianus*, *Cumingia californica*, and some or all forms of *Chione* may have lived in muddy substrates also. However, the abundance and good condition of *Macoma* at all three localities, one of which is a mile from the other two, makes this explanation seem the least credible. At any rate some explanation seems called for to account for the persistent presence of *Macoma nasuta* in Pleistocene sandy-bottom associations, not only in the collections at hand, but at numerous localities in California and Baja California.

Rocky or shelly intertidal or shallow subtidal substrates are indicated by a number of species which are generally rare, as *Mytilus californianus*, *Acmaea digitalis*, and *Littorina scutulata*. These forms have probably been transported to the depositional site from more exposed shores nearby. *Calliostoma doliarium* may have been transported from offshore kelp or from rocky-shore seaweeds or rocks.



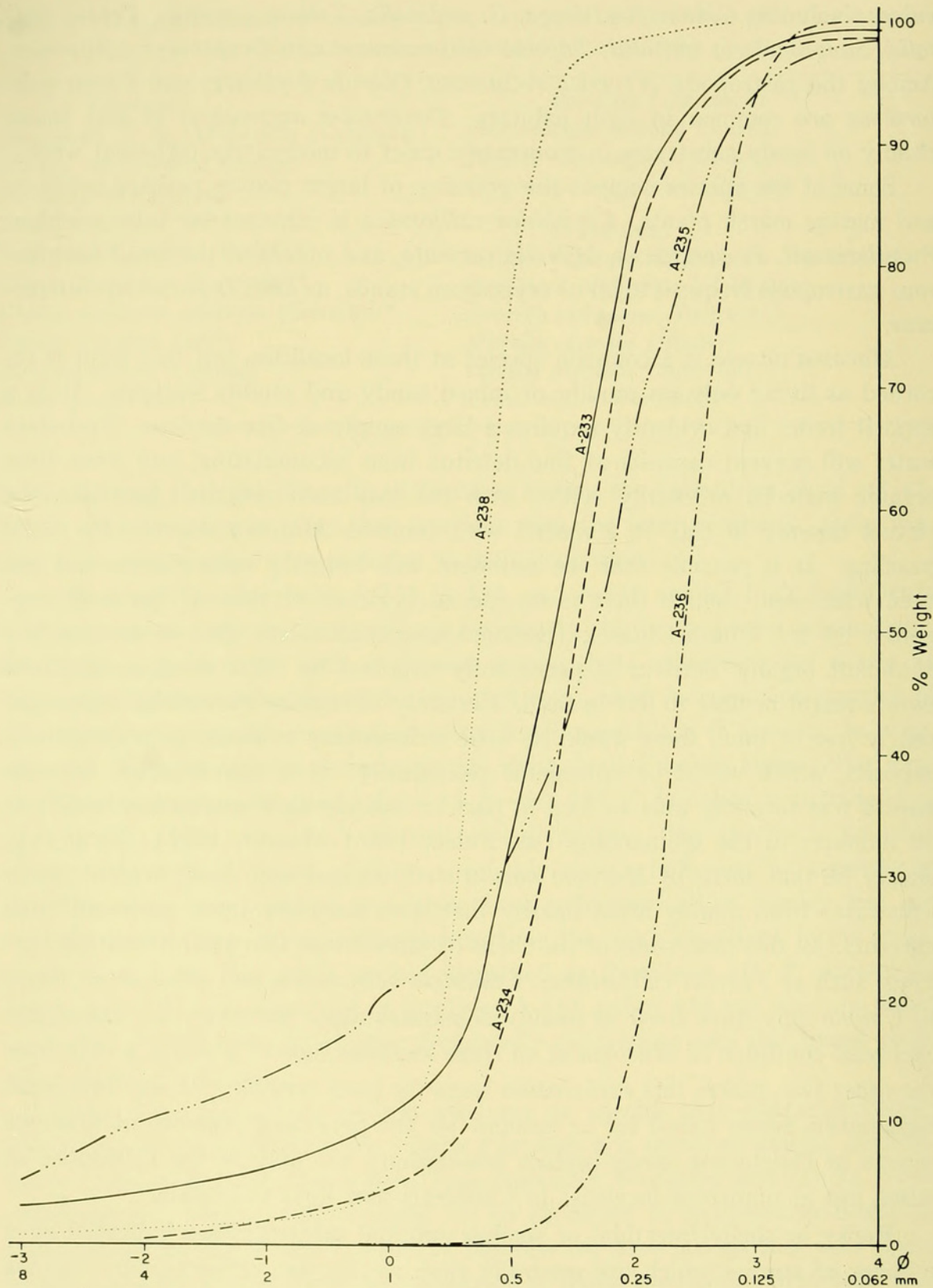


FIGURE 5. Cumulative size-frequency curves of matrix from fossil localities.



One additional element deserves special comment. The suspension-feeding bivalves *Tivela stultorum* and *Donax gouldii* are present at all three localities, yet they are typically inhabitants of shallow nearshore zones along exposed sandy beaches. In a study of statistically bonded species' associations in the California Pleistocene record (Valentine and Mallory, 1965), *T. stultorum* and *D. gouldii* each were found to occur significantly often (at the .001 level) with a large number of species that obviously formed a quiet-water association. This was interpreted as owing to the consistent presence of sand barriers to protect the quiet-water forms from waves which at the same time provided exposed sandy-beach biotopes on their seaward sides. Storms would naturally tend to mix the windward exposed-shore shells into the leeward quiet waters. Warme (1966) has found that this situation is common at Mugu Lagoon, where shells of *Tivela* and *Donax* wash over the barrier bar into lagoonal biotopes. A similar situation probably accounts for *Tivela* and *Donax* in the present collections. The shells in the collections are small, especially of *Tivela*, and often chipped or broken. Probably the rocky-shore shells represent washover material also.

Thus, although a number of habitats have contributed shells to the fossil assemblage, they are habitats that would not be unusual as contributors to a sand-bottom lagoon assemblage.

Each of the other localities contains a rather distinctive association. The collection from locality A-235 is characterized by epifaunal rather than infaunal bivalves—two mytilids, an ostreid, three pectinids, an anomiid, and a chamid, for example. This is in keeping with the conglomerate sediment which suggests a former cobbly gravel substrate. The infaunal bivalves that do occur are mostly recorded as being tolerant of such a habitat, and one of them, *Semele decisa* may prefer it (Burch, 1944–1946). The sandy portion of the matrix (fig. 5) is mostly a medium to fine sand with less than 2 percent by weight finer than sand size. At least one of the species (*Cerithidea californica*) has evidently been transported from another habitat. Probably this is a shallow subtidal gravel association.

Locality A-236 is in a very well-sorted fine to very fine sand but appears to represent nearshore sands off an exposed beach. *Tivela stultorum* and *Donax gouldii* are common or abundant, occasionally paired, and represented by some large (for the species) well-preserved valves. *Dendraster* is also common. Some of the rarer shells are of forms that tolerate such biotopes (*Protothaca staminea*, *Tellina bodegensis*, *Siliqua lucida*, *Nassarius fossatus*) but others have evidently been assembled from separate habitats (*Acmaea mitra* and *Homalopoma carpenteri* perhaps from rocky shores, *Acmaea insessa* and *Tegula marcida* perhaps from large brown algae, and so on). The association is certainly not unusual for a death assemblage along exposed shores.

The matrix of locality A-237 is a cobble and boulder gravel with closely-



packed clasts. A sediment sample was not collected. Most of the bivalves are badly broken, but *Lucinisca nuttalli* was collected in good condition and an excellent specimen of *Sanguinolaria nuttallii* was found with valves articulated. The large extinct calyptreid *Crepidula princeps* is common. Most of the specimens are badly broken, with only the thick internal deck preserved. There is little doubt about the identification, however, as the deck characters—thick, with a single broad sweeping asymmetric indentation and an adapertural furrow corresponding to the apex of the indentation (Woodring and others, 1946, p. 70)—are definitive. It is possible that these large suspension-feeding forms were living on subtidal cobbles or boulders now represented by conglomerate clasts.

#### GEOGRAPHIC RANGES

For many years the Californian Pleistocene has been correlated chiefly on the basis of the presence of southern or northern elements, usually interpreted as warm- or cool-water indicators. As knowledge of the fauna has grown the picture has become increasingly complicated and the thermal interpretation less clear. However, the presence of some elements that are extralimital today still seems to have stratigraphic significance locally. The present collection contains both northern and southern species (table 4). The northern forms all range at least to the San Diego-Tijuana region or to South Coronado Island, and thus their fossil occurrences are very near their present southern range end-points. The southern species, on the other hand, are not known to live in the Californian province at all today, but seem restricted to the Panamanian region and to the coast of southwestern Baja California south of Cedros Island, the Surian province of Valentine (1967).

#### GEOLOGIC RANGES AND AGE

The terms Upper and Lower Pleistocene as employed herein refer to the California sequence, which has been worked out chiefly in the San Pedro district and nearby coastal regions of southern California. There, sediments termed Lower Pleistocene are chiefly thick basin deposits that have been deformed. Sediments termed Upper Pleistocene are chiefly terrace veneers, relatively undeformed, that locally lie unconformably upon Lower Pleistocene strata. Deformation of the Lower Pleistocene rocks is associated with a "Mid-Pleistocene Orogeny." The low terrace platforms of northwestern Baja California do not truncate badly deformed Lower Pleistocene rocks. Nevertheless they seem as if they are southern continuations of the low Upper Pleistocene terraces of southern California and it is a reasonable working hypothesis that they are of Upper Pleistocene age.

In addition to extralimital forms that are extinct locally, Pleistocene assemblages contain a few forms that are not known to be living, and some of these characterize biostratigraphic units. Two species in the collections at hand



TABLE 4. *Species that are recorded living today only to the north or only to the south of the fossil localities, or that are not known to be living.*

<i>Southern species</i>	<i>Present range</i>
<i>Pecten vogdesi</i> Arnold	Magdalena Bay, Baja Calif. to Peru (Keen, 1958).
<i>Chione gnidia</i> (Broderip and Sowerby)	Cedros Island, Baja Calif. to Peru (Keen, 1958).
<i>Northern species</i>	<i>Present range</i>
<i>Mysella aleutica</i> (Dall)	Bering Sea to So. Coronado Is., Baja Calif. (Dall, 1921; U.C.L.A. Coll. no. 20328).
<i>Spisula catilliformis</i> Conrad	Bering Sea to San Diego, Calif. (Dall, 1921).
<i>Semele rubropicta</i> Dall	Forrester Is., Alaska to "Tia Juana" (beaches?) (Dall, 1921).
<i>Calliostoma doliarium</i> (Holten)	Afognak Is., Alaska to San Diego (Burch, 1946, no. 58, p. 1-2).
<i>Bittium rugatum subplanatum</i> Bartsch	Monterey to Coronado Is., Baja Calif. (Burch, 1945, no. 57, p. 30).
<i>Turbonilla mörchi</i> Dall and Bartsch	Monterey to So. Coronado Is. (Burch, 1946, no. 61, p. 32).
<i>Extinct species</i>	<i>Fossil distribution</i>
<i>Crepidula princeps</i> Conrad	Miocene to Pleistocene, including the U. Pleistocene of the San Pedro region (Grant and Gale, 1931; Woodring <i>et al.</i> , 1946).
" <i>Cancellaria</i> " <i>tritonidea</i> Gubb	Pliocene and Pleistocene, including the U. Pleistocene of the San Pedro region (Grant and Gale, 1931; Woodring <i>et al.</i> , 1946).

are believed to be extinct (table 4). Both are reported most frequently in the Pliocene and Lower Pleistocene but have been found in the Upper Pleistocene as well. The assemblages are essentially Recent in aspect, and would be expected to contain other extinct elements if as old as Pliocene. The two southern species are members of the "*Dosinia ponderosa* element" (Valentine, 1961) which is certainly identified only from the Upper Pleistocene of Baja California del Norte and of southern California south of the Santa Monica Mountains. This region embraces the Late Pleistocene Verdean molluscan province. The presence of a few northern forms intermixed with such southern species is not uncommon, and is in fact characteristic of the province. Thus, from all lines of evidence, an Upper Pleistocene age seems most likely.

CONCLUSIONS

The preceding evidence may be interpreted and synthesized into an historical model. At some time in the Late Pleistocene, the sea stood somewhat above 130



feet higher than today relative to the land between Rosarito Beach and the International Boundary. The shore line at that time lay somewhat to the east of its present position but had nearly its present character, except in the extreme north where an embayment centered near the mouth of the Tia Juana River, and in the south, where the coast was embayed in the vicinity of Rosarito Beach. The shores of the Rosarito Beach embayment were generally sandy, and in some regions spits or other sand barriers provided wave protection to coastal lagoons or marine ponds of unknown plan. The exposed sides of the sandy barriers supported such forms as *Tivela stultorum* and *Donax gouldii*, while more quiet-water forms such as species of *Chione* and *Macoma* lived in the protected sediments in the lee of the barriers. Stands of algae and/or eel grass in the lagoons or ponds supported what seems to be an epiphytic element that included small gastropods; *Pupillaria* was abundantly included in sediments at the present quarry site; *Mitrella* was common especially near locality A-238; and other small forms were present. There is no indication that the temperature of the protected waters was different from similar habitats in this general region today. The assemblages, however, are small. The extinct "*Cancellaria*" *tritonidea* was found, probably in a lagoonal association.

Sea level then fell and when it stood near 100 feet above its present level a shallow nearshore or beach deposit of gravelly sands was developed on the volcanic platform of the gravel pit. Destruction of the morphology of the 130-plus-foot nearshore features there was probably substantially accomplished by this time. The fauna is predominantly epifaunal and includes the markedly southern species *Pecten vogdesi*, suggesting the possibility of waters warmer than at present. It is possible that the cobble and boulder gravel containing *Crepidula princeps* dates from about this time, or it may be younger. Later, gravels were washed onto the terrace sediments, probably by streams, and the *Crepidula* gravel clasts may be derived from this source.

Further reductions in sea level led to the development of a rather extensive terrace which is chiefly below 75 feet. This is commonly the lowest well-defined marine terrace level along this coast, and it is deposits on this terrace that yielded the assemblages described by Valentine (1957). These assemblages are chiefly of rocky-shore species, but consistently include exposed sandy-shore forms as a minor constituent. Evidently this is the same terrace that has yielded the exposed sandy shore or nearshore assemblage at locality A-236. The Surian and Panamanian species *Chione gnidia* at A-236 suggests that waters may have been warmer than today, at least at times. Southern species are also recorded among the rocky shore assemblages.

The lower assemblages thus resemble typical Verdean Province associations and can be tentatively correlated with the Palos Verdes Sand or low terrace deposits at Palos Verdes Hills that also contain such associations. The ages of



typical Verdean assemblages have been estimated as around 115 to 140 thousand years b.p. by radiometric methods (Fanale and Schaeffer, 1965). The higher assemblages—the coastal lagoon faunas—probably are earlier. Whether or not they antedated the appearance of southern elements that typify the Verdean is not known.

#### DESCRIPTION OF FOSSIL LOCALITIES

- U.C.D. Locality A-233. The westernmost exposure of buff sands about 5 feet stratigraphically above volcanic beds, at the eastern end of the south-facing wall of the gravel quarry located just north of the Tijuana–Ensenada toll road approximately 0.9 miles north and west of its most northerly intersection with Mexican Route 1.
- U.C.D. Locality A-234. Sands from the same horizon as A-233, but 40 feet eastward near the extreme eastern end of the gravel quarry.
- U.C.D. Locality A-235. Conglomeratic sands in the northern cut along the toll road west of the gravel pit described in A-233. Exposure just north of the northern quarry face.
- U.C.D. Locality A-236. Sands in a west-facing stream cut about 50 feet southeast of the intersection of North–South coastal road with the stream draining the central portion of the Tijuana Playas in the central region of the Tijuana Playas about 1.0 mile south of the International Boundary.
- U.C.D. Locality A-237. Basal two feet of a conglomerate bed at the eastern end of the northwest-facing wall of the gravel pit containing localities A-233 and A-234.
- U.C.D. Locality A-238. Sands in the east bank of the road cut 100 yards south of the southerly of the two bridges over the Tijuana–Ensenada toll road, where this road intersects Mexican Highway 1 about a mile east of the Rosarito Beach power station.

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