Paleoecology of the upper Miocene Castaic formation, Los Angeles County, California

Thesis by

Robert James Stanton Jr.

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Abstract

The Castaic formation comprises the upper Miocene marine sediments deposited in the Soledad Basin, northwestern Los Angeles County, California. The Soledad Basin is topographically the eastern extension of the Ventura Basin. Geologically, the two basins of deposition are separated by the San Gabriel fault along which an uncertain amount of lateral movement has taken place. Therefore, detailed correlation of the sediments of the Castaic formation with contemporary sediments of the Ventura Basin is not possible. The age of the Castaic formation is Mohnian and Delmontian. The sediments were deposited in part along an open coast and in part within a broad, open embayment.

Late Miocene movement on the San Gabriel fault, relatively up on the southwest, defined the western margin of the basin of deposition. A land mass on the west side of the fault northwest of Castaic, created the embayment of the northwest part of the basin. It is likely that a submerged extension of this land southeast of Castaic formed a sill along the western margin of the rest of the basin and restricted the circulation of bottom water.

The formation is about 7000 feet thick. It consists mainly of interbedded sandstone and mudstone. The two rock types occur in units 25 to 250 feet thick. Coarse-grained basal sediments were deposited at the margin of

the basin of deposition. Megafossils are largely confined to the basal sediments. The nature of the basal sediments deposited at the margin of the transgressing late Miocene sea **is** related to the provenance and the relief along shore. Conglomeratic basal sediments were deposited along the northeast margin of the basin along a steep shore composed of the well-indurated Martinez formation. These sediments were derived locally from the conglomerate and sandstone beds of the Martinez formation.

Sandy and thin conglomeratic basal sediments were deposited along the southeast margin of the basin. Near-shore relief was low. The sediments were derived largely from the finer-grained, less consolidated sediments of the Mint Canyon formation. The very coarse-grained, poorly-sorted Violin breccia was derived from a nearby source of considerable relief that was northwest of the embayment.

The fauna of the Castaic formation is largely molluscan. Other phyla are represented by one species of brachiopod, two species of echinoderm, a balanid, a bryozoan, foraminifers and fish remains--both bones and scales. Approximately 100 species are present. Probably new species of *Nerita*, *Colus* (*Anomalosipho*), *Marginella*, and *Arene* occur in the formation. Other forms in the Castaic formation previously unreported or rarely reported from upper Miocene sediments of California are *Anadara* (*Anadara*) *trilineata trilineata*, *Glycymeris* cf. *G. branneri*, *Chlamys hodgei*, *Spondylus* sp., *Eucrassatella* cf. *E. subgibbosa*, *Pseudochama* sp., *Corbula luteola*, *Periploma* cf. *P. discus*, *Tegula gallina*, *Calyptraea* (*Trochita*) sp., *Polinices* (*P.*) *uber*, *Oliva spicata*. The fauna is comparable to that found at present at the northern limit of the recent Panamic molluscan province.

All the near-shore assemblages in the formation are essentially contemporaneous. Faunal variations are indicative of environmental variations which existed along the margin of the basin. In particular, the geographic distribution of the fauna can be related to differences in water depth and substrate, and to environmental differences associated with bay versus open coast habitat.

Analysis of the fauna suggests that: oxygen content of the water was probably less than normal at the bottom of the basin; the water was of normal marine salinity; most of the megafauna and associated sediments were deposited in water less than 25 fathoms deep; the maximum depth of the sill which probably existed along the western margin of the basin was about 100 fathoms; the marine climate was apparently uniform geographically within the basin of deposition and was much like that found at present off the southwest coast of Baja California. The average maximum annual surface temperature was about 22°C. The average minimum annual surface temperature was about 19°C. The Castaic formation was deposited at the northern limit of the late Miocene Panamic molluscan province.

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Two faunal lists.

I. Introduction

Objective

The objective of this thesis is to study within the framework of west North American Cenozoic geology two aspects of paleoecology:

1. The applicability of a detailed study of the megafossils contained in a sedimentary unit in order to determine the environment of deposition; in particular, the usefulness of the assemblage as the unit of analysis, and the degree to which faunal variations can be related to environmental variations.
2. Paleozoogeography as it applies to the determination of paleoclimate, and the usefulness of the assemblage rather than the genus as the unit of analysis.

The upper Miocene Castaic formation has been studied and the fauna contained in it has been critically analyzed in order to fulfill this objective. The Castaic formation was chosen as a model for the following reasons:

1. Fossil localities could be related easily to one another and the sedimentary framework because of few structural complications.
2. The megafauna is adequately varied and plentiful, and large variations in the geographic distributions of forms were suggestive of correspondingly large ecologic variations.

Work done

Field work was done intermittently from June 1956 to August 1959. Most of the mapping and collecting was done during 1956 and 1957. Attention has been concentrated on the faunal and sedimentary details of the basal sediments of the Castaic formation. The fossils were prepared and identified during 1957 and 1958. This report was prepared during 1959. An original intention was to analyze the fauna geochemically, but this proved not to be feasible because of insufficient well preserved material.

Field area

The Castaic formation crops out in a series of discontinuous patches in a northwesterly aligned belt, the southeast end of which is several miles east of Newhall; the northwest end is about ten miles north of Castaic. The most complete exposure of the formation is north of Castaic and Elizabeth Lake Canyon. It is this area that has been studied in most detail.

All parts of the formation can be easily reached by several main highways in addition to numerous other roads. Probably any part of the formation can be reached in less than an hour by walking. Relief is moderate to high. Steep slopes are commonly developed by the incising, predominantly intermittent, streams.

Vegetation is typical of the low coastal mountains of southern California--thick chaparral up to 8 feet high everywhere except on terraces and valley floors that have been cultivated. Sycamore and oak trees are common along canyon bottoms. The thick cover of brush is the greatest obstacle to field work.

Previous work

The geology of the eastern part of the Ventura basin has been studied by numerous persons, largely within the last 50 years. There are three reasons for the greater than average interest shown in this area:

1. The occurrence of petroleum in correlative sediments in the Ventura Basin west of the San Gabriel fault.

2. The convenient location near the universities of the Los Angeles area.

3. The presence of interbedded marine and nonmarine sediments which are important in the correlation of the local marine and nonmarine sections.

As a result, many papers on the geology of the area exist both in the published literature and as theses in the local university libraries. Those papers which have been most pertinent to this study are discussed below in terms of the extent to which each has been utilized.

Kew (1924) in a reconnaisance study of parts of Ventura and Los Angeles Counties mapped the Castaic formation (as "Modelo?") south of 34^{o} 31' at a scale of 1:62,500. He lists, p. 68, a small fauna which he collected between Haskell and Dry Canyons, and which B. L. Clark identified. This paper has been of little use in this, more detailed, study.

A number of papers have been concerned primarily with the age relationships of the Castaic and Mint Canyon formations. Those that contain faunal lists or mention correlatively important elements of the Castaic fauna are by Woodring (1930), Maxson (1938), Stirton (1933), Wright (1948), White and Buffington (1948), Jahns (1940) and Durham (1948). All these papers report collections made from outcrops of the Castaic formation south of Dry Canyon. The paper by Wright (1948) is based on a study of the fauna collected in Reynier Canyon and was submitted by him as a PhD minor thesis in 1951. This thesis has proven to be useful, although a restudy of the collection has resulted in numerous changes, so that the faunal list in this report is different than that presented by Wright. The paper by White and Buffington is the result of work done for M.S. theses submitted in 1947. In these cases too, collections have been restudied and faunal lists have been revised. Maps accompanying these two theses, and that of Martin (1947), illustrate the distribution of the formation between San Francisquito and Bouquet Canyons. The three maps differ in detail only. A composite of the three based on field checks has been used in this paper. The

San Francisquito Canyon-Dry Canyon area, however, has been remapped.

Clements (1932) mapped a large area north of that mapped by Kew (1924). The area includes the northern part of the outcrop area of the formation. Because the work was of a reconnaissance nature, the stratigraphic subdivisions were large and little is written of sedimentary variations within the Castaic formation. Some faunal collections were made but were only partly identified and listed. Little use was made of this paper; Clements' collections, however, were of value.

M. S. theses by Pfaffman (1941), Jackson (1952), and Dehlinger (1950) deal with the Castaic formation exposed north of Castaic and Elizabeth Lake Canyon. They have been used very little in this study. Dort (1948), Smith (1948), and MacNeill (1947) have mapped the Castaic formation south of Bouquet Canyon. Their maps have been field-checked and several areas have been remapped. The map accompanying this report, however, is essentially the same as theirs.

Wright (1943) mapped the Mint Canyon-Castaic contact. He mapped the San Francisquito Canyon-Elizabeth Lake Canyon area differently than did either Ruiz-Elizondo (1953) or the Cal Tech geology summer field camp in 1947. Of the three maps, that from the field camp is most accurate. This map has been used in Charlie Canyon. The rest of the area between San Francisquito and Elizabeth Lake Canyons has been remapped.

Papers by the following authors have been of value in understanding the regional setting of the Castaic formation: Eaton (1939), Crowell (1952), (1954a),(1954b), Jahns and Muehlberger (1954), Winterer and Durham (1954), and Muehlberger (1958).

Ecologic and zoogeographic data have been gathered from many sources. Those which have proven most generally valuable are: Keen (1958), Burch (1944-46), MacGinitie and MacGinitie (1949), Ricketts and Calvin (1952), Bandy (1958), and Hertlein and Strong (1940-51). In addition, pertinent references for particular species can be found in Chapter VIII.

Regional setting

The Castaic formation occurs on the east side of the San Gabriel fault within the Soledad Basin. This basin, geographically the eastward continuation of the Ventura Basin, is related geologically to the Ventura basin; the degree of relationship depends upon the amount of lateral movement that has taken place along the San Gabriel fault. The Soledad Basin is bounded on the north, east, and south by pre-Tertiary crystalline rocks. It probably did not exist as a distinct basin of sedimentation prior to the deposition of the Vasquez formation, but was important as such from that time until middle-Pleistocene time. The orientation of the Soledad Basin is parallel to that of the Transverse ranges. In contrast, the Ridge Basin is parallel to and is more clearly related to the San Gabriel fault, which cuts diagonally across the regional structural trend of the Transverse ranges. Sedimentation along the east side of the San Gabriel fault began during late Miocene time and continued through late Pliocene time.

The oldest sediments occurring east of the San Gabriel fault are 12,000 feet of clastic sediments referred to the Martinez formation in the literature because of the presence of Paleocene marine invertebrate fossils correlative with those found in the Martinez formation of the Coast ranges of central California. These sediments have no other connection with the typical Martinez formation. The name has been applied to them in a time sense based on faunal comparison. The extension of Pacific coast formation names to have time significance has come about naturally enough because of the problems of correlation in attempting to apply the standard Tertiary stage-age names typical of Europe. It is undesirable, however, because superpositional control between Tertiary Pacific coast lithologic units is inadequate in many cases, and because the distinction between time units and rock units is likely to be ignored through ill-defined terminology. Nevertheless, the term Martinez will be used in this report because the strata have not been studied in the detail necessary for renaming them.

Crowell (1954b) states that the sediments referred to the Martinez formation are Paleocene and Eocene in age. There is no published account of Eocene fossils found within the formation. Pfaffman (1941), Simpson (1934), and Johnson (1952) have reported finding fossils only within the lower part of the Martinez formation. Thus, considering the thickness of the formation, the upper part may well be Eocene in age.

Pfaffman (1941) concluded from a study of clasts in the formation that it was derived from a source to the north-northwest. Conglomerates are found only in the northwest part of the outcrop area, where the thickest section is also found. The basal contact of the Martinez formation is exposed for a short distance in the upper reaches of Castaic Creek north of the Clearwater fault. Elsewhere the Martinez formation is in fault contact with the older, crystalline, rocks. Sediments that have also been referred to the Martinez formation occur within the San Andreas fault zone at Valyermo, south of the San Gabriel fault zone north of Sunland, and in the Santa Monica mountains and Simi hills. Paleocene sediments are not found on the north flank of the Ventura basin, west of those being described, although if the Martinez formation is in part Eocene, these may be correlative in part with Eocene strata to the west. Considering the possibly large amount of lateral movement on the San Andreas and San Gabriel faults, the present distribution of the Martinez sediments indicates little concerning the original distribution east of the San Gabriel fault. Crowell (1954b) and Jahns and Muehlberger (1954) however, believe that the Martinez formation was deposited over vast areas. If so, considerable erosion took place prior to the deposition of the Vasquez formation in the Soledad Basin. The Soledad Basin as such originated with the deformation and erosion that followed the deposition of the Martinez formation. The Vasquez is the oldest formation found localized within the basin.

Mudstone, sandstone, and conglomerate are present in the Martinez formation. The mudstone is generally olive gray, relatively nonresistant and noncalcareous, and occurs as thick units or as beds several feet thick between sandstone beds. The sandstone occurs in massive beds as much as 10 feet thick. It is well-bedded, well-sorted, medium-to coarse-grained, and silica-cemented. Johnson (1952) reported the composition of four samples as follows:

	Percent Range	Average Percent
Quartz	35-52	44
Microcline and Orthoclase	2-9	6
Plagioclase	Tr	Tr
Biotite	4-9	6
Chlorite	0-5	2
Opaque minerals	Tr-1	1
Interstitial clays	25-50	35

The quartz grains are slightly rounded with no secondary overgrowths.

A sample collected at Locality 7-7-21 had the composition: Quartz, 45 percent; feldspar, 15 percent; rock fragments (fine-grained igneous types), 15 percent; mica, 5 percent; interstitial clay, 20 percent. The matrix is clay with some silt-size shreds of biotite.

The conglomerates are the most interesting sediments of the formation. They are perhaps best exposed in Fish Canyon along the road from Castaic Canyon to Cienaga Camp Ground. They are hard, well-cemented cobble-pebble conglomerates. The rock generally breaks across the clasts. The cobbles are well-rounded, spherical, and are most commonly four to eight inches in diameter. Johnson (1952) reports that the composition of the clasts is:

	cobbles	pebbles
quartzite	40 percent	60 percent
volcanic rocks	30 percent	20 percent
gneiss and leucocratic plutonic rocks	30 percent	20 percent

The volcanic rocks are dacite or quartz latite.
10 percent contain clear euhedral quartz phenocrysts.
15 percent contain slightly altered orthoclase and plagioclase phenocrysts.
75 percent are microcrystalline devitrified glass with flow structures.
The phenocrysts are 2-4 mm. across.
The granitic rocks are quartz diorite or biotite granite.

North of Elizabeth Lake Canyon, the Castaic formation lies unconformably upon the Martinez formation, and its composition is clearly related to that of the underlying Martinez.

After the deposition of the Martinez formation, deformation, uplift, and erosion occurred, followed by the deposition of the nonmarine Vasquez formation. Preservation of Martinez sediments in only a small down-faulted block indicates that erosion was considerable. In large part, the Vasquez formation lies upon the crystalline basement. The time span occupied by the erosion and deformation of the Martinez formation and the deposition and subsequent deformation and erosion of the Vasquez formation is not known precisely. The early limit is uncertain because the age of the upper part of the Martinez formation is unknown. The end of the span is marked by the deposition of the nonmarine lower Miocene Tick Canyon formation. The Vasquez formation is generally considered to be questionably Oligocene, corresponding in whole or in part to the Sespe formation of the Ventura Basin. Deposition of the Vasquez formation was largely within several fault-bounded basins. The formation consists of coarse clastics in general, but differs in detail from basin to basin. Interlayered with the sediments are andesite and basalt flows and sills with an aggregate thickness of several thousand feet. The local nature of deposition is illustrated by the presence of volcanic rocks in only one of the three basins (Muehlberger, 1958, p. 1823). The Castaic formation is in contact with the Vasquez formation in only a small area between Elizabeth Lake and San Francisquito Canyons. The nature of the deposition of the Castaic formation was relatively unaffected by the distribution of the Vasquez formation.

The lower Miocene Tick Canyon formation unconformably overlies the Vasquez formation in the Mint Canyon area. It is several hundred feet thick, nonmarine, and is composed of sandstone, siltstone, and a basal cobble-boulder conglomerate. The formation is present in several small patches disconformably beneath the Mint Canyon formation. Its distribution did not affect the deposition of the Castaic formation.

The upper Miocene nonmarine Mint Canyon formation, on the other hand, is of considerable importance in the history of the Castaic formation. It underlies the Castaic formation with a slight angular unconformity in the southern part of the outcrop area. The Mint Canyon formation consists of clastic sediments with some intercalated tuffs. In comparison with the underlying sediments, the Tick Canyon and Mint Canyon formations are much less deformed. They are also, in contrast, poorly lithified and consequently erode to form a badland topography.

The Castaic formation is overlain unconformably south of the Santa Clara River by the marine Towsley formation of upper Miocene and lower Pliocene age. Between the Santa Clara River and Elizabeth Lake Canyon, the Castaic formation is overlain unconformably by the upper Pliocene and Pleistocene nonmarine Saugus formation; north of Castaic, it is overlain conformably by the upper Miocene and Pliocene Ridge Basin group. The Towsley formation is mudstone and sandstone where it overlies the Castaic formation. The lower, marine sediments of the Ridge Basin group are, by comparison, massive, coarse-grained pebbly sandstone. They are contemporaneous with the Towsley formation but probably were deposited in part during the hiatus between the Castaic and Towsley formations. Early in the Pliocene epoch, the depositional environment of the Ridge Basin changed from marine to nonmarine, while that of the Soledad Basin probably remained marine until mid-Pliocene time; however, most of middle Pliocene time in the Soledad Basin is represented only by the Towsley-Saugus unconformity. During the time span represented by this unconformity, approximately 20,000 feet of sediments were deposited in the Ridge Basin. The contact between the Castaic formation and the Ridge Basin group has been arbitrarily drawn by Crowell (1954b) at the transition from the mudstone-sandstone section below to massive sandstones above. Dehlinger (1950, 1952) discriminates between the two formations in more detail. Crowell's and Dehlinger's maps, however, differ in minor respects as might be expected considering the interfingering relation. The marine-nonmarine transition can not be placed exactly, but lies within the Ridge Basin group. So, also, does the Miocene-Pliocene boundary, judging from the scanty faunal evidence.

The Violin breccia is contemporaneous and interfingers with both the upper part of the Castaic formation and almost all of the Ridge Basin group. Thus, it is both upper Miocene and Pliocene. Whether it is marine or nonmarine correlative with the Castaic formation and the marine section of the Ridge Basin group will be considered in the detailed discussion of the sediments. It is certainly nonmarine higher in the Ridge Basin group.

Structure

Few faults cut the Castaic formation. All are less than a mile in length, are approximately vertical, and do not fit into any clear cut pattern of orientation or movement. The age of most is indeterminable. The fault south of Solamint is post-Towsley, pre-Saugus, and parallels the nearby San Gabriel fault to which it is probably closely related.

The San Gabriel fault is the dominant structural feature of the Castaic formation as it is of all the sediments in the Ridge Basin. Movement is first recorded by the presence of Violin breccia along the east side of the fault, indicating that the land west of the fault was relatively high. The deposition of Violin breccia began midway during the deposition of the Castaic formation. It continued then contemporaneously with the Castaic formation and most of the Ridge Basin group. Crowell (1952, 1954a) has suggested that in addition to large vertical displacement, approximately 20 miles of right lateral movement has taken place on the fault. Considering the distribution of the Castaic formation in an elongate band bordered by the fault, movement concurrent with deposition would be reflected in the paleogeography, the environment, and the sediments and life in the late Miocene sea. Conclusions that can be derived from the fauna as to the amount of movement will be discussed in the chapter on Paleogeography.

II. Sediments

Introduction

The Castaic formation is composed entirely of clastic sediments. These can be divided into four members for the purpose of description, but the limits between these are gradational. In general, however, these four main members are easily recognized. They are:

1. Mudstone, occurring throughout the outcrop area and the stratigraphic section of the formation.
2. Mid-basin sandstone, found interbedded with the mudstone.
3. A complex of sandstone, pebbly sandstone, and conglomerate found along the east border of the outcrop area. This member comprises the basal sedimentation of the transgressing late Miocene sea. More or less present along the entire basal contact, this type of sediment is best exposed and most abundant along the east side of Castaic Canyon north of Necktie Canyon.
4. Violin breccia occurs along the northwest edge of the outcrop area next to the San Gabriel fault. This coarse-grained, poorly-sorted member is genetically related to the fault and is found only within about one-half mile of it.

The types of sediment will be considered below in more detail.

Mudstone member

Mudstone is the most abundant sediment in the Castaic formation. Its characteristics are uniform throughout the formation north of Soledad Canyon. South of Soledad Canyon, it is more or less diatomaceous. The mudstone occurring in the northern part of the outcrop area is silty claystone with as much as 10 percent sand; it is olive gray (5Y 4/1) and weathers to pale- to moderate-yellowish brown (10YR 6/2 - 10YR 5/4); unweathered, it is calcareous and contains a meager fauna of foraminifers and mollusks; many of the foraminifers are filled with pyritic material; bedding is variable, laminated to massive. The color is a constant feature. The texture, however, is somewhat variable. Silty claystone is the most common textural type, but sand-size grains are distributed irregularly through the mudstone. Fine-grained sand is a common component of the mudstone; coarse-grained sand has been found only as a component of mudstone that is close to the basal contact--within one-quarter mile parallel to the bedding plane. The sand grains are floating within the mudstone; they are generally well disseminated but the coarse-grained sand occurs in some places concentrated in ill-defined lenses that are several inches long and less than 1 inch thick. The lenses are not bounded by any distinct surface; they only represent an increase in the amount of sand floating in the mud. Sand may comprise as much as 30 percent of such lenses. An indication of the size distribution of the sand is given by the following analysis. A sample from Locality 7-7-12 of approximately 4 cubic inches volume was sieved. The sample contained material from a sandy lense and from adjacent, less sandy mudstone. Twenty percent of the sample was sand; the remainder was silt and clay. The percentage size distribution of the sand component was:

very fine sand	27
fine sand	14
medium to coarse sand	54
very coarse sand	5
	100 percent

This analysis is typical for the mudstones deposited near the basal contact and illustrates the bimodal texture. Away from the basal contact, sand generally comprises less than 1 or 2 percent of the rock. The grains are angular to subrounded.

Fresh, unweathered mudstone is uncommon, having been found only along stream cutbanks where erosion is relatively rapid. It is faintly laminate, but the laminae differ apparently only in color; no textural differences could be found. The laminae are 3 to 10 mm. thick. In some outcrops, also, beds 10 to 30 cm. thick are present. The bedding is not plane in many cases, but is hummocky over pod-like masses of mudstone. Maximum local bedding relief is approximately 10 cm. This probably represents the local relief on the depositional surface ---the sea floor. The relation of relief and patches of sand concentration is not known.

South of Soledad Canyon and north of the northwest trending fault, mudstone is uncommon. South of this fault, diatomaceous mudstone about 200 feet thick is present. The differences in lithology and section in this area are the result of differential erosion and differences in depositional conditions. This mudstone is sand-free, more definitely bedded, and is somewhat fissile. It is yellowish gray (5Y 8/1). North of Soledad Canyon, the mudstone is locally only slightly diatomaceous.

The fossil content of the mudstone in the Castaic formation is low. In addition, shell material is completely dissolved during weathering, so preserved specimens can be found only at the few exposures of fresh, unweathered rock. A sparse forameniferal fauna has been found at several localities and is probably present throughout the formation.

The contacts between the mudstone and adjacent members, principally mid-basin sandstone and basal sediments, are sharp and distinct. No gradational contact has been seen between mudstone and any coarser-grained sediment. Mudstone lies directly upon the Martinez formation in only a few localities---along the east fork of Necktie Canyon and along the south flank of Fish Canyon. At these places, no coarse detritus is found along the contact, although the Martinez surface must have had considerable relief upon it.

Gypsum and jarosite? are very common secondary minerals in the weathered mudstone, occurring primarily on exposed surfaces and in fractures. At Locality 1623, gypsum has formed casts of Chlamys discus, and at the localities in Haskell Canyon, gypsum occurs as overgrowths on mollusk shells.

Skolnick and Arnal (1959) have described in detail the features of the mudstone from a subsurface sample. In particular, they discuss the fauna, largely Foramenifera, and the pyritic test fillings. Their ecologic conclusions differ somewhat from those of this report and will be discussed in the section on the environment of deposition of the formation.

Mid-basin sandstone member

Interbedded sandstone and mudstone are volumetrically the dominant sediments of the Castaic formation. The bulk of the formation consists of alternating mudstone and sandstone units 25 to approximately 250 feet thick. The proportions of the two sediments vary from one area to another; but, over all, mudstone is slightly more abundant.

Individual sandstone beds are commonly 1 to 10 feet thick and are separated from other beds in a unit by mudstone or fine-grained sandstone partings a fraction of an inch to 1 foot thick. Commonly these partings contain abundant carbonized plant fragments, whereas the adjacent sandstone contains little plant material and mudstone units contain only scattered, but locally abundant, plant material. The base of a sandstone unit is sharply defined by a number of massive beds. In contrast, the top of the unit may be somewhat transitional as sandstone beds are thinner and separated by increasingly thick mudstone beds going up in the section. All individual beds are bounded by sharp, distinct, smooth contacts.

In general, the sandstone is moderately sorted, medium to coarse grained with scattered granules, and is even-textured from the bottom to the top of a bed. Many beds, however, contain pebbles which are scattered or are concentrated in vaguely bounded lenses. This is particularly true of those sandstones deposited near the basin margin. Also, a form of graded bedding is found in sandstones at a number of localities. Although the sandstone itself is of typical and uniform texture, the pebbles within are graded. The largest are near the base and successively smaller-sized clasts are found higher in the bed. In these beds, pebbles rarely form 10 percent of the rock; they are floating in the sand matrix. At a number of localities various types of intrabed deformation have occurred, suggestive of slumping and movement while the sediment was still fluid. At a few localities the pebbly basal parts of bed were contorted and flowed southwestward, indicating that the surface of deposition sloped in that direction. In several outcrops, individual thin beds were apparently broken, bent, and even overturned while still unconsolidated but cohesive. All the structural and textural features of the sandstones can be explained without invoking turbidity currents.

Sandstone units can be mapped for distances of several miles, but individual beds are rarely continuous for more than one-quarter of a mile. A particularly well-exposed unit cropping out on the west side of Castaic Canyon is composed of a series of offlapping beds progressively younger to the south.

The contact between the Castaic formation and the

Ridge Basin group has been drawn at the transition from mudstone and sandstone below to massive sandstone above. The contact is uncertain and irregular because, as exposed on the west wall of Castaic Canyon, the massive sandstones to the north intertongue and overlap the Castaic formation to the south. Although the division is perhaps desirable, it neither coincides with the Miocene-Pliocene boundary nor with the transition from marine to nonmarine conditions. The sandstone in the lower part of the Ridge Basin group is texturally similar to sandstone of the Castaic formation although it is perhaps somewhat more pebbly. Mudstone in the lower part of the Ridge Basin group is indistinguishable from that in the Castaic formation. Dehlinger (1952) states that the sands of the Ridge Basin group are more micaceous. Some beds were found to be, whereas others were not. Ostracods from mudstone in the Ridge Basin Group have been termed nonmarine by Dehlinger, but have been found stratigraphically below marine fossils.

The generalized features of the sandstone found in the Castaic formation are valid throughout the formation except that no penecontemporaneous deformation structures have been observed south of Castaic Canyon. Naturally, all types of sandstone can be found within the formation from those verging on pebble conglomerate to relatively well-sorted fine-grained sandstone, but by far the vast majority of sandstone beds are texturally as described above. All are arkosic or feldspathic arenite, and grains are angular to subangular.

Fossils are scarce in sandstone north of Dry Canyon but are common to abundant in the sandstone found in the southern part of the outcrop area. This relation will be discussed in the section on the environment of deposition.

Basal member

a. General

In contrast to the relatively uniform, invariant, mudstone and sandstone deposited in the central part of the basin, the sediments deposited at the base of the Castaic formation, as the late Miocene sea transgressed over the older sediments, are inhomogenous. They are strand deposits reflecting the variability possible in sedimentation along a shore as a result of differences in relief, exposure to water turbulence, nature of the surface being transgressed, and provenance.

The basal contact of the Castaic formation is exposed for a distance of some 20 miles, from upper Castaic Canyon southeast to Sand Canyon. Because the sediments of the Castaic formation lap onto the underlying rocks, the strata exposed along the basal contact of the Castaic formation are not all exactly contemporaneous. For example, north of Elizabeth Lake Canyon along the contact, successively younger beds overlie the Martinez formation. The relative age of all the basal beds exposed are considered in detail in the section on correlation. All the sediments exposed are uppermost Miocene, Mohnian and Delmontian in terms of the micro-faunal time-rock scale.

b. Red breccia

At several places along the contact, very poorly sorted reddish breccia occurs. The rock consists of clasts locally derived from the underlying Martinez formation. Clasts range in size from pebbles to blocks as much as 6 feet in diameter. They are composed principally of Martinez sandstone; igneous and metamorphic clasts are reworked from Martinez conglomerates. The sedimentary clasts are angular to subrounded; those reworked from conglomerates are commonly well rounded. Little rounding occurred during erosion from the Martinez formation and ensuing deposition in the Castaic formation. No clear distinction can be made between matrix and clasts because a complete gradation is generally present. The reddish color of the sediment is imparted by the soil-like matrix; the larger clasts appear to be essentially unweathered.

Bedding is absent or faint. The stratification present is caused by slight textural changes---differences in maximum clast size and degree of sorting. Bedding planes are gradational. See Plate 34.

This rock type appears to have been deposited in isolated areas along relatively short lengths of the shore. The exposed thickness of this rock type is about 250 feet. The factors controlling the discontinuous distribution are not clear, although several of the occurrences appear to be limited to areas that were topographically low at the time of deposition. Whether these sediments are marine or nonmarine is debatable. The fact that they are nonfossiliferous means that they could be nonmarine in origin; it does not rule out the possibility that they could have been deposited subaqueously. The lack of well-defined bedding and sorting indicates that the sediment was deposited rapidly enough that reworking was at a minimum. In other words, sediment was introduced and deposited in layers more than several feet thick in essentially a single step. At three localities, sediments containing marine fossils lie conformably over the unsorted conglomerate. At the other two localities, there is an interfingering contact between the two types of sediment. The texture and structure are similar to those seen in alluvial fan deposits; the reddish color and the lack of marine fossils are suggestive of nonmarine deposition. On the other hand, if the breccia is nonmarine and the transition from nonfossiliferous to fossiliferous sediment marks the strand line, there should be evidence of a certain amount of reworking of the seaward margin of the reddish sediment. Concomitant with this reworking, some clasts from the breccia should have been deposited in the adjacent contemporaneous sandstone. None, however, have been found. The exact environment of deposition is not known. The breccia was deposited at or very near the strand line and is genetically related to the marine sediments of the Castaic formation.

Geologists who have studied and reported upon the region containing the Castaic formation have interpreted this red breccia in several ways, but all have referred them to a formation other than the Castaic. Clements (1937) referred the sediments to the Mint Canyon formation and believed that the sediments in that area graded into the Castaic formation. Jahns (1939 p. 822; 1940, p. 166), on the basis of detailed mapping in the Bouquet Canyon-Haskell Canyon area, showed that, contrary to what Clements had reported; the Mint Canyon-Castaic contact is an unconformity. Johnson (1952) placed the breccia in a separate unit, the Taylor formation, of nonmarine origin. He believed the contact is a disconformity and points out the textural differences between the Mint Canyon formation and the Taylor formation. Jahns and Muehlberger (1954) referred the sediments in the Elizabeth Lake Canyon area to the Mint Canyon formation, and stated that the Mint Canyon and Castaic formations are unconformable; they illustrate the relationship of the two south of Soledad Canyon to prove the point. Crowell (1954b) refers the sediment to the Mint Canyon formation and places it unconformably beneath the Castaic formation. The breccia is merely a locally deposited near-shore or on-shore member of the Castaic formation. Therefore, Clements correctly interpreted the contact but was mistaken in relating the sediments to the Mint Canyon formation, which, in reality, does not crop out northeast of Charlie Canyon. All the later authors except Johnson erred in correlating the sediments with the Mint Canyon formation and in concluding that the contact between the two formations is an unconformity in Elizabeth Lake Canyon. Johnson (1952) separated the sediment from the Mint Canyon formation on the basis of lithologic differences--the correct conclusion but not the correct or sufficient reason. Thus Clements, the earliest worker in the area, correctly described the contact but confused the situation for all the later workers by correlating the red conglomerate with the Mint Canyon formation.

c. Normal basal sediment

The more common type of basal sediment consists of a more or less fossiliferous conglomerate several feet thick overlain by sandstone, pebbly sandstone, or conglomerate that is very fossiliferous. A complex of these units of different texture and fossil content generally is present. The units are hard, well-cemented with calcite. As in the case of the reddish breccia, these sediments differ slightly in age due to onlapping deposition. Also, at different times and places the relatively coarse-grained basal, near-shore sediments were deposited out into the basin to different extents. Thus the basal sediments intertongue with the finer-grained and generally better-sorted mid-basin sediments. These statements are broad generalizations which apply particularly well to the Castaic Canyon area. South of Necktie Canyon, conglomeratic sediments are less common, and cementation is less complete. Because of the great variety of sediments present along the contact, separate areas will be discussed individually and examples of particular interest will be discussed in some detail.

Castaic Canyon north of Necktie Canyon

The complex nature of the basal sediments is most apparent in Castaic Canyon north of Necktie Canyon. Along this sector of the contact all the basal sediments have a common source---the adjacent Martinez formation. All boulders and cobbles over 6 inches in diameter are composed of Martinez formation sandstone. About three-fourths of the smaller cobbles are reworked from Martinez formation conglomerate; about one-fourth are of Martinez formation sandstone. With decreasing clast size, the proportion of sandstone decreases so that pebbles are almost entirely reworked clasts from Martinez formation conglomerates. Sandstone cobbles and boulders are sub-rounded to rounded. The clasts derived from conglomerates are either very well rounded or very angular. The nature of rounding is an indication of the relatively short amount of transportation and abrasion to which the clasts were subjected. Clasts in Martinez formation conglomerates are well-rounded and subspherical. Considering that they are composed of igneous and metamorphic rock, they evidently had had a long history of abrasion. Those that were eroded and deposited in the Castaic formation are still very well rounded. The corners and edges of those that were broken during this step, however, were only slightly rounded. No clasts were found in the Castaic formation north of Necktie Canyon that could not have been derived locally from the adjacent Martinez formation. It is possible, of course, that some of the gneissic and plutonic igneous clasts could have been derived directly from terrane of such composition that is situated north and east of the Castaic and Martinez formations. This possibility is considered to be unlikely because all the clasts are uniform in texture, denoting a uniform sedimentary history. South of this sector of the contact, basal sediments have been derived from a variety of sources, but, in every case, clasts can be related to a local source.

The most common rock types represented in the clasts which are derived from the Martinez formation are volcanic rocks, quartzite, gneiss, and plutonic igneous rocks. These rock types are discussed in the previous description of the sediments of the Martinez formation. The volcanic types are a relatively minor constituent of the Castaic formation conglomerates.

The Martinez sandstone, which is the source of much of the Castaic formation in the Castaic Canyon area, is a graywacke containing about 40 percent quartz, 10 percent feldspar, and 35 percent matrix. The grains are angular to subangular. If, as seems probable, sands in the Castaic formation are largely derived from those in the Martinez formation, the grains have been little worn in the reworking; better sorting has been the primary effect. In spite of the great lithologic variability along the contact, the basal complex can be described by considering the most abundant rock types.

A poorly-sorted, brownish-gray, cobble conglomerate is generally present at the base of the Castaic formation. The clasts are as described above. At most outcrops, the conglomerate is only several feet thick. It is texturally similar to the reddish conglomerate previously described except that maximum clast size is less; color is different, and fossils are present at some localities. Whole valves and fragments of C. titan are the only fossils that have been found in this conglomerate; these fossils appear to have been transported and worn before final burial. The thickness and texture of the conglomerate varies greatly over short distances. At several localities it grades laterally into better sorted conglomerate or sandstone which may be very fossiliferous. Generally the unit is poorly cemented. Where better sorted, however, it may be firmly cemented with calcite and is brownish-gray as a result.

The most common type of sediment in the basal member consists of pebble conglomerate, pebbly sandstone, and sandstone, characterized by great local variability in thickness, distribution, and fossil content. At most outcrops along the contact, the unit is resistant, well-cemented, and conspicuous by the light gray color. Associated with the basal sediments are tongues of conglomerate and sandstone extending out into the mudstone for distances greater than one-half mile. The tongues, which are less than 20 feet thick, consist of beds of cobble conglomerate, pebble conglomerate and pebbly sandstone. These tongues are lithologically like the basal sediments, but represent deposition under relatively infrequently occurring conditions.

The actual nature of the sediments can best be understood by considering details of some outcrops.

North of the fault that cuts the basal contact near the shelter house in upper Castaic Canyon, the basal unit is poorly-sorted, unfossiliferous, unbedded cobble conglomerate that is 20 to 50 feet thick. Overlying the conglomerate at Locality E is mudstone. Fragments of _C. titan_ are present in the upper two feet of the conglomerate section 200 feet south along the contact. At this locality, E-1, the clasts are pebbles only, rather than a combination of pebbles, cobbles, and boulders. Although the rock is poorly sorted, it is much better sorted than at Locality E. The average maximum dimension of clasts is three-fourths inch. This is the most northerly occurrence of fossils in the basal sediments. The basal conglomerate farther north is like that at Locality E. The transition from the basal sediment of the Castaic formation to that of the Ridge Basin group occurs a short distance north of Locality E, at the location where massive-bedded sandstone, rather than mudstone, lies directly upon the basal conglomerate. There is no particular change in the conglomerate accompanying this transition. Between Locality E-1 and Locality 2101, the basal member is like those at Locality E-1. Fragments of *C. titan* 1 to 2 inches across are present in the upper part of a bed of poorly sorted pebble conglomerate 2 to 5 feet thick. Mudstone overlies the conglomerate. In addition to *C. titan*, a few small unidentifiable gastropods have been found. At Locality 2101, the sediments are better exposed and somewhat more complex:

Measured section of the Basal member, Castaic formation, at Locality 2101, 400 feet N. 15° W. of the junction of Castaic Creek and Fish Creek

	Maximum thickness exposed (feet)
Mudstone member	
Mudstone, grayish brown.	
Basal member	
Unit 4	
Sandstone, fine grained, light gray, well cemented with calcite, beds 1 to 2½ feet thick, pebbly at base where directly over Martinez formation; *Crassostrea titan* are abundant (75 percent of the bed in some areas), shells articulated, attached to one another, 8 to 10 inches long.	4
Unit 3	
Sandstone, fine grained, light gray, well cemented with calcite, saccharoidal appearance, very fossiliferous with a variety of gastropods and pelecypods--	

Lyropecten crassicardo, *Glycymeris grewingki*, and numerous indeterminate forms, *Crassostrea titan* absent, fossils not evenly distributed but concentrated in patches. 2

Unit 2

Sandstone, pebbly, coarse grained, light gray brown, thick to massive bedded (3 to 30 feet), unfossiliferous. 65

Unit 1

Conglomerate, cobble, poorly sorted, poorly bedded, unfossiliferous. 8

Unconformity

Martinez formation

Sandstone and shale.

The unconformity is not well exposed but appears to be smooth. From the small gully to the west of Locality 2101, east to the contact and north along the contact, successively higher beds in the section are basal as lower beds wedge out against the unconformity.

South of this sector of the contact and along the west side of Castaic Creek, the basal sediments and unconformity are well exposed (Plate 33). The onlapping nature of the sediments is particularly evident. For example, in unit 2 of the section given below, successively younger beds wedge out against the basal contact as one follows the unit northward. In addition, the member is largely conglomerate to the north but contains numerous lentils and tongues of shale and sand to the south.

Measured section of the Basal member, Castaic formation, about 2200 feet N. 19° W. from junction of Castaic Creek and Fish Creek. Section B, Plate 2.

	Maximum thickness exposed (feet)
Mudstone member	
Mudstone with scattered interbedded sandstone, light brown to brownish gray, thin bedded; abundant gypsum and charcoal fragments.	
Basal member	
Unit 6	
Sandstone with interbedded pebbly sandstone, pebble conglomerate, and sandy mudstone; light gray; pebble content diminishes from bottom to top of unit so that upper beds are largely well sorted medium-grained sandstone; bedding planes are gradational textural changes; rare *C. titan* fragments about 1 cm. across are present.	123
Unit 5	
Sandstone with interbedded pebbly sandstone and pebble conglomerate; sandstone medium brownish gray, contains scattered cobbles; worn and broken *C. titan* valves present in the conglomeratic beds.	29
Unit 4	
Conglomerate, cobble, poorly sorted, with thin (4 to 8 inches thick) sandstone tongues; lithology of tongues as in Unit 3.	27
Unit 3	
Sandstone laterally grading from thin-bedded mudstone to pebble conglomerate.	2
Sandstone, fine-grained, brown on weathered surface; upper 3 inches of bed is thin-	

bedded siltstone containing abundant plant fossils.	1 1/4
Sandstone, fine-grained, well-sorted, gray on weathered surface; lower contact irregular.	1 1/4
Sandstone, silty, brown, contains abundant plant fossils; top 2 inch bed is granular, coarse grained, cross bedded.	3
Sandstone, silty, grayish yellowish brown, pebbly, grades laterally to pebble conglomerate; plant fossils abundant.	3
	10½
Unit 2	
Sandstone, coarse grained, greenish-gray, contains scattered pebbles, grades laterally to conglomerate; lower contact gradational from underlying conglomerate; a single massive bed; plant fossils common, some *Astrodapsis* fragments present.	8
Unit 1	
Conglomerate, cobble-boulder, very poorly sorted, bedding faint, average clast diameter 12 inches; maximum, 5 feet; clast composition and texture as described in discussion of basal conglomerate. Matrix is medium-to very coarse-grained sand, the composition of the matrix is like that of Martinez sandstone; it is more poorly sorted and contains more dark minerals and rock fragments than does the normal Castaic formation sandstone. The basal few feet of the unit are covered by slope wash. The relief on the underlying contact does not exceed	

2 feet per 100 feet. 24

Unconformity

Martinez formation

Mudstone, dark gray, thin bedded.

The top of the cliff illustrated in Plate 33 is essentially the top of Unit 6. The other side of the hill is a dip slope. The features of particular interest in this exposure are the onlapping nature of the sediments, the lateral variations in texture, the pinching out of fine-grained sediments near the shoreline, and the abundance of plant fossils but paucity of invertebrate fossils.

On the first main ridge south of Fish Canyon, on the east side of Castaic Creek, the onlapping relation can be seen on a gross scale. At the base of the ridge, the basal member lies upon the Martinez formation. Higher on the side of the ridge, however, this member pinches out and mudstone is basal. Even higher, sandstone is basal. The four stratigraphic sections (Plate 3) of the basal sediments present on the south side of Fish Canyon indicate the variations that occur in the basal unit within short distances. These four localities are less than 400 feet apart.

Probably the outcrops best illustrating the nature of the basal sediments are located on the broad ridge, referred to as Triangle ridge herein, which is transected by the north boundary of section 26, T. 6 N., R. 17 W. The photo-mosaic (Plate 37) pictures the outcrops along the north side of the ridge. The features of sedimentation to be noted in this area are the same as those found along the west side of Castaic Creek at stratigraphic section B: the red breccia that is poorly sorted, only vaguely bedded, and of spotty distribution; the typical gray, well-cemented basal conglomerate and sandstone which overlie the red conglomerate; the onlapping nature of the strata; and, the pinching-out of sandstone beds within conglomerate toward the basal contact. Although the sediments are like those which occur on the west side of Castaic Creek, which were previously described, they differ in that they contain abundant fossils.

From Triangle ridge southeast to the next main tributary to Castaic Creek, Cow Canyon, the Castaic formation exposed east of Castaic Creek is largely the dip slope formed by the upper surface of the basal sediments. Only a few small gullies cut into the basal unit. The Martinez-Castaic contact in this area is uneven with local relief of 15 to 25 feet. Cobble conglomerate partly fills these depressions. Overlying the cobble conglomerate is pebble conglomerate and pebbly sandstone that are more or less fossiliferous. The upper surface of the basal complex is hummocky with as much as several feet of local relief.

North of Cow Canyon, the basal member directly overlies the basal contact and is in turn overlain in general by mudstone. On the east side of Cow Canyon, however, in addition to the typical basal member, which is about 15 feet thick, a unit which is lithologically similar occurs higher in the formation, separated from the basal member by about 70 feet of mudstone. This unit is not continuous along the strike in either direction; presumably, if the formation had not been eroded, the unit would extend to the northeast and connect with basal beds younger than those in Cow Canyon. This is the most northerly occurrence of basal sediments forming tongues which extend out into the mudstone.

Because this unit is well exposed and is typical of several similar units in the Elderberry Canyon area, a description of it and adjacent overlying beds is given below:

	Maximum thickness exposed (feet)
Mudstone, typical unfossiliferous.	
Sandstone, medium grained; upper part of bed is coarse grained with clasts of mudstone flakes.	1 1/2
Mudstone, typical.	1 1/2
Sandstone, fine to medium grained, micaceous, thin bedded (1-3 inches), relatively well sorted but with scattered very coarse sand and granule lenses about 1 inch thick; siltstone partings between beds; the upper few inches of this unit are very coarse grained, gypsiferous, with abundant charcoal fragments, overlain by a coquina of small (less than 2 inches across) angular shell fragments. Loc. 2072	2
Mudstone, typical, with scattered small well-rounded pebbles and small fragments of *Crassostrea* and *Lyropecten*. Four feet above the base is a coquina of shell fragments which are as much as 8 inches across; the coquina is uncemented. Several sandstone beds 2 to 6 inches thick are in the lower 5 feet of the mudstone.	15
Sandstone and conglomerate; interbedded granular to pebbly sandstone and pebble cobble conglomerate; sandstone is coarse to very coarse grained with 5 to 10 percent granules and small pebbles and with 10 percent *Crassostrea* and *Lyropecten* scraps which are as much as 1 1/2 inches across; conglomerate consists of:	

35 percent subrounded to angular pebbles, cobbles, and boulders up to 1 1/2 feet in diameter, 50 percent fragments of *Crassostrea* and *Lyropecten* which are as much as 8 inches in maximum dimension, although most are about 3 inches across; 15 percent sand matrix.	8
This unit is divided into these beds:	
Sandstone with basal conglomerate as much as 6 inches thick.	2
Mudstone parting.	
Sandstone with basal conglomerate as much as 6 inches thick.	2
Mudstone parting.	
Sandstone.	1 1/2
Conglomerate.	1 1/2
Sandstone.	1 1/2
All contacts are sharp but with 3 inches of relief along 3 feet of contact.	
Mudstone, typical.	70

Basal member.

Southward from Cow Canyon along the basal contact, a number of such fossiliferous conglomeratic tongues extend out into the mid-basin sediments. It is possible that such units exist north of Cow Canyon but are not exposed. In the area between Cordova Ranch and Necktie Canyon several tongues of basal-type lithology can be traced from within mudstone laterally to the basal contact. Several others, however, composed largely of sandstone with little conglomerate, may well represent sandy areas offshore that were not connected to the contemporaneous basal sediments of the shore line.

The tongue of conglomerate that crops out on the ridge south of Elderberry Canyon was studied in detail to determine what features of lithology or fossil content are related to the distance of deposition from the contemporaneous shore line. Although the unit is not connected to the basal sediments because of erosion, originally it probably was. No lithologic trends were found from the study of hand specimens and 12 thin sections. Rather, the lithology varies considerably across short distances and according to no apparent pattern. Beds within the unit could not be correlated between outcrops, so the samples represent typical pebbly sandstone or sandstone for each locality. It is possible that a conglomerate bed is in every case finer grained or coarse grained at the next locality away from shore; that the overall lithology of any particular outcrop does not reflect the uniform trend of individual beds because of an onlapping or offlapping relation that maintains the generally uniform lithology. The alternative is that each bed was deposited over a considerable area near shore but is of variable lithology normal to the shore line because long-shore rather than off-shore forces were dominant. Considering the close relation between the basal near-shore sediments and these tongues, this alternative seems unlikely. Sandstones sampled from throughout this particular tongue are very similar in composition. In the classification of Williams et al (1954), most are calcareous arkosic arenite. For 12 thin sections of sandstone, the percentage composition is:

	average	range
quartz	60	40-75
feldspar	25	10-40
lithic grains	15	0-40
mica	Tr.	0-5

Fossils commonly comprise 10 to 50 percent of the rock, calcite cement, 10 to 20 percent, pebbles, 5 to 20 percent, and argillaceous matrix, 5 percent. Composition is relatively invariant; the primary variables are texture (amount of pebbles and cobbles) and fossil content. All the samples from this unit contain relatively little argillaceous material--only one or two could be considered a wacke. In comparison, a detailed study of the sand wedges exposed at Triangle ridge shows that many of the sands there contain 10 to 20 percent argillaceous material and that fossil content can be related to the abundance of both the finer and the coarser material admixed with the sand.

The basal sediments found in Elderberry Canyon represent the most interesting outcrops of the basal member. The map and cross sections (Plates 6, 32, 38) illustrate the geometry of the units present. The important features of this exposure are the onlap of the Unit A, the complexity of the basal sediments, and the linear bar-shaped body, C. It is particularly interesting to note that although this sand was covered at different times (by Units F and G), it continued to be built up in the same location. All these units differ primarily in texture. Thus Unit C indicates a continuing set of physical conditions at this locality which were only infrequently disturbed. It is believed that this area represents an offshore bar and the associated fore-and back-bar sediments. Details of the lithology and faunal content are given in the next chapter in the section on the fauna of the basal sediments.

Necktie Canyon to Haskell Canyon

South of Necktie Canyon the well-cemented, gray, fossiliferous, basal sediments found to the north are absent. Instead, the sediments exposed along the basal contact are primarily mudstone and sandstone. Between Necktie Canyon and Haskell Canyon, conglomeratic fossiliferous beds occur near the contact but higher stratigraphically than those strata which are actually at the contact. These fossiliferous beds resemble the tongues of basal sediment described from the Cow Canyon--Necktie Canyon area and may represent the offshore continuation of coarse fossiliferous basal sediments that have subsequently been eroded.

Mudstone is the basal sediment on the eastern slope of Necktie Canyon. Only a single bed a few hundred feet above the contact is similar to the tongues of fossiliferous sediment exposed northwest of Necktie Canyon. This bed, if not eroded, would abut against the Castaic-Martinez contact within one-quarter mile of the presently exposed contact, considering the dips of the sediments and of the contact.

Red breccia is basal in Elizabeth Lake Canyon. On the west side of the Canyon, the red, unbedded, unsorted, boulder cobble rubble grades upward into better sorted and bedded, less reddish conglomerate and sandstone which in turn interfinger with typical Castaic formation mudstone. This interfingering relation is exposed only on the west side of Elizabeth Lake Canyon; elsewhere, the typical basal sediments appear to conformably overlie the red breccia.

Between Elizabeth Lake Canyon and San Francisquito Canyon the basal sediments are typical mid-basin type mudstone and sandstone. Fossils are rare except for occasional carbonized plant fragments and molds of Macoma? in the mudstone. Scraps of Crassostrea, Lyropecten, Chione, Tellina, and Crepidula have been found rarely in granular or pebbly lenses within the sandstone. These lenses are relatively well indurated. On the east slope of Elizabeth Lake Canyon, pebble and cobble conglomerate is abundant in the basal several hundred feet of the Castaic formation above the red breccia. Some of the conglomerate is in sharply defined layers interbedded with sandstone and mudstone; some occurs as stringers or lenses within the sandstone. None of the conglomerate is fossiliferous.

On the west side of San Francisquito Canyon, the basal sediments consist of thick-bedded to massive sandstone. Occassional thin, more resistant pebbly horizons may contain fossils. The sediments of the Castaic formation do not change as the basal contact is approached except that small patches of unfossiliferous well-cemented medium-gray pebble conglomerate are preserved in slight depressions on the contact.

In Dry Canyon, the contact is a disconformity with local relief on the order of 4 feet per 15 feet. Approximately 60 percent of the basal 15 feet of the Castaic formation is conglomerate. The rest is massive sandstone. Conglomerate is generally not basal; no fossils have been found near the contact. The highly fossiliferous pebbly sandstone at Locality 1670 is about 600 feet above the basal sediments and is largely an offshore tongue of shore-derived material.

The basal sediment in Haskell Canyon is massive pebbly sandstone overlain by interbedded mudstone, sandstone, and pebbly sandstone. Fossils have been found in all these types of sediments in this area.

South of Haskell Canyon

The basal sediments in Bouquet Canyon and Plum Canyon are similar to those in Haskell Canyon, although cobble conglomerate 10 to 20 feet thick directly overlies the contact. They are only locally fossiliferous. The Castaic formation is clearly unconformable upon the Mint Canyon formation in Haskell Canyon.

Between Bouquet Canyon and Soledad Canyon, The Castaic formation has been covered by the Saugus formation and is only poorly exposed. On the south slope of Soledad Canyon, little of the formation is exposed beneath the Towsley formation. A graphic column of the stratigraphic section in this area is given in Plate 4. Also on this plate are columns protraying the sections at the first ridge south of Localities 2069 and 1663, and at Locality 1849. The thickness of the formation is very different at these three localities because of both erosion of upper units and because of variations in the thickness of individual beds. These variations are the result of relief on the underlying surface and perhaps of thinning toward the nearby shore. The formation ranges in thickness from 200 feet at Locality 2069 to the vanishing point 800 feet to the east. The decrease in thickness is mainly the result of thinning of individual beds rather than by erosion of the upper strata. The lower units pinch out first; the last remaining bed is in the upper half of the section measured at Locality 2069. The basal sediment is a highly fossiliferous pebble cobble conglomerate which is approximately 5 feet thick and lies unconformably upon Mint Canyon sediments. Local relief on the contact is several feet per 20 feet. The basal conglomerate, a single massive unconsolidated bed, contains clasts as large as 6 inches in diameter in a matrix of medium-grained sand. Clasts are primarily gneissic and plutonic; a few are volcanic, quartzite, and tuff. Most are well rounded.

The composition of these clasts illustrates the local provenance of material that composed the Castaic formation. In the Castaic Canyon area, clasts are largely derived from the adjacent Martinez formation. In the San Francisquito Canyon-Bouquet Canyon area, clasts are derived from the Pelona schist and the Mint Canyon and Vasquez formations. South of Soledad Canyon the clasts are derived from the nearby San Gabriel Mountains and the underlying Mint Canyon formation.

The basal sediments in the Sand Canyon-Reynier Canyon area consist of fine-grained, massive sandstone which contains conglomeratic lenses and, in places, a prominent basal boulder conglomerate. Clasts are primarily of plutonic origin. Fossils are abundant in the unit but are largely confined to concretionary lenses within the fine-grained moderately indurated sandstone. The basal contact is an angular unconformity (Plate 4, section G).

d. Summary

The sediments exposed along the basal contact are heterogeneous but can be divided into two primary groups: (1) the coarse-grained complex of well-cemented fossiliferous sediments and the unsorted reddish breccia in the Castaic Canyon area, and (2), the largely unfossiliferous, poorly-consolidated sandstones, conglomerates, and mudstones south of Elizabeth Lake Canyon. In general, the nature of the basal sediment can be directly related to the relief of the surface being transgressed by the late Miocene sea. The coarse and complex basal sediments are only found north of Charlie Canyon, where the relief was great. The amount of relief can be seen in the variation in sediment thickness parallel to the trend of the then-existing shore line, and most readily, in the difference in dip of the contact and the overlying beds and in the overlap of the basal sediments. In contrast, basal sediments south of San Francisquito Canyon are essentially parallel to the underlying contact, indicating that there was little relief on the depositional surface and no ready source of coarse sediment. Only at Locality 1849, adjacent to the San Gabriel mountains, do the basal sediments contain boulders, but even this locality was of distinctly lower relief than were those in Castaic Canyon.

This correlation of shore-line relief and sediment type is valid in general but not in detail. It is applicable to the distribution of the reddish breccia, but not entirely to that of the basal member north of Necktie Canyon. The basal member was only deposited along a shore of considerable relief, but its distribution must have been controlled by other factors as well, for it is absent between Necktie and Charlie Canyons. In this area, the basal sediments abut against what must have been a relatively steep shore. The paucity of offshore tongues of coarse, fossiliferous sediments south of Necktie Canyon indicates that sediment distribution was perhaps largely geographically controlled. However, there is also evidence that the formation of this basal shoreline complex was also temporally controlled within the geographic setting. Thus, the southern limit of distribution of the complex is that point at which older Castaic formation sediments are exposed along the basal contact. Although this is but a single control point, it possibly indicates the beginning of deposition of the complex. The end of large-scale deposition of the member is indicated by the absence of tongues of the characteristic sediment higher in the section. Such tongues should be preserved if younger basal sediments had been formed. Even more indicative, however, that the basal member ceased to be deposited is its overlapping by mudstone south of Fish Canyon. The cessation of deposition of coarse sediments can be explained by assuming that the source area was eroded so it could no longer supply the necessary coarse materials. Such an explanation might be applicable if the land near shore were eroded but more distant source areas remained to provide the abundant sand present in the formation. However, the basal mudstone and sandstone south of

Fish Canyon abut against a contact as steep as that beneath the underlying coarse-grained sediments. Thus, the deposition of coarse-grained strand deposits is primarily controlled by the distribution of source areas, but other factors---whether climatic, tectonic or otherwise--are also important.

Violin breccia

The Violin breccia was deposited along the west side of the Ridge Basin contemporaneous with the upper one-third of the Castaic formation and most of the Ridge Basin group. The breccia has been described by Crowell (1954a, 1954b). It is composed primarily of gneissic material that is unsorted and unbedded near the San Gabriel fault, but, within three-fourths of a mile, becomes finer grained and well bedded and interfingers with sandstone of the Castaic formation. Although many of the clasts are moderately rounded, the sediment has the general appearance of having been transported only a short distance. For this study, the interesting aspect of the unit is the environment in which it was deposited.

Crowell (1954a, 1954b) has proposed that the Violin breccia is a talus or alluvial deposit laid down at the base of the San Gabriel fault scarp. The great thickness of the breccia is indicative of a continuously elevated land mass on the west side of the fault. The small lateral extent of the breccia, however, indicates that, although it consists of extremely coarse material, it comprises volumetrically only a very small amount of the sediments within the Castaic formation and Ridge Basin group. The relative importance of the west and the east sides of the basin in supplying detritus is particularly well seen in the sediments of the middle of the Ridge Basin group, exposed in the Piru Gorge area. All these relations are suggestive of a source area for the Violin breccia of high relief but small extent situated close to the site of deposition.

The lack of sorting and bedding and the very coarse clasts are what might be expected in a talus deposit. However, the degree of rounding is indicative of more transportation than talus sediments undergo. Irrespective of the amount of transportation that took place, the breccia was certainly deposited with no sorting or subsequent reworking. The important question is, therefore, whether the breccia is marine or nonmarine. If it was deposited in shallow water, at least a few bedding planes should be present which would have been formed by winnowing, reworking, and sand deposition during the intervals between those probably rare occasions when coarse, unsorted material was being deposited. In addition, near-shore coarse clastics deposited in shallow water should contain some fossils, considering the abundance of fossils present in coarse clastics along the east side of the basin. If the conditions were suitable for life, lack of organisms on a shallow rocky botton could only be explained if water movement kept the clasts in motion so that organisms on the bottom would be broken and any shells present would be pulverized. The lack of sorting and bedding of the breccia shows, however, that such reworking did not take place. Two possibilities remain:
1. The breccia was deposited below the level of wave action and winnowing in relatively deep water adjacent to shore. The lack of fossils is explained by the absence of shallow water conditions in which the preponderance of molluscan life exists. 2. The breccia and adjacent interfingering sandstone **were** deposited on land; fossils are absent in the sandstone because the environment was not suitable for life and for fossil preservation. The lack of fossils in the sandstone interfingering with the

breccia is not diagnostic; along the east side of the basin fossils are generally absent in sandstone beds although they may be abundant in nearby contemporaneous conglomerate and pebbly sandstone. This second mode of deposition seems more probable, but more intensive study of both the Violin breccia and Recent near shore sedimentation is necessary before a definite answer can be given.

III. Correlation

Variations in fauna within the Castaic formation can be explained by environmental variations only if it can be shown that the assemblages analyzed from the different parts of the formation are contemporary, or if it can be shown that, although the environment of deposition was different in different parts of the basin of deposition, it was constant in any particular part of the basin. In this latter case, assemblages might be of different age but would nevertheless be representative of the environment in different parts of the basin of deposition. Neither case can be proved completely for the Castaic formation, but a combination of the two can be demonstrated with a fair degree of assurance.

The maximum thickness of the Castaic formation is about 7000 feet. The Basal member in Castaic Canyon and its characteristic fauna were formed while approximately one-half of the formation was being deposited. The environment in which the Basal member was deposited was uniform. Therefore it is necessary to show that the localities in the southeast part of the formation are contemporary with one another and with some part of the Basal member. This is difficult for the following reasons: 1. Locality 1849 is separated from the main body of the formation by a fault of unknown displacement. 2. The formation is discontinuously exposed from Bouquet Canyon to the south side of the Santa Clara River Valley. The gap is the result of erosion and of burial under the Saugus formation. 3. Marker beds bearing any demonstrable relation to time lines are lacking within the formation.

Because of these obstacles, correlation within the Castaic formation is only approximate. Correlation is based on bedding planes as a rough approximation to time planes. It can be shown at several localities in the formation that this approximation is very crude. Nevertheless, it is the best available and is sufficient for the task.

By projecting bedding planes westward from the Basal member in Castaic Canyon, it can be seen that the deposition of the member in part antedates the Violin breccia but is largely contemporary with it. By projecting bedding planes southeastward from the Basal member, it can be seen that the basal strata exposed in Elizabeth Lake Canyon are older than those in Castaic Canyon. Between Elizabeth Lake Canyon and San Francisquito Canyon, exposures are very poor. The sediments are folded into several broad, northwest-trending folds, and a large flexure is present in the basal contact. It appears that the basal sediments exposed in Elizabeth Lake Canyon are overlapped by younger basal sediments southward along the contact to San Francisquito Canyon. The basal sediments in San Francisquito or Dry Canyons are contemporary with the older part of the Basal member. The basal sediments of Haskell Canyon are older than those of Dry Canyon. Locality 1670, high in the section in Dry Canyon, is essentially contemporary with the localities in Haskell Canyon low in the section, and with the lower or middle part of the Basal member. The sediments in Bouquet and Plum Canyons are essentially contemporary with the Haskell Canyon localities.

Correlation of the sediments in Plum Canyon with those in the hills south of Humphreys is based on the alignment of the structural trends of the formation in the two areas. No major structural features occur between the two areas. This is crude indeed, but not much more crude than the rest of the correlation. Correlation southward across the fault to Locality 1849 is based on the premise that displacement on the fault has not been large, as evidenced by the amount of offset of contacts and lithologic units. None of the correlations are precise, but they indicate that all the localities are approximately contemporary and were deposited during a short period of time.

Previous workers have concluded that the Castaic formation was deposited late in the Miocene epoch. The question of the age of the Castaic formation has been amply discussed previously (Durham, Jahns, and Savage, 1954, p. 66) and will not be considered further in this report.

IV. Environmental analysis of localities

General

The sediments and fossils of the major localities or groups of localities will be analyzed individually in order to determine the environment of deposition of the various parts of the Castaic formation. The analysis makes use of the Recent ecology of the forms found in the Castaic formation or of the Recent ecology of forms closely related to those found in the formation. The value of comparing Recent and fossil forms is dependent upon the closeness of relationship between the two. A species or subspecies ranging from late Miocene to Recent is of greatest value. A late Miocene species compared to a Recent closely related species is of less value. Generic comparisons must be general in nature because of the variety of ecologic niches occupied by the individual species within a genus. Besides knowing the ecologic requirements of the forms comprising an assemblage, it is also necessary to consider whether the animals were transported after death. Transported animals, unless recognized as such; may be misleading as ecologic indicators. Pelecypods that appear to have been buried in living burrowing position or are attached to the substrate have probably not been transported, and pelecypods and brachiopods that are articulated probably have not been transported far, if at all. Of course, in many cases, very little transportation is necessary to mix creatures living in different niches, and every burial assemblage, to a certain extent, is such a mixture. It is difficult to determine if disarticulated valves, organisms containing a single shell, and shell fragments have been transported. Although it seems likely that unworn shells were not transported far before burial, abraded and fragmental material does not necessarily indicate extensive transportation.

Many specimens have been weathered so that it may be impossible to determine the state of preservation at the time of burial. In many cases, on the basis of Recent ecologic data, one can identify a fossil as having been transported from another environment before burial if it occurs in an otherwise ecologically uniform assemblage, or if it occurs in a sediment different from that in which the animal could have lived.

The classification of marine environments described by Hedgpeth, (1957) p. 18, is used in this paper. It is, in part:

Highwater level)
(littoral
low water level)
(inner sublittoral
about 50 fathoms)
(outer sublittoral
about 100 fathoms)
(bathyal

Normal marine water is considered to have a salinity of 30 ‰ to about 36 $^{0}/_{00}$. Less saline water is termed brackish.

The ecologic date used in the environmental analysis of the localities has been derived from a thorough survey of the pertinent literature. The principal references are given in Chapter I. More complete data than is given in this discussion of localities are given in Chapter VIII. Refer to the individual descriptions of the species occurring at a locality for the information upon which the ecologic conclusions have been based.

Locality 1849.

According to Wright (1951), p. 8, 10, locality 1849 is 15 feet above the base of the Castaic formation. See Plate 4, section G. His description of the formation is, approximately:

	Maximum thickness exposed (feet)
Towsley formation	
Unconformity	
Castaic formation	
Unit 4	
Siltstone and diatomaceous shale, very pale orange, even bedded. Loc. 1626, 20 feet above base.	220
Unit 3	
Sandstone, very pale orange to pale yellow-orange, in alternating layers of fine-grained massive and shaly strata, beds about 10 feet thick. Unit grades to the west into diatomaceous shale similar to Unit 4.	120
Unit 2	
Sandstone, yellow-gray, fine grained; the upper part of the unit is shaly, gypsifferous.	40
Unit 1	
Sandstone, yellow-gray, fine grained, friable, massive to even bedded; contains discontinuous concretionary layers with abundant marine megafossils: conglomerate layers common and basal conglomerate prominent in eastern Reynier Canyon area. Boulders, mostly granitic, up to 2 feet in diameter are present in the conglomerate. Loc. 1849.	20
	400
Unconformity	
Mint Canyon formation	

The fauna from locality 1849 was collected largely from conglomeratic and calcitic concretionary lenses near the top of Unit 1, about 15 feet above the basal conglomerate. No overlapping of basal beds is observed in the outcrops in Reynier Canyon---evidence that the surface covered by the transgressing late Miocene sea was relatively level. The distance to the shore when the organisms were buried is not determinable, but lenses of conglomerate in the basal unit, associated with the fauna, **are** suggestive of near-shore deposition.

Locality 1849 contains a larger and more varied fauna than any other locality in the Castaic formation. The fossils are mainly in well-cemented fine-grained sandstone.

The related Recent forms of nearly all the species present are found in the inner sublittoral zone. Recent forms related to *Trachycardium quadragenarium*, *Nemocardium centifilosum*, *Nuculana ochsneri*, and *Lucinoma acutilineata*, are most common in the inner sublittoral zone although they also occur at greater depths. Recent forms related or ecologically comparable to *Trachycardium quadragenarium*, *Crepidula adunca*, *Polinices reclusianus*, *Olivella pedroana*, *Conus californicus*, *Anadara*, *Tivela*, *Caliostoma*, *Astraea*, and *Mangelia*, are found in the littoral zone, but none are restricted to that zone. *Panope generosa* is found at present from the low water line to 25 fathoms. Specimens of it at Locality 1849 are articulated, well preserved, and evidently not transported. The Recent species *N. taphria*, closely related to *Nuculana ochsneri*, is found from 5 to 80 fathoms, but is most abundant from 10 to 20 fathoms. About 20 percent of the specimens *N. ochsneri* at Locality 1849 are articulated; all are well preserved. *Turritella cooperi* is found living from 10 to 55 fathoms, but is most abundant below 25 fathoms. Fossils of this species are abundant at Locality 1849. Articulated specimens of *Lucinoma* acutilineata are abundant and unworn at Locality 1849. The Recent analogue, L. annulata, is found in water deeper than 10 fathoms but is most common from 30 to 50 fathoms. Unworn but disarticulated shells of Amiantis callosa are common at the locality. The species is found living at present from the low water line to a depth of 5 fathoms. Of the species found that are not now extinct, only Lucina excavata and Amiantis callosa are not found within the depth zone of 15 to 25 fathoms and must have been introduced. Both species are found in shallower water. The two species are common at Locality 1849 but no specimens are articulated. In summary, all the sufficiently known Recent species comparable to closely related species in the Castaic formation are found at the depth of 15 to 25 fathoms. No other depth zone fits the assemblage so well. The specimens of Panope generosa, Nuculana ochsneri, and Lucinoma acutilineata are the only ones for which there is good evidence of burial in place.

Only one of the species present---Crassostrea titan--is in a genus which is generally indicative of brackish water. All of the species with late Miocene to Recent ranges are at present restricted to water of normal marine salinity. Considering those forms which can only be related to Recent genera, a number of the genera, Crassostrea, Macoma, Solen, Crepidula, include Recent species found in brackish water but, as a whole, however, the genera are characteristic of a normal marine environment.

A number of the species found at Locality 1849 occur at present both in bays or in bay inlets and along the open coast. These are Panope generosa, Crepidula adunca, Polinices reclusianus, Sinum scopulosum, Olivella pedroana, and Conus californicus. In addition, the Recent analogue of Dosinia arnoldi is found in the open ocean and in bays. However, the Recent forms comparable to Lucina excavata, *Nemocardium centifilosum*, *Amiantis callosa*, *Tivela*, *Caliostoma*---are restricted to open exposed coasts with a considerable amount of wave action. This strongly suggests that such a coast must have been present when the sediments of Locality 1849 were deposited.

Most of the forms are typically found on or in sand. Only *Crepidula* is restricted to a firm substrate of rock, shell, or kelp. The abundance of *Calyptraea* and *Crepidula* at Locality 1849 appears anomalous considering the relative lack of attachment surfaces: especially so because these genera are absent in the northern part of the outcrop area, where rocky substrate that would appear to have been suitable for them is much more abundant. The distribution of these genera illustrates the fact that the presence of absence of a species can not always be simply related to a single element of the physical environment. *Crepidula* is found abundantly at Locality 1849 apparently because the preferred habitat is attachment to particular species of gastropods, and suitable gastropods are most abundant at Locality 1849. The relative abundance of gastropods at localities south of Dry Canyon can not be simply explained.

The mudstone facies

Locality 1626, about 185 feet stratigraphically above Locality 1849, contains a meager fauna of *Anadara montereyana*, *Macoma?* sp., and fish remains. Recent species of *Anadara* are restricted to the littoral and inner sub-littoral zones; they occur in sand and mud, as did apparently the specimens in the Castaic formation. Recent species of *Macoma* are found in the littoral to bathyal zones, and so without definite specific identification this form is of little value in determining the environment of deposition of the Castaic formation sediments. Unfortunately, as mentioned in the discussion of the mudstone member in chapter II., Macoma? is the only fossil commonly found in the mudstone facies.

The following fossils have been found in the mudstone at localities in Castaic Canyon:

Macoma? sp., common at many places.

Nuculana sp., Locality 7-11-24.

Pelecypod, circular in outline, small, diameter 2 to 4 mm. Hinge and sculpture not preserved. Locality 7-11-24.

Pelecypod, Tellinidae, elongate with small altitude. Locality H-5.

Pelecypod, shell large, thin, with nacreous luster; shell edge smooth; valves compressed; sculpture of concentric groves 5 mm. apart. Alt. 50 mm., Long. about 70 mm. Locality 7-7-12.

Gastropod, small, moderately high spired. Locality 7-7-12.

Fish remains are relatively more common than mollusks and have been found throughout the formation in the mudstone. Both skeletal material and scales havebeen found. They have not been studied. The presence at Locality 1626 of A. montereyana, indicates that the sediments there were deposited in water less than 50 fathoms deep. Depth control is lacking for mudstone found elsewhere in the formation. The fauna of sandstone tongues intercalated with the mudstone in the northern part of the outcrop area is suggestive that the mudstones of the Castaic formation were largely deposited in water deeper than 25 or 30 fathoms. An approximate maximum depth of 100 fathoms in the vicinity of Castaic is indicated by a foraminiferal assemblage analyzed by Skolnick and Arnal (1959) They describe in detail a core taken from a well drilled in the Tapia Canyon field, southeast of the town of Castaic. The sediment is mudstone like that found in outcrops and described in the chapter on sediments. Very thin coal streaks occur throughout the core; pyritic shot are disseminated in the mudstone and occur in thin layers. The shot are either single or in irregular and spherical aggregates. The pyrite originated as fillings of diatom, Radiolaria, and Foraminifera tests. About 25 percent of the fauna consists of planktonic forms---Globigerina, Radiolaria, and diatoms. These are normal in size. The remainder of the fauna is composed of seven species of benthonic foraminifers. Bolivina vaughani, a species noted for its ability to live in rigorous environments, is the dominant species. The benthonic foraminifer are in general small; many are dwarfed and morphologically abnormal. The assemblage is indicative of sedimentation in water 20 to 100 fathoms deep in water connected to the open ocean. The pyritic fillings indicate reducing conditions either in the bottom water and/or beneath the sediment-water interface. The absence of diatoms and Radiolaria may be explained by the hypothesis that the siliceous tests of the Radiolaria and the diatoms were dissolved whereas the calcareous tests of the foraminifers were not. Therefore, the interstitial and perhaps also the bottom water was neutral or alkaline. Skolnick and Arnal (1959), believe the dwarfed fauna was largely the result of a brackish environment and that oxygen depletion and low Eh were perhaps contributing factors. They conclude that the environment was brackish for the following reason: Recent dwarfed foraminiferal assemblages have been found in a number of environments, including deep enclosed basins below sill depth and brackish shallow water with restricted circulation---the two enviroments they consider most likely to explain the fauna in the Castaic formation. They believe that the shallow water foraminifera indicate that the Castaic formation was not deposited in a deep basin. Therefore, they conclude that the environment must have been brackish.

Instead, it is suggested that the environment of deposition was not brackish and that the assemblage described by Skolnick and Arnal was formed in a bottom environment of low Eh. The reasons for believing that this interpretation is more probable are:

1. Nearly one-fourth of the specimens in the assemblage are planktonic, normal-size forms. If the water were brackish and normal marine water bearing planktonic organisms were introduced only occasionally, it does not seem probable that these species would comprise such a large part of the assemblage.

2. There is no evidence in the sediments of the formation that would indicate the presence of any sizeable inflow of fresh water. Neither is there any evidence of a barrier separating the ocean from the water mass in which the sediments of the Castaic formation were deposited.

3. The sample studied by Skolnick and Arnal was deposited near the entrance of the embayment in which the northern part of the Castaic formation was deposited. The western margin of the embayment was formed by movement along the San Gabriel fault. The vertical component of movement along the fault probably created a sill, which may have formed a reducing environment to the east below sill depth.

4. Skolnick and Arnal reject a low Eh environment because the foraminifers are indicative of shallow water rather than a deep silled basin. They present no evidence showing that such an environment can not occur at shallow depths.

5. The megafauna, living along the margin of the basin, contemporaneous with the microfauna studied by

Skolnick and Arnal, lived in sea water of normal marine salinity. The presence of marine water at shallow depths and brackish water at greater depths can not be reconciled.

Localities 2069 and 1663

The castaic formation is approximately 200 feet thick where these two localities occur. See Plate 4, section H. Locality 2069 is in the basal bed; Locality 1663 is in a bed 32 to 52 feet above the basal contact. The entire section is described below. See Plate 39 for location.

Maximum thickness exposed (feet)

Towsley formation

Mudstone, brown, poorly or indistinctly bedded. (Basal stratum only of formation)

Unconformity

Contact smooth, angularity slight

Castaic formation

Unit 7

Siltstone, sandy, weathered color is light yellowish gray; contains scattered rounded pebbles and beds of pebble conglomerate; poorly consolidated; fossiliferous. ca. 150

Unit 6

Sandstone, medium grained, pebbles and small cobbles are scattered through sandstone and occur in lenses; clasts up to 3 inches in diameter, most less than one-half inch in diameter. Bedding indistinct; unit poorly cemented but patches are very well cemented with calcite, forming small cliffs. The more resistant parts of the unit contain an abundant and varied fauna; the poorly cemented parts, in contrast, contain only sparse valves of <u>Lyropecten estrellanus</u>. Loc. 1663. 20

Unit 5

Sandstone, medium grained, poorly cemented better sorted than Unit 6, pebbly; the basal part of the unit is pebble conglomerate which grades upward into sandstone bearing only occasional scattered pebbles. No bedding planes within the unit. Pebbles of metamorphic and plutonic igneous composition, rounded, maximum diameter, 1 inch; average diameter, three-eighths inch. 11

Unit 4

Sandstone, medium grained, like Unit 5 except that maximum pebble diameter is 3 inches, average is three-fourths inch. 12

Unit 3

Sandstone, fine grained, a single bed, uncemented. 1/2

Unit 2

Sandstone, fine grained, uncemented, grading upward into pebbly sandstone. Maximum pebble diameter is 5 inches, diameters of most pebbles are one-fourth to 1 inch; pebbles are gneissic and plutonic igneous, a few are volcanic; pebbles are rounded. Basal few inches of unit are included in Locality 2069; they are very fossiliferous. 1 1/2

Unit 1

Conglomerate, cobbles and pebbles as large as 6 inches in diameter in a matrix of medium-grained sand. Clasts mainly of gneiss, some plutonic igneous, a few volcanic and sedimentary. Clasts well rounded, a few have been bored by pelecypods. A single bed, unconsolidated; grades within 1 inch into Unit 2, Loc. 2069. 6

ca. 200

Unconformity

Contact angular, several feet of local relief.

Mint Canyon formation

Sandstone, poorly consolidated, contains scattered pebbles and pebbly zones; interbedded with thin strata of pebble conglomerate. Pebbles angular to subangular, gneissic and plutonic igneous.

The presence of *Panope generosa* shells in living position in the Mint Canyon formation is discussed in chapter VIII. It indicates that the basal conglomerate is not the result of reworking of the transgressed surface but that it was deposited on the sea floor following a period during which conditions had been suitable for *P. generosa* to live. The species is found at present burrowing in sand in the inner sublittoral zone at depths as great as 25 fathoms. The assemblage present at locality 2069 was largely if not wholly introduced. A depositional site of cobble or pebble conglomerate is not a suitable habitat for the species represented in Locality 2069. Fossils in the conglomerate are largely fragmental but little abraded. In addition to the rare occurrence of articulated *Panope* previously mentioned, one articulated specimen each of *Solen* and *Eucrassatella* have been found. The fragmental but unworn state of preservation of most of the shells is perhaps indicative of rapid transportation, crushing, and deposition of shells without sufficient time for the slower process of abrasion. The most abundant species at Locality 2069 are, in order of abundance: *Astraea?* sp., *Polinices reclusianus*, *Lucina excavata*, *Lyropecten estrellanus*, *Crassostrea titan*, and a large, unidentified pelecypod.

Most of the specimens of *Polinices reclusianus* and *Lucina excavata* occur at the very top of the conglomerate and within the bottom inch or two of Unit 2. They may have occupied the site following cessation of conglomerate deposition. Valves of *L. excavata* are well preserved but disarticulated. *Polinices reclusianus* now lives in the littoral zone and the inner sublittoral zone to 25 fathoms. *Lucina excavata* is found in water 3 to 11 fathoms deep. These depths are the same range as the bathymetric range of *Panope generosa*, the only other species present of ecologic significance. Of the other abundant species present, *Lyropecten estrellanus* is of little value because no Recent equivalent species is known. *Astraea?* sp. is also of little value because it has not been identified. *Astraea* is now most common in depths of less than 15 fathoms. If the form is *Astralium*, it must indicate shallow water, for this occurrence would represent the northern most known late Miocene east Pacific limit of this essentially tropical genus. All the other forms are uncommon at the locality and have probably been transported. The assemblage is indicative of shallow depth; the sediments of Locality 2069 were deposited in water less than 15 or 20 fathoms deep.

Unit 3 contains numerous unidentified bone fragments.

Units 4 and 5 contain no fossils.

As noted above in the description of the measured section, the fossil content and cementation vary laterally in Unit 6. No lithologic variation can be seen corresponding to these variations. The factors producing the concentration of fossils at Locality 1663 are not known. Cementation was apparently localized where the supply of $CaCO_3$ was greatest. This relation is common not only at Locality 1663 but throughout the formation; the most fossiliferous sediments are also the most throughly indurated by $CaCO_3$ cement.

At Locality 1663, the species represented most abundantly are Lyropecten estrellanus and Lucinoma acutilineata. Specimens of both species are well preserved; most are articulated. L. estrellanus occurs throughout the unit, apparently ecologically independent of the conditions that caused the concentration of other species at Locality 1663. L. estrellanus can not be related closely to any Recent species and so is of little value in determining the depth at which the unit was deposited. The specimens of L. acutilineata are not only articulated but are oriented in living position in the pebbly sandstone. This species therefore is most diagnostic of the environment of deposition. The Recent very closely related species L. annulata is found in the open ocean at depths of 8 to 200 fathoms on sandy substrate. The species is most common, however, in water 30 to 50 fathoms deep. Other species common at Locality 1663 are Nuculana ochsneri, Eucrassatella cf. E. subgibbosa and Crenomytilus coalingensis. Most of the specimens of these three species are articulated and little worn, indicating little if any transportation before burial. N. taphria, the Recent equivalent of N. ochsneri---in fact, the two may be synonymous---is found in the open ocean at depths of 3 to 80 fathoms, but is most abundant at depths of 10 to 20 fathoms. It is commonly found on mud or sand substrate. *E. gibbosa*, the Recent equivalent species of the *Eucrassatella* found at Locality 1663, occurs at depths of 7 to 61 fathoms on substrate ranging from mud to shell sand. *Crenomytilus* is an extinct mytilid genus and hence the species *coalingensis* is of little ecologic value. The other species present at Locality 1663 are relatively rare; only a few specimens of each have been found. Of these species, however, *Chione fernandoensis*, *Chlamys hodgei*, *Miltha sanctaecrucis*, *Hinnites* cf. *H. multirugosus*, and *Terebratalia occidentalis* are represented by well preserved articulated specimens. *M. xantusi*, the Recent equivalent of *M. sanctaecrucis*, is found in the Gulf of California at depths greater than 30 fathoms on sand and weed substrate. *H. multirugosus* is found on gravel substrate or among rocks, from low tide to 12 fathoms. *Chione fernandoensis* and *Chlamys hodgei* are not of use in determining the environment because the Recent analogues are not known. *Terebratalia occidentalis* is found living at depths of 30 to 120 fathoms, but most commonly, at depths of 30 to 50 fathoms on a substrate of gravel and sand. All the species of gastropods are rare, and so are of doubtful ecologic value. The presence of *Lucinoma acutilineata* preserved in living position, the relatively large number of species represented by articulated specimens, the fact that most of the species characteristically occur on a substrate similar to the sediment of Unit 6, and the fact that most of the equivalent Recent species are found at similar depths indicate that the fauna is largely a life assemblage with few introduced forms. The assemblage is indicative of approximately 30 fathoms water depth along an open coast. *H. multirugosus* is the only articulated pelecypod restricted at present to considerably shallower depths. *Panope generosa* is indicative of water less than 25 fathoms deep but only very rare fragments are present. *Tivela*, *Arene*, *Astraea*, and *Calyptraea*, are suggestive of shallower water but these genera are represented by single specimens or scarce fragments. *Turritella cooperi*, most commonly found at present in water 25 to 55 fathoms deep, is present, whereas *Turritella* aff. *T. freya*, probably indicative of water less than 10 fathoms deep, is absent.

The sediments above Locality 1663, Unit 7, are silty fine-grained sandstone. Some plant fragments are present. Molluscan fossils consist of external molds of *Chione*, *Eucrassatella*, and the *Macoma*? that is common in the mudstone facies. This small assemblage is probably indicative of water depth at least as great as that existing during the deposition of the sediments of Locality 1663; that is, at least 30 fathoms.

This section containing Localities 1663 and 2069 is of particular interest because it contains two of the largest assemblages in the Castaic formation. The two assemblages indicate that the water depth was increasing with time - that the rate of subsidence was greater than the rate of sedimentation.

Locality 1627.

The fossils are imbedded in fine-grained sandstone overlying a poorly-sorted basal conglomerate. Single articulated specimens of *Apolymetis biangulata*, *Panope generosa*, and *Lucinoma acutilineata* have been found at the locality. *A. biangulata* is now found at depths of less than 40 fathoms; *P. generosa*, at depths less than 25 fathoms; and *L. acutilineata*, at depths of 8 to 200 fathoms, but most commonly, at depths of 30 to 50 fathoms. These three species, together with *Solen*, *Chione*, and *Polinices reclusianus*, are indicative of water less than 25 fathoms deep.

Lucinoma acutilineata is indicative of an offshore marine environment. All the other species are indicative of either a bay or offshore environment. Therefore it is very probable that this assemblage lived in an offshore environment at a depth of 25 to 30 fathoms.

Plum Canyon.

Dort (1948) lists a small fauna collected in the basal conglomerate on the south side of Plum Canyon. In Plum Canyon the basal conglomerate is overlain by mudstone. Only a thin section of the formation is exposed. The fauna reported by Dort includes Lyropecten sp., Lunatia (probably Polinices (Euspira) lewisii of this report, Ostrea (probably Crassostrea titan of this report), and Corbula? sp. The fossils from this area have not been examined by the writer. The reported fauna is small and not ecologically diagnostic.

Locality 1623.

The stratigraphic section exposed in Bouquet Canyon consists of a basal cobble conglomerate about 20 feet thick overlain by interbedded siltstone and fine sandstone about 75 feet thick with irregular and indistinct bedding planes, overlain in turn by typical mudstone. Locality 1623 is in the sandstone and siltstone about 50 feet above the base of the formation. Chlamys discus is the only species found at this locality. The fossils are molds and gypsum casts. The shells were unworn; some were articulated. This species is not ecologically diagnostic; it is abundant only at this locality.

Haskell Canyon.

Collections of fossils have been made in the past from a number of localities on the west side of Haskell Canyon. All the localities are in the basal 100 feet of the formation. The fauna from these localities has been analyzed by White (1947). The same collections have been restudied for this report. The localities could not be definitely located from the descriptions available. Therefore, they have been grouped under a single heading---Haskell Canyon---in the faunal list. Localities 1672, 1674, 1675, 1676, 1677, and 1678 could not be relocated and the collections from them studied by White (1947) could not be found. Therefore, these localities have not been considered in this study.

Locality 230 is in the basal pebble conglomerate. The fauna consists of *Lyropecten crassicardo*, *Crassostrea titan*, and *Oliva spicata*. Apparently the entire assemblage was transported before burial---the specimens of *Lyropecten* and *Crassostrea* are disarticulated and broken, and *Oliva spicata* now lives in a sandy substrate, not pebbly sand or conglomerate. The depth at which the sediment was deposited is unknown.

Localities 231, 232, 233, and 1624 are 70 to 90 feet above the base of the formation. Locality 231, in pebble conglomerate, contains disarticulated and broken specimens or *Lyropecten crassicardo*, *Crassostrea titan*, *Chione elsmerensis*, and *Lucinoma acutilineata*. Specimens of *Terebratalia* are articulated and well preserved. A single specimen of *Ficus ocoyana* is present, also. This small fauna is a mixture of elements from different environments. *Crassostrea* is indicative of relatively shallow water, whereas the species of *Terebratalia* and *Lucinoma* are indicative of somewhat deeper water-30 to 50 fathoms. Deposition was probably at this depth with transportation of *Crassostrea* from shallower water, and of *Chione* and *Lucinoma* specimens from a finer-grained substrate. The well preserved specimens of *Terebratalia* may not have been transported before burial - specimens of the species are found living on a substrate of sand and gravel.

Locality 233 is in slightly coarser conglomerate than Locality 231 and contains a very similar fauna. However, *Lucinoma acutilineata* is not present, and poorly preserved specimens of *Polinices reclusianus* and a *Calliostoma*--like form are present. As in the case of Locality 231, the mixed fauna and the conglomeratic sediment indicate that the specimens are representative of different environments and, at least in part, have been transported before burial. Although the fauna is composed largely of shallow-water forms, it was probably deposited in the lower part of the inner sublittoral zone based on the articulated well-preserved specimens of *Terebratalia*.

The fauna at Locality 1624 contains the following species.

- *Lyropecten crassicardo*
- *Crassostrea titan*
- *Lucinoma acutilineata*
- *Tegula gallina*
- *Astraea* sp.
- *Crepidula adunca*
- *Ficus ocoyana*
- *Conus californicus*
- *Mangelia* sp.
- *Terebratalia occidentalis*

The species of *Tegula*, *Crepidula*, *Mangelia*, *Astraea*, and *Conus* are indicative of the littoral zone and the inner sublittoral zone down to about 20 fathoms. *Lyropecten* and *Crassostrea* also are indicative of the shallow inner sublittoral zone. *Ficus ocoyana* is not diagnostic. *Lucinoma acutilineata* and *Terebratalia occidentalis*, on the other hand, are most commonly indicative of depths of 30 to 50 fathoms. The assemblage is composed of a mixture of two elements representing widely separate environments. It is possible that deposition occurred in shallow water on a gravel and sand bottom adjacent to a rocky coast. If so, *Lucinoma* and *Terebratalia* were living at a shallower depth than is common for the recent analogues of the two species. However, the shallow-water forms could have been transported down and mixed with *Terebratalia* and *Lucinoma* at the depth most common for the two. Because of the mixed assemblage and because of the lack of well preserved, clearly non-transported specimens, the depth range of the fauna can not be determined more precisely than the inner sublittoral zone.

Locality 1671.

This locality is in fine- to very fine-grained, brown, well indurated calcareous sandstone. The diagnostic species collected from this locality are *Polinices* cf. *P*. (*Euspira*) *lewisii*, *Periploma* cf. *P*. *discus*, and *Colus* (*Anomalosipho*) sp. Specimens of these are well preserved, and in the case of *Periploma*, articulated. *Polinices* cf. *P*. *lewisii* is indicative of water less than 25 fathoms deep; *P*. *discus*, of depths less than 5 fathoms. *Astrodapsis* preferred a substrate of clean sand in shallow water;*Anadara* is commonly found living in very shallow water; and *Crassostrea titan* apparently lived in shallow water on a sand substrate. *Colus* (*Anomalosipho*) is found at present only in the outer sublittoral or bathyal zone. Such depths are not in accord with depths indicated by the rest of the fauna. On the other hand, the specimens of *Colus* are abundant and well preserved and so are not an introduced element in the fauna. This anomalous situation is explained either by assuming that the genus is misidentified or that this new species was the exception among the species of the genus and lived in shallow water. All the species in the assemblage probably lived essentially where buried. The assemblage is indicative of a sandy bottom, considerable water movement, and a depth of not more than 5 fathoms. The salinity was normal for water of the open ocean.

Locality 1670.

Locality 1670 is very different from the localities previously described and is similar in many respects to the localities yet to be discussed which are in the north part of the outcrop area. The locality is transitional in the sense that it contains a number of species otherwise found in the formation only north or only south of the locality. The locality contains a mixed and transported assemblage; none of the species can be shown to have lived where buried. The following evidence supports these conclusions. 1. Forms present are indicative of a wide variety of bathymetric zones, from the littoral zone to the base of the inner sublittoral zone. 2. Bivalves are largely disarticulated. 3. Many shells are fragmental. 4. The locality is in a unit of conglomeratic sediments. The composition of the assemblage is related to the depositional texture of the sediment, for the larger fossils are in the strata containing larger clasts. 5. Few of the species present are now found living on a substrate as coarse as that in which the fossils are buried. 6. No well-preserved specimens are found in living position on the upper surface of the unit.

This assemblage probably represents deposition at approximately the base of the inner sublittoral zone. The conglomerate may represent a single episode of deposition of coarse sediment in an area where the usual sediment deposited was sand or mud. Apparently, a variety of invertebrates was carried out and deposited with the coarse clastics. The sediment is very similar to tongues of conglomerate deposited out from the rocky shore in the Castaic Canyon area.

Mid-basin sandstone facies

Fossils are scarce in the mid-basin sandstone occurring northwest of Dry Canyon. Commonly, only small fragments of Crassostrea titan approximately one-half inch across are present, in pebbly strata. Localities 279, 2097, and 2098, essentially correlative, are in coarse-grained to pebbly sandstone. The assemblages consist of few and generally poorly preserved specimens. None of the pelecypods are articulated but the specimens of Nemocardium centifilosum have undergone little wear, and are the most diagnostic species. This species now lives in water 20 to 80 fathoms deep, but most commonly in water 30 to 50 fathoms deep. Turritella cooperi has a similar bathymetric range. Sinum scopulosum lives at depths of 10 to 20 fathoms. Crassostrea titan and Lyropecten crassicardo are probably indicative of water less than 20 fathoms deep. However, judging from the worn and fragmental specimens, shells of these two species and the associated Ostrea vespertina have been transported before deposition. The probable depth of water during the deposition of the sediments at these localities was greater than 20 fathoms. It can not be determined more precisely.

Basal sediments north of Dry Canyon

Except for two localities, the basal sediments and the fossils contained can be described in terms of several general relationships. Between Dry Canyon and Necktie Canyon, fossils are very scarce. None have been found in the basal strata; only a few have been found in pebbly sandstone near the basal contact. Those that have been found are largely fragmental, and are not indicative of depth of deposition; only, that the species lived in the inner sublittoral zone. The fauna is very small in the basal complex. *Crassostrea titan* and *Lyropecten crassicardo* are the dominant species. *Astrodapsis* cf. *A. fernandoensis* and *Glycymeris grewingki* are the only other species that are widely distributed. Other species reported from localities in the basal sediments are found only at a few localities and are represented by few specimens. Specimens that were probably not transported before burial are very rare. Generally, fossils are found in pebbly sandstone or in conglomerate, disarticulated and broken, and the fragments are associated with clasts of comparable size. Specimens of *Crassostrea titan* in living position are found only in medium-to coarse-grained sandstone that is not pebbly. Although *C. titan* is the most abundant species in the basal complex, it does not form "reefs" similar to those formed by *Crassostrea virginica* along the Recent coast of Texas. Where *C. titan* is most abundant, it is the only species present. At a few localities *C. titan* and *Lyropecten crassicardo* apparently lived together. At Locality 2104, *Spondylus*, *Balanus*, and *Ostrea vespertina* were apparently associated with *C. titan* in a life assemblage. Where articulated specimens of *crassicardo* are most abundant, other species are absent. In general, the fauna found in the basal sediments lived in water shallower than 5 fathoms. At Locality 2075, *Glycymeris* cf. *G. branneri* is indicative of water 4 to 7 fathoms deep. The sediments at Locality 2104, however, were probably deposited in water about 15 fathoms deep. Recent west American species of *Spondylus* live at depths of 15 to 45 fathoms. The *Spondylus* at Locality 2104 probably lived at the upper limit of the bathymetric range because it was living at the northern limit of the geographic range.

Abundant tests or fragments of tests of *Astrodapsis* cf. *A. fernandoensis* are found only in relatively well-sorted sandstone beds within one-half mile of the contemporaneous shore. *Astrodapsis* spines, however, are more widely distributed and are particularly abundant in pebbly sandstones and conglomerates. Where basal sediments consist of interbedded sandstone and conglomerate, as at Localities 2084, 2085, 2086, and 2087, at Triangle ridge, the pebble conglomerate typically contains fragments of *Crassostrea titan* and *Lyropecten Crassicardo*; the pebbly sandstone may contain fragments of these two species, but also, possibly, whole valves or articulated specimens of the two. The best-sorted sandstone may be unfossiliferous or may contain *Astrodapsis* tests; rarely, it may contain abundant articulated specimens of *Crassostrea titan*. Gastropods are rare in the basal sediments. Only a few specimens of *Caliostoma*, *Astraea*, and *Polinices* have been found, and these occur largely in tongues of sediment extending out from the basal complex. A single specimen of *Nerita* has been found, at Locality 2072, in a tongue of coarse clastics. The absence of rocky shore forms is explained in two ways. Many forms were restricted by the embayment environment and the resulting effect on water roughness and food supply. Probably more rocky-shore forms were present, but the chance of preservation for species living in such an environment is low. Shells would be quickly broken and abraded among the coarse-grained substrate.

The predominance of conglomeratic sediments along the contact gives the impression of a steep rocky coast with coarse conglomeratic sediments being deposited close off-shore. Actually, the near-shore substrate must have been sandy in large part but was not preserved. This conclusion is based on the fact that fragmental fossils of *Crassostrea* are abundant in the coarse sediments but specimens apparently lived only on a sandy substrate. Therefore sand must have been much more common near shore than is indicated by the sediments. Probably sand was the usual near-shore substrate, but occasional storms would wash out the sand and deposit coarse clastic material.

An indication of what the near-shore sediments generally were like is gained from the exposures of the basal member on the north side of Elderberry Canyon. See Plates 6, 32, 38. There, a thick wedge of sandstone composed of a number of sand bodies is overlain by a tongue of conglomerate and pebbly sandstone extending out into the mudstone. Presumably after the deposition of this conglomeratic tongue, more sand was deposited along the shore line, to be removed later or buried by another conglomeratic tongue.

The units comprising the sandstone wedge differ from one another only in detail. All are moderately-sorted sandstone or pebbly sandstone. All are arkosic. Differences are in texture, color (but all are light gray to grayish brown), and degree of cementation. Whole, articulated specimens of *Crassostrea titan* are very abundant in Unit D. Unit B contains articulated *C. titan* in living position as well as scattered disarticulated valves of *Lyropecten crassicardo*. *Glycymeris grewingki* valves, *Astrodapsis* spines and fragments of several unidentified species of pelecypods are also present. Unit C is less well cemented and is unfossiliferous. Units G, H, and I are apparently unfossiliferous. Units E and F are composed of pebbly sandstone and contain only a sparse fauna of fragments of *Crassostrea titan*, fragments and whole tests of *Astrodapsis*, and whole valves of *Lyropecten crassicardo* and *Glycymeris grewingki*. Articulated specimens of *Lyropecten crassicardo* are largely confined to Units F and G along the trend of the "bar" marking the seaward limit of the sand accumulation. The steep dips along the west edge of the "bar" are partly depositional and partly the result of slumping that occurred before complete compaction of the sediments. The sand wedge was deposited at a depth of about 5 fathoms, as indicated by the presence of *Glycymeris branneri* in living position in Unit F on the south side of Edlerberry Canyon.

Chione elsmerensis and *Turritella cooperi* are largely confined to offshore tongues of coarse sediments. The presence of *T. cooperi* in these tongues suggests that deposition of these tongues at perhaps one-half mile from shore was in water more than 20 fathoms deep.

Locality 2093 contains an anomalous fauna. *Crassostrea* and *Lyropecten* are very rare, whereas forms that are rare at other localities, such as *Sanguinolaria* cf. *S. alata*, *Dosinia arnoldi*, *Apolymetis biangulata*, *Corbula luteola*, and *Acteon* cf. *A. boulderana* are present. Judging from the bathymetric distribution characteristic of the forms present, the depth of deposition was probably less than 10 fathoms at the locality. The factors leading to this distinctive assemblage are not known. Possibly one of the principal factors was relatively great water movement at this locality.

Faunal variations

The faunal variations that occur in the Castaic formation are the result of environmental variations. In the discussions of individual localities, principal stress has been placed on the relation between assemblage composition and bathymetry. The nature of the substrate, the relief along shore, and all the factors of embayment versus open-ocean environments are equally as important as water depth in determining the composition of the fauna. Species that characteristically live on a sandy substrate along an open coast are found at the localities south of Dry Canyon. Such habitats were not present in the northern part of the basin of deposition and so the fauna there is largely different. The fauna in the northern part of the outcrop area is composed of relatively few species. It has been suggested, that part of the Castaic formation was deposited in a brackish environment (Jahns, 1940, p. 166). Such is not the case, for the entire fauna is indicative of a normal marine environment. The bay environment differed from the open coast environment in such factors as water agitation, and stability of the substrate, temperature range, and food supply.

V. Paleozoogeography

Premises

Changes in the distribution of a species or other taxonomic unit can be explained either by changes in the environment or by changes in the ecologic requirements of the species, or by a combination of the two. In analyzing a species apart from the other organisms with which it is associated, it is impossible to tell which has changed--the environment or the species.

By analyzing the whole assemblage, however, changes in both environment and ecologic requirements can be noted if it is assumed to be unlikely that the ecologic requirements of all or most of the species would concurrently change in a uniform manner. Thus, a systematic shift in the distribution of many species is the result of external factors. The more random distributional changes of individual species is more probably the result of evolutionary changes.

Many of the species found in the Castaic formation have limited time ranges and the geographic distribution of each has been compared with that of the most closely related form during the Cenozoic. Comparisons with larger taxonomic groups are not as desirable as those which are specific because they are based on the assumptions that morphologically similar species have similar niches and that the distribution of a species is comparable to that of the genus to which it belongs. Such assumptions are dangerous because the distribution of a genus is the summation of the more or less overlapping distributions of all the species in the genus, and because closely related species commonly occupy very different niches. Zoogeography, using the genus as the unit of study, must be done with these facts in mind. Using genera rather than species has the advantage, however, that mistaken identifications are less likely because the unit is taxonomically more stable and well defined. The validity of subgeneric or generic comparison is dependent upon the closeness of relationship and the diversity of the species within the superspecific group. Whenever possible however, specific comparisons will be made because of the greater detail thus obtainable.

In order to learn of the marine climate in which the sediments of the Castaic formation was deposited, the late Miocene distribution of forms found within the formation will be compared with the present distribution of the same or closely related forms. Then, the geographic distribution of the equivalent Recent assemblage will be determined. It is presumed that the environment in which the Castaic formation fauna lived was similar to that in which the Recent taxonomically equivalent fauna lives.

The location of this equivalent Recent fauna is stated in terms of latitude. This indirect method of determining the environment is only as good as Recent and Tertiary ecologic and zoogeographic data. No more can be known of the late Miocene environment than is known of the equivalent Recent environment. The method used gives only a bare outline of the physical environment. The biologic factors are largely unknown.

The gross paleoclimate of the Castaic formation can be determined by the method outlined because the fauna being compared are situated along a north oriented coast and because climatic changes are reflected in latitudinal shifts of isotherms along the coast. If there were a uniformly negative temperature gradient from tropics to polar region, and, assuming that climate was the primary factor limiting the geographic distribution of a species, the latitudinal zoogeographic limits could be correlated with climatic limits (Hutchins, 1947). Faunal distribution along the Pacific coast of North America is complicated in a number of ways, however:

1. Currents and the configuration of the coastline perturb the gross equator-to-pole temperature gradient, affecting strongly the boundaries of faunal provinces.

2. In some shallow bays along the western Baja California coast the water is warmer than that present in the open ocean outside the bays. In such warm-water embayments, Panamic species live which are otherwise found only farther south in water of comparable warmth.

3. The surface water at many places along the Pacific coast and in the Gulf of California is cooler than the surrounding water. These areas of cold water are caused by upwelling. Along the outer coast of Baja California upwelling occurs most commonly south of headlands. In the isolated, discontinuous areas of cooler water along the coast of Baja California, species are found which are otherwise unknown south of Point Conception. Emerson (1956a, 1956b) and Valentine (1955) have discussed upwelling in relation to molluscan distribution and Pleistocene paleoecology, correlation, and climate.

4. Many cool-water species live in progressively deeper water equatorward. R. H. Parker (personal communication January 11, 1960) has recently found specimens living in the lower sublittoral zone in the Gulf of California that had formerly been unknown south of southern California where they live in shallower water. He suspects that with further sampling of the outer shelf fauna the distribution of these elements will be shown to be continuous.

5. Because of upwelling, equatorward submergence, and the general southward larval transport, the southern limits of cool-water species are difficult to analyze along the Pacific coast of North America. Conversely,

discontinuities in the northern limits of warm-water species are smaller and less likely.

Because generally a species is found in shallower water at the northern margin of its area of distribution, the northern limit of a warm-water species can be reliably compared for different times and essentially the same bathymetric zone will be represented. For this reason, the results obtained by Durham (1950a) from analyzing the northern limits of the distribution of genera found in a number of assemblages are very similar to those obtained in this report from a detailed analysis of a single fauna. Many of the unknown factors are minimized by comparing the northern limits of species. The presence of species in the Castaic formation which are found at present only in the Panamic molluscan faunal province is of prime importance.

The molluscan fauna of California and the west coast of Mexico is grouped into three faunal provinces--Oregonian, north of Point Conception; Californian, from Point Conception to Cedros Island; and, Panamic, south of Magdalena Bay. The fauna between Magdalena Bay and Cedros Island is transitional Panamic-Californian. The Gulf of California is placed in the Panamic province. Newell (1948) has presented the statistical basis for the definition of these faunal provinces. Keen (1958, p. 3) states that few Panamic molluscan species may be found north of Magdalena Bay, and that between Magdalena Bay and Cedros Island a mixture of Panamic and Californian species is found. Keen considers the Gulf of California to be a subprovince of the Panamic molluscan province and says that the fauna in the northern part of the Gulf is different than that in the southern part. Garth (1955) has concluded from studying crabs that the northern Gulf constitutes a warm temperate province distinct from the tropical Panamic province and equivalent to the Californian province. Hertlein and Emerson (1956) are unable to detect this subdivision in the Pleistocene molluscan fauna of the Gulf. In this report, the whole Gulf of California is placed within the Recent Panamic molluscan province. If the Recent molluscan fauna of the Gulf of California is Panamic and warm temperate, it was certainly Panamic earlier in the Cenozoic when the climate was warmer and more uniform (Durham, 1950a).

By equating similar late Miocene and Recent faunas with similar climates, the tacit assumption is made that climate is the only, or at least the primary, factor affecting faunal distribution. I believe that this assumption is valid when working with assemblages and on the scale of the present study. Other elements of the physical environment might well restrict the distribution of an assemblage, but the restriction would be on a smaller scale than that caused by the broad regional climatic conditions.

In the detailed analysis of the environment of deposition of the Castaic formation, elements of the fauna are analyzed in terms of their probable depth distribution. In the zoogeographic analysis the total fauna, containing elements from a variety of niches, is compared to a total Recent fauna, also derived from a variety of niches.

Explanation of Distribution Figure

The distribution figures included in the faunal list show the latitudinal distribution of each form for five different time intervals during the Cenozoic era: Recent, Pleistocene, Pliocene, late Miocene, and earlier Tertiary. For each time interval a line represents the maximum distribution of the particular species or most closely related taxonomic group, which may be the subgenus, genus or a closely related species. The intervals are arranged in order of increasing age downward as indicated opposite the first species on the list. The names of the intervals are not repeated opposite each form because the "0" signifying the late Miocene Castaic occurrence is a sufficient guide. Arrows at the ends of a line indicate that the distribution extends beyond the limits of the plot -- 15° and 50° north latitude. An "X" indicates a single occurrence or widely separated occurrences during a particular time interval. In addition to the latitude in degrees, Cape San Lucas, the Gulf of California, and Mazatlan are marked by C.S.L., G., and M., respectively, between 20° and 25°, but not at true scale. These localities delineate an area in which occur the limits of distribution of many Recent species. Pliocene occurrences marked under "G" represent fossils found both in the Gulf of California and in the Imperial formation.

The nature of the taxa, the distribution of which is plotted, is indicated to the left of the distribution figure: SS indicates it is the same subspecies as the Castaic formation form; S, the same species; C, a closely related species or group of species; G, the genus which includes the specimen. If the occurrence in the Castaic formation is the only one reported from upper Miocene sediments, or if specific identification is not possible, no letter is present opposite the late Miocene. The distribution limits are joined to form a closed polygon.

The data presented in these distribution figures are the result of a thorough search of the literature dealing with the Cenozoic molluscan fauna of west North America. Although many papers have been studied, several have been particularly important. Grant and Gale (1931) provide a relatively complete coverage of the Pliocene and Pleistocene fauna of California, although their nomenclature is revised in some details. Weaver (1943) has similarly complied the Tertiary mollusks of Oregon and Washington. Oldroyd (1925-27), Burch (1944-46), Hertlein and Strong (1940-51), and Keen (1958), have been the most inportant references to Recent mollusks.

Any paleozoogeographic study is limited by the extent of current knowledge and by the distribution of potentially fossil-bearing sediments. The effect of each of these limitations on the present study will be discussed. Durham (1950a, p. 1251) has stated that probably less than 50 percent of the Pacific coast Tertiary marine fauna is known, and perhaps not even 25 percent. As he points out however, the 50 to 75 percent unknown constitutes the smaller, and the less common fossil forms. In addition, many of the early taxonomic studies were based on gross morphology rather than on more critical details. For example, a number of pelecypod holotypes are poorly preserved incomplete specimens with dentition either not preserved or not exposed. In addition, many genera were split too finely because the variation possible within a population was not appreciated. The earliest faunal studies on the Pacific coast dealt with material from the Coast Ranges of central California, and most of the type specimens have come from this region.

Durham (1950a, p. 1249-1251) discusses briefly the distribution of Tertiary sediments. Although Tertiary sediments are widely distributed, those of any particular series are limited. If one is seeking sediments of both a certain age and facies, the distribution is even more limited. This limitation seriously influences the distributions plotted on the faunal check list.

Marine sediments correlative with the Castaic formation occur only between the San Francisco area and the Los Angeles basin; many of these sediments are shale and diatomite and would not be expected to contain the same assemblage found in the near-shore coarse sediments of the Castaic formation. No correlative marine sediments have been reported south of the Los Angeles basin through Central America. Pliocene sediments of the same facies as the Castaic formation have been found throughout the Coast ranges of the United States as well as along the west coast of Baja California, in the Gulf of California, and in the Colorado Desert of California. No Pliocene marine sediments have been reported between Baja California and the Burico Penninsula, Costa Rica. Pleistocene marine sediments occur along the west North American coast as far south as Baja California. Except for a locality in Oaxaca, no Pleistocene sediments with marine fossils have been reported between Baja California and the Burico Penninsula. Pre-late Miocene Tertiary sediments occur throughout the Coast ranges. Middle and lower Tertiary sediments are known to occur in Baja California but little has been published on the fauna they contain. Thus, the occurrence of Tertiary sediments is much more limited than indicated by Durham (1950a, p. 1259).

Patterns of distribution--Interpretation

The paleozoogeography of the forms found in the Castaic formation can be summarized from the distribution figures.

1. The Castaic formation occurrence is at or near the known southern limit of the late Miocene distribution of all the forms listed. This is readily explained by the lack of upper Miocene sediments south of southern California. As will be presented later, it is also possible that the Castaic formation represents approximately the actual southern limit of distribution of many of these species.

2. The distribution of many forms has moved south-

ward during the Cenozoic. Both southern and northern limits have shifted. This is comparable to Durham's (1950a) conclusion. Durham, however, does not continue his analysis into the Pleistocene and Recent, but merely states that isotherms fluctuated during the Pleistocene. Intra-Pleistocene correlation is not at present resolved. The northern limits of a number of forms have shifted northward since the Pleistocene but the southern limits of most of these forms do not shift northward to an equal extent. Durham (1950a, p. 1259, fig. 3) indicates a northward shift of the February isotherms during the late Pliocene. He presents no evidence to substantiate this reversal in the general southward shift of the isotherms. Late Cenozoic faunal distributions are little affected by the distribution of sediments as are the late Miocene faunal distributions. Few pre-late Miocene distributions are plotted because the fossils of the Castaic formation fauna can be more clearly related to species of younger faunas than to older ones.

3. A number of Recent forms equivalent to forms found in the Castaic formation are restricted to the Panamic province; some of these forms had not previously been found in middle or upper Cenozoic sediments of the Coast ranges; some had not even been reported previously from Cenozoic sediments of the Pacific coast. These forms are:

- Glycymeris cf. G. branneri
- Eucrassatella cf. E. subgibbosa
- Miltha sanctaecrucis
- Arene n. sp.
- Nerita sp.
- Calyptraea (Trochita) sp.
- Pyrene sp.
- Olica spicata

- *Marginella* sp.
- *Conus* sp. A.
- *Turricula?* sp.

In addition, the following forms are Panamic, or are related to forms which are Panamic, but are found on the west coast of Baja California in the Californian-Panamic transition zone.

- *Lyropecten crassicardo*
- *Spondylus* sp.
- *Dosinia arnoldi*
- *Turritella* aff. *T. freya*
- *Polinices* (*P.*) *uber*

Astraea sp. can not be definitely identified, but the opercula found associated with the specimens at Locality 2069 are like the opercula of the subgenus *Astralium*. *Astralium* is a tropical group found at present primarily in the Caribbean faunal province. From this evidence, it seems clear that the equivalent Recent assemblage is found at the northern limit of the Panamic province in the vicinity of Magdalena Bay.

4. Many of the other forms found in the Castaic formation can not be related to Recent forms because they can not be sufficiently identified or because they belong to extinct genera. The Recent distribution of many of the genera could be plotted but this would add little to the picture created by the more precise specific data. Most of the Recent forms that have been related to the remaining Castaic formation species are found in the Californian Province; a few are found in the Oregonian Province. If the Castaic formation fauna is equivalent to a Recent fauna located at the northern limit of the Panamic province, the Castaic formation must represent essentially the shallow water southern limit of the northern, cooler-water forms. As mentioned previously, this southern

limit of the Californian fauna is not as reliable in zoogeographic studies as the northern limit of Panamic forms because it can be blurred by several factors, the most important of which are upwelling and equatorward submergence. In addition, the molluscan fauna does not change abruptly at a provincial boundary. Rather, the boundary is the illustration of a statistical conclusion; it represents the area in which the composition of the fauna is changing particularly rapidly. Although the boundary of a faunal province is transitional, a province can be defined precisely in terms of characteristic, diagnostic genera or species. It is these forms which have been listed above.

It is impossible to show conclusively that the southern limit of late Miocene distribution was at the Castaic formation. However, the following oblique approach will indicate that this was indeed so. Pliocene and Pleistocene sediments and fossils are known throughout the Coast ranges and in Baja California. Therefore it is assumed that the southern limits for the Pliocene, Pleistocene and Recent faunal distributions are reliable. The Pliocene southern limit of a form must be at or south of the late Miocene limit because of the general southward shift of isotherms during the Tertiary. For most of the forms the Pliocene limit is within a degree or two of the Castaic formation. Thus, the late Miocene limit could not have been more than a few degrees south of the Castaic formation. The reported southern limit of many of the comparative Recent forms is along the southwestern coast of Baja California, near the position of the equivalent Recent locality.

5. Only a few of the specimens found in the Castaic formation are clearly related to Recent Oregonian forms. They are:

Glycymeris grewingki
Chlamys cf. *C. hastatus*
Chlamys parmeleei?
Chione (*Securella*) *elsmerensis*
Colus (*Anomalosipho*)

These comprise only a small part of the fauna and their association with Panamic and Californian forms can be explained by either of the two factors previously discussed that affect the warm-water limits of a fauna.

6. The absence of many genera typically found in the present Panamic province is explained in two ways: A. The Castaic formation was deposited at the northern boundary of the late Miocene Panamic province. Thus the distribution of many Panamic forms did not extend as far north as the site of the Castaic formation. For example, no common Recent cassid occurs north of Cape San Lucas, south of the Recent equivalent fauna, and so no late Miocene cassid might be anticipated in the Castaic formation. B. Preservation is so poor in the Castaic formation, as in most sediments, that a representative sample should not be expected. An indication of the improbability of fossil preservation is the fact that many of the species recorded from the Castaic formation have been found at only a single locality. Many of these species are represented by only single specimens. Thus it is likely that much of the fauna has not been preserved at all, and many species are so rare that they have not been found.

7. The equivalent Recent fauna exists in the vicinity of 25°N latitude. Thus a 9° southward shift in latitude of marine climatic conditions has occurred since the late Miocene. This corresponds to a decrease of 7°C. in the regional February surface isotherm--from about 20° C. to about 13°C. The Recent regional August surface

isotherms off southwest Baja California and southern California are about 24°C. and 16°C. respectively, representing a decrease off southern California of about 8° C. By contrast, the study of Tertiary flora of southern California indicates that the late Miocene atmospheric climate was somewhat similar to the present climate. Axelrod (1939, 1940, 1950, 1956) has shown that during the late Tertiary the climate became more continental, less maritime. Although the annual amount of rainfall has not changed markedly, it presently occurs more seasonally--largely limited to the winter months rather than throughout the year as in the middle Tertiary. Mean temperatures have remained fairly constant but the range has become greater, with colder winters and warmer summers.

Studies by Emerson (1956a, 1956b), Addicott and Emerson (1959), Valentine (1955), and others, have shown that adjacent faunas may differ considerably if a headland or embayment is present so that one assemblage lived in a protected environment whereas another assemblage lived in an area of colder, upwelling water. The deposition of the northern part of the Castaic formation in an embayment and the southern part along an open coast is geographically very similar to the Pleistocene and Recent cases that have been reported in the literature. If thermal anomalies caused by upwelling had occurred in the late Miocene, the assemblages from the northern part of the formation should contain more warm-water elements than the assemblages from the southern part. This is not the case; this study furnishes no evidence of upwelling having occurred. Panamic forms are equally abundant in both parts of the formation. The same is also true of the Oregonian forms.

Durham (1950a, p. 1257, 1259) concludes that the late Miocene February surface marine isotherm at 34°N latitude was 18°C. The late Miocene faunas he analyzed are from Washington and central California. The conclusion from this study is that the temperature was 20°C. Considering the differences in detail involved in the two studies, the conclusions are very close. The maps, plates 12, 13, are redrawn from maps published by Scripps Institute of Oceanography (1958a, 1958b, 1958c, 1958d). The typical depth---temperature curves are derived from data in these papers. These maps and curves are indicative of the general conditions which existed during the deposition of the Castaic formation. The temperature profiles are drawn from data collected at hydrographic stations established within approximately 50 miles from shore, in water 20 fathoms to over 2000 fathoms deep. Surface water temperature data from along shore are not known to exist. These maps and profiles, when compared with the maps of February and August surface isotherms in Sverdrup, et al (1942) illustrate the low near-shore temperatures resulting from upwelling. The effect of upwelling is particularly evident during spring and early summer. At least locally, therefore, near-shore surface water is even cooler than during January or February. Seasonal temperature fluctuations are largely confined to the water in the upper 50 fathoms of the ocean. Below that depth, temperatures fluctuate no more than several degrees from January to August, and the temperature profiles for these months have very similar shapes. The inflection point on the profiles is shallower during summer than during winter. This is a reflection of the slight temperature range in the water within the upper 15 to 20 fathoms of the ocean during the winter months. The range in this zone is also small during the months of active upwelling. The water in the upper 10 to 15 fathoms of the ocean is significantly warmed only during July and August.

VI. Paleogeography

The fauna studied consists mainly of shallow-water, near-shore assemblages. The shoreline during the deposition of these assemblages is marked approximately by the present outcrop limits of the formation. At the north end of the outcrop area, in Castaic Canyon, the contemporary shore line probably extended generally westward or northwestward to the San Gabriel Fault. It is unlikely that the marine basin of deposition extended very far north along the east side of the San Gabriel fault. During the late Miocene the sea encroached over the land and the basin of deposition of the Castaic formation increased in area. The limits of the marine basin at its greatest extent are unknown.

Crowell (1952, 1954a) has presented evidence that shows that at least 20 miles of right lateral movement has taken place along the San Gabriel fault since the late Miocene. More recently, it has been suggested that lateral movement on the San Gabriel fault has been slight, and the Castaic formation was deposited in a brackish-water environment similar in shape and setting to San Francisco Bay. The faunal analysis here presented indicates that the environment was not brackish. Corey (1954, fig. 7) presents a map of upper Miocene geography. According to this map, land was present along the south side of the San Gabriel fault as far to the northwest as the site of Saugus. If this map correctly depicts the present location of late Miocene land and sea, at least 3 to 5 miles of right lateral movement has taken place along the fault, for if not, the localities south of the Santa Clara River Valley would have been within an embayment. The assemblages at these localities, however, are indicative of an open coast environment.

VII. Conclusions

The Castaic formation was deposited in the transgressing late Miocene sea. It was deposited upon a surface of eroded Tertiary sediments of the Martinez, Vasquez, and Mint Canyon formations. Part of the formation was deposited along the open coast; part was deposited within a broad, open embayment formed by movement along the San Gabriel fault. Along the northwest, faulted margin of the embayment, the Violin breccia was deposited contemporaneously with the upper half of the Castaic formation and with the largely Pliocene Ridge Basin group. The Violin breccia was derived from adjacent land areas of high relief. The breccia probably deposited on-shore. The nonmarine- to marine transition is probably in the sandstone which interfingers with the breccia.

Along the eastern margin of the basin of deposition, relief was relatively high north of the present location of San Francisquito Canyon. Sediments deposited along this sector of the shore were largely conglomerate and conglomeratic sandstone. Sand was deposited along this steep rocky shore and supported a fauna composed of few species but numerous individuals. However, the shallow-water sand was largely removed by occasional storms or because of shifts in the position of the shore line. Near-shore sand is preserved along this sector of the contact at only a few localities. To the southeast, relief along the shore was low; the land being transgressed was composed of slightly consolidated, slightly dipping terrestrial clastics of the Mint Canyon formation. Sediments deposited along this sector of the shore were relatively well-sorted sandstone and mudstone. The sediments comprising the Castaic formation were derived from local sources, primarily the underlying Tertiary sediments. The sediment clasts in the Castaic formation are not texturally more mature than the grains in the older sediments. They are somewhat better sorted however.

A longshore current flowed northward along the west side of the embayment. Probably the pattern of circulation along the coast was similar to that existing at present---a primary southerly current and a near-shore counter current on the lee side of headlands. Water roughness along the shore was greatest in the part of the basin of deposition south of the present position of San Francisquito Canyon. North of this, water roughness was much less along the east side of the embayment; it was probably at a minimum along the west side of the embayment.

Movement on the San Gabriel fault created a sill along the seaward margin of the basin of deposition. Behind and below this sill, circulation was limited and a reducing environment of low Eh was probably present at the sediment---water interface and within the bottom water.

The maximum depth of the sill was about 100 fathoms. Only a small foraminiferal fauna lived in the reducing environment below sill level. Mudstone rich in organic matter was deposited in mid-basin within the outer sublittoral zone. The sandstones and coarser-grained sediments in the formation were deposited within the inner sublittoral zone. Fossiliferous sediments were deposited at depths ranging from about 5 or less to about 40 fathoms. Most assemblages and the associated sandstones were deposited at depths of less than 30 fathoms.

The marine climate was like that found at present off the southwest coast of Baja California in the vicinity of Magdalena Bay. It was relatively uniform throughout the basin. There is no evidence of abnormally low temperatures along the open coast because of upwelling, nor of abnormally high or low temperatures within the embayment because of great summer insolation or winter cooling. The average annual minimum temperature at the surface was about 20°C. It was about 17°C. at 25 fathoms, 14°C. at 50 fathoms, and 11°C. at 100 fathoms. The average annual maximum temperature at the surface was about 24°C. It was about 18°C. at 25 fathoms, 16°C. at 50 fathoms, and 12°C at 100 fathoms. The temperature range (in degrees C.) was about: 18 - 22 at Locality 1849, 18 - 22 at 2069, 15 - 17 at 1663, 16 - 17 at 1627, 15 - 16 at Haskell Canyon localities, 20 - 24 at 1671, 14 - 15 at 1670, and 19 - 24 at the localities in Castaic Canyon. Recent specimens of *Terebratalia occidentalis* from the Gulf of California have grown at an average temperature of about 17°C, according to oxygen isotope determinations (H. A. Lowenstam, personal communication). This temperature is in accord with the proposed temperatures at localities where this species has been found in the Castaic formation, lending support to the validity of applying the Recent marine temperature profiles to the interpretation of the depositional environment of the Castaic formation.

The water throughout the basin was of normal marine salinity.

These ecologic conclusions pertain primarily to the time during which sediments containing abundant fossils were deposited. Such sediments are restricted to the middle horizons of the formation. During the deposition of the uppermost strata of the Castaic formation, vast massive beds of sandstone were deposited out into the center of the basin. These sediments are probably indicative of either the regression of the late Miocene sea or of the shoaling of the basin as sedimentation kept pace with transgression.

In studies in which conclusions are derived from comparison of living and fossil forms, the degree of detail possible is directly related to the level of taxonomic precision attained. By determining the paleozoogeographic setting of the fauna being studied, much can be learned of the paleoclimate during the life of the fauna. Conversely, by applying detailed taxonomy and by considering in detail the bathymetric distribution of organisms and the related marine temperature profile,Tertiary west North American marine paleoclimate can be determined more precisely than has been done in the past.

VIII. Systematic paleontology

The synonomy given has been limited to the original description of the species and the latest papers that discuss the species to any extent and contain a complete synonomy.

Incomplete descriptions are due to incomplete specimens. All dimensions are in millimeters. The primary measurements given are:

for gastropods

Altitude - maximum dimension parallel to axis of coiling.

Diameter - maximum dimension perpendicular to axis of coiling.

for pelecypods

Longtitude - the maximum dimension parallel to the hinge line.

Altitude - the maximum dimension perpendicular to the hinge line in the plane dividing the two valves.

Diameter - the maximum dimension perpendicular to the plane dividing the valves. In many cases, the diameter measurement is for only a single isolated valve, and thus is approximately half the diameter of an articulated specimen. Such cases are always noted. Many specimens measured are not quite complete, but the original outline can be closely approximated. In these cases, reconstructed dimensions are given, preceded by ca. (approximately).

Ecologic and zoogeographic data have been gathered from many sources. Those which have proven most generally useful are noted in Chapter I.

In the descriptions of plates, both a dimension and magnification are given for each specimen. The magnification, given for easy comparison of figures, is approximate in many cases.

VIII. Systematic Paleontology

Pelecypoda

Nuculana *(Sacella)* *ochsneri* (Anderson and Martin)

Leda ochsneri Anderson and Martin, 1914, Calif. Acad. Sci. Proc., ser. 4, v. 4, p. 53, pl. 3, figs. 8a, b, c.

Shell small, elongate, rostrate; beak opithsogyrous, central. Posterior dorsal margin concave; other margins convex, continuous except at beak and at pointed rostrum; anterior end rounded but with radius of curvature less than one-eighthof shell longitude. Sculpture of fine concentric ridges. Lunule narrow, circumscribed but not depressed, anterior end coincides with anterior end of dentition; escutcheon wider than, but about as long as lunule, depressed, posterior end coincides with posterior end of dentition. Teeth of uniform size, boomerang shaped, concave towards the hinge extremities; long axis of each tooth perpendicular to shell margin. Dimensions in mm. of seven specimens from locality 1849:

Long.	20	17	17	16	16	15	10
Alt.	12	10	10	10	9	9	6
Diam.	8	8	8	4.5	*4	*3.5	*2.5

*of single valve.

The Castaic specimens resemble most closely *N. ochsneri*, found in and described originally from the middle Miocene Round Mountain silt member of the Temblor formation in the Bakersfield area. *N. taphria* and *N. ochsneri* are very similar. *N. taphria*, according to Grant and Gale, 1931, p. 121, has been found in Pliocene sediments certainly, and perhaps in Miocene sediments. *N. ochsneri* and the Castaic material differ from *N. taphria* only in shape, being less pointed posteriorly, with a straighter, flatter dorsal margin. The difference is relatively slight, and a study of larger samples would probably show that the two species represent a single gens that has evolved little since early Miocene time. Material collected from locality 1539, Pliocene of Elsmere Canyon, is like that from Castaic Canyon, and better fits into N. ochsneri than into N. taphria. Material from locality 601, Pliocene of Los Angeles, on the other hand, is similar to N. taphria. Thus it is probable that the range of N. ochsneri extends into the Pliocene. A more detailed study of the group should determine the relation between the two species, the variability in shape of each, and the effect of ecology on the shape.

The species has been found in the Castaic formation only at localities 1849 and 1663, both south of Soledad Canyon. At locality 1849 it occurs in the basal few feet of the formation in pebbly sandstone; about 20 percent of the specimens are articulated. At locality 1663 it occurs in pebbly sandstone; most of the specimens are articulated. According to Grant and Gale, 1931, p. 121, the Pliocene distribution of N. taphria is from northern to southern California; the Pleistocene distribution is southern California and Baja California; the Recent distribution is from Bodega Bay to Baja California. If the distributional data are adequate, the N. ochsneri - N. taphria gens originated and was localized in the Transverse Ranges and Southern San Joaquin Valley during the Miocene epoch. The range expanded, mostly northward, during the Pliocene epoch, shifted southward during the Pleistocene, and expanded northward again post-Pleistocene to essentially its Pliocene position. The Castaic occurrence of N. ochsneri fits neatly into this general picture.

N. taphria is presently found offshore at depths of 3 to 80 fms. Keen, 1958, p. 19, says it occurs at depths of 6 to 45 fms. Bandy, 1958, p. 706, records the species between 4 and 80 fms. in the San Pedro Basin, being most abundant there between 8 and 20 fathoms. Burch, 1944-1946, part 1, no. 33, p. 11, reports that along the southern and Baja California coast, *N. taphria* is common on sand or mud bottom at depths of 3 to 51 fms., and most abundantly between 10 and 20 fms.

Nuculana sp.

Shell minute, elongate, rostrate; beak opithsogyrous, anterior, one-third of length back from anterior margin. Posterior dorsal margin straight, other margins convex. Anterior of shell short, broadly rounded. Sculpture consists of concentric ridges. Dimensions in mm.:

Long.	6	5
Alt.	4	3
Diam. (of single valve)	2	-

Two right valves have been found at locality 7-11-24, in mudstone. This species differs from N. ochsneri, also found in the Castaic formation, in being much smaller and in having a different shape--the posterior dorsal margin is straight rather than concave and the beak is farther anterior.

Anadara aff. *A.* (*Anadara*) *montereyana* (Osmont)

Plate 15, Figure 3.

Arca montereyana Osmont, 1904, Univ. Calif. Publ. Geol. Sci., v. 4, p. 96, pl. 9, figs. 5a, b.

Anadara (*Anadara*) *montereyana* (Osmont), Reinhart, 1943, Geol. Soc. America Spec. Paper 47, p. 47, pl. 10, figs. 1, 3, 4, 9.

Shell medium size, inequilateral, equivalve, subovate, elongate, uninflated; beak prosogyrous, prominent umbo located about one-third of way from anterior to posterior margin; anterior margin more sharply curved than posterior margin; hinge line straight, about five-eighths the shell length; umbo located centrally in relation to hinge length. Sculpture 30 to 34 radial ribs, interspaces flat, narrower than ribs, ribs flat-topped or slightly rounded, with shallow median groove on large specimen; concentric growth lines faint on most specimens. Teeth perpendicular to hinge line under beak, slightly oblique and perpendicular to shell margin at ends of hinge line.

Dimensions in mm.:

Locality	1671					1626				
Long.	80	30	30	30	17	42	34	40	30	47
Alt.	50	18	20	20	12	34	22	30	22	34
Diam. (single valves)	15	4	7	6	4				5	

This material has previously been referred to several other species: L.A. Wright, 1951, referred the specimens from locality 1626 to *Anadara* cf. *A.* *obispoana* (Conrad). However, his description of the external features of the shell is based on an internal mold of a left valve. Jahns, 1940, p. 167, lists *A.* *osmonti* and *A.* *obispoana* from the Castaic formation. According to White, 1947, p. 23, 35, the localities from which came the species listed by Jahns are, respectively, 1624 and 1626. The specimens identified by Wright as *A*. cf. *A*. obispoana are the same as those listed by Jahns as *A*. *obispoana*. In his manuscript, White, 1947, p. 21, erected a new species, *A*. *haskellensis*, for the specimens from locality 1624 that had been referred to *obispoana* by Jahns and Wright, and for similar specimens from localities 232, 1671, and 1676. White considered that these specimens were distinctive in shape and sculpture. In particular, the rib count is 30 to 34, whereas that of *A*. *montereyana*, the most similar form, is 29 to 31. According to data presented by Reinhart, 1943, the rib count of most species of *Anadara* varies by less than three for any particular species, although it is not always significant for immature individuals. In this report the specimens will not be referred to a new species because of the overall similarity to *montereyana* and because of the lack of a sufficient collection to determine the actual range of morphologic variability that occurs.

A. aff. *A*. *montereyana* has been found only in the southern half of the outcrop area of the Castaic formation, at localities 232, 1624, 1626, 1671, 1676, and 1677. At locality 1626 it occurs in the form of molds in light brown diatomaceous mudstone. Many of the shells are articulated. They are associated with *Chlamys* *discus* and *Macoma*? sp. The material from the Haskell Canyon-Dry Canyon localities occurs in medium-grained to pebbly sandstone beds within a predominantly mudstone section. In this area, too, the shells are generally articulated.

According to Reinhart, 1943, p. 48, *A*. *montereyana* has been found in the central California Coast Ranges and in the lower Astoria formation of Washington, and its stratigraphic range is Saucesian to Mohnian. Therefore, the occurrence of this form in the Castaic formation is near the upper limit of the stratigraphic range of montereyana and is south of its known distribution.

No closely related Recent species exist on the Pacific Coast. The genus is exclusively marine, and occurs in the littoral to inner sublittoral zones.

Anadara (Anadara) trilineata trilineata (Conrad)

Plate 14, Figure 3.

Arca trilineata Conrad, 1856, Acad. Nat. Sci. Phila. Proc., v. 8, p. 314.

Anadara (Anadara) trilineata trilineata (Conrad), Reinhart, 1943, Geol. Soc. America Spec. Paper 47, p. 57, pl. 5, fig. 9, pl. 6, figs. 1-3, 5, 7, pl. 7, fig. 1.

Four specimens are referred to this species. Two, from locality 1663, are articulated; one, from locality 1627, and one from locality 1849, are not. The identification is based on one specimen from locality 1663. The other three are grouped with it because of similarity in shape and similarity (partly inferred) in sculpture.

Shell medium size, inequilateral, equivalve, subovate, moderately inflated. Beak prosogyrous, prominent, slightly more than one-third the distance from the anterior to posterior margin. Anterior margin more sharply curved than posterior margin; hinge line straight, about five-eighths the shell length. Sculpture of 25 radial ribs, interspaces slightly narrower than the ribs, ribs flat-topped with deeply incised secondary groove and two finer tertiary grooves, one on either side of the secondary groove; the anterior tertiary groove is larger than the posterior one. Concentric growth lines faint where shell well preserved. With weathering, the concentric sculpture becomes relatively more prominent. Dentition not exposed. Dimensions in mm.:

Locality	1663		1849	1627
Long.	59	30	33	13
Alt.	40	25	22	10
Diam.	30	18	*9	*4

*single left valve.

These four specimens are distinguished from A.

montereyana, also found in the Castaic formation, on the basis of: 25 ribs rather than 30 to 34; the presence of well developed secondary and tertiary grooving on flat rib tops and the less elongate more inflated shape. Reinhart, 1943, p. 58, pl. 6, fig. 7, notes that this subspecies is characterized by beaded ornamentation on the ribs. The ribs of the Castaic specimens are crossed by growth lines but they are not beaded. However, on pl.7, fig. 1, he illustrates an example of the subspecies which appears to have sculpture very like that of the Castaic forms. Weaver, 1942, pl. 12, fig. 19, also illustrates a similar specimen. The Castaic specimens differ from *A. obispoana* in being more inflated, having more prominent beaks, and in having better developed tertiary grooves on the ribs.

A. (*A.*) *trilineata trilineata* has been found at localities 1663 and 1627. These localities lie within the larger area in which *A.* aff. *A. montereyana* has been found. The specimens are in medium-grained to granule sandstone,very much like the sediments containing *A.* aff. *A. montereyana* in the Dry Canyon-Haskell Canyon area.

Reinhart, 1943, p. 58, 59, reports that *A.* (*A.*) *trilineata trilineata* is abundant in many of the Pliocene formations of central and southern California, including the basal Pliocene of Elsmere Canyon. Hall, 1958, has reported the only definite occurrence of the subspecies in upper Miocene sediments, from a locality in the San Francisco Bay Region. Thus the Castaic formation occurrences have extended the known late Miocene geographical distribution southward.

There are no Recent species of *Anadara* that are closely related to *A. trilineata*. The genus is found at present in the littoral to inner sublittoral zones of the open ocean.

Glycymeris cf. *G. branneri* Arnold
Plate 14, Figure 1, Plate 15, Figure 2.

Glycymeris branneri Arnold, 1908, U. S. Nat. Mus. Proc., v. 34, p. 377, pl. 34, fig. 1.

Glycymeris branneri Arnold, Nicol, 1947, Jour. Paleontology, v. 21, p. 346, pl. 50, figs. 12-15.

Shell large, orbicular, equivalve, inequilateral; beak prominent, orthogyrous. Sculpture not preserved except for concentric growth lines; poor preservation caused by coarse recrystallization and weathering of shell. Shell thick, internal margin of valve crenulate. Cardinal area broad, dorsal margin rounded under beak; chevron grooves poorly preserved; altitude of the cardinal area is the altitude of the hinge under the beak because the teeth are restricted to the ends of the hinge by overlap of the cardinal area upon the central teeth. Teeth boomerang shaped, lying nearly horizontally within the hinge.

Dimensions in mm.:

Long.	70	95
Alt.	75	95
Diam.	25 (single valve)	60
Shell thickness, approximate, in center of shell	5	7

G. branneri has been found in upper Oligocene and lower Miocene sediments of the California Coast Ranges from the Santa Cruz Mountains south to the Santa Ynez Mountains and the southern San Joaquin Valley. Comparing illustrations of the species as illustrated in Arnold, 1908, Nicol, 1947, and Loel and Corey, 1932, pl. 7, fig. 5a, b, it is clear that the shape of individuals in the species is variable. Further, much of the material illustrated is poorly preserved. *G. Branneri* is the only Tertiary *Glycymeris* similar in size to the specimens from the Castaic formation. The Castaic species most closely resembles the early Miocene specimens from the San Emigdio Mountains figured by Loel and Corey, 1932. No positive identification can be made, however, because the material is not suitably preserved, and the illustrations of *G. branneri* are inadequate. The specimens could be compared with *Glycymeris gigantea* (Reeve) equally well. *G. gigantea* differs from *G. branneri* only in size and prominence of secondary ribbing. *G. branneri*, the Castaic formation specimens, and *G. gigantea* are closely related representatives of a group of warm water glycymeridids that occurred as far north as California in the middle Tertiary, but are now restricted to the Panamic province. The distribution of *G. gigantea* is:

Pliocene--Colorado Desert and Gulf of California.
Pleistocene--Gulf of California and San Ignacio Lagoon, Baja California.
Recent--Magdalena Bay, Baja California through the Gulf of California to Acupulco.

This *Glycymeris* has been found in the Castaic formation only at locality 2075, on the south side of Elderberry Creek. It is abundant there and many of the shells are articulated. See Pl. 36, fig. 2. *Pecten crassicardo*, many individuals of which are also articulated, is associated with it. *Crassostrea titan* is rare. The species is restricted to a single bed a few feet thick, which is the basal unit of the Castaic formation at that place. *Glycymeris* sp. occurs in a pebbly sandstone, the pebbles of which are less than 5 mm. in diameter. Between the sandstone and the underlying Martinez formation is a coarser, more poorly sorted pebble conglomerate with average pebble diameter of about 25 mm. Fragments of *Ostrea titan* are scattered in this coarser-grained part of the basal Castaic sediment. Mudstone containing scattered sand grains but few fossils overlies the Glycymeris bearing unit.

The closely related Recent species G. gigantea has been dredged from sand and sandy mud substrate at depths of four to seven fms.

Glycymeris grewingki Dall

Plate 14, Figures 2a, b.

Glycymeris grewingki Dall, 1909, U. S. Geol. Survey Prof. Paper 59, p. 107, pl. 2, fig. 13.

Glycymeris grewingki Dall, Weaver, 1942, Univ. Wash. Publ. Geol., v. 5, p. 62, pl. 10, fig. 19.

Shell medium size, oval, nearly equilateral, equivalve; beaks prominent, central. Sculpture of about twenty flat radial ribs with much narrower grooves between, sculpture preserved to a variable degree, depending on how weathered the shell is. Hinge broadly arcuate, cardinal area about one-third as wide as the dentition; dorsal margin and chevron grooves broadly obtuse under the beak, individual teeth straight, not boomerang shaped. Average dimensions: long.-40 mm., alt.-38 mm., diam. of single valve-12 mm.

Grant and Gale, 1931, p. 135, have grouped together in *G. grewingki*, the species *G. gabbi* Dall, *G. larvata* Hanna, and *G. coalingensis* Dall. The differences between *G. grewingki* and the last two species seem to be largely the result of differences in weathering. *G. gabbi*, however, differs in number of radial ribs and in rib interspace width, so this species cannot be referred to *G. grewingki* so surely without a study of the variability of large samples of the different species. The Castaic formation forms agree well with the description of *G. grewingki*, and with the illustrations of it in Dall, 1909, in Weaver, 1942, and in Woodring, Stewart, and Richards, 1940, pl. 29, figs. 10, 11; pl. 33, figs. 7, 8.

G. grewingki has been found in upper Miocene and lower Pliocene sediments of the Pacific Coast from Washington south to the Ventura Basin. Thus the Castaic occurrence fits into the known distribution and stratigraphic range of the species.

Specimens have been found at a number of localities in Castaic Canyon between Necktie and Elderberry Canyons, and at localities 1676 and 1677 in Haskell Canyon.

G. grewingki is scarce in the Haskell Canyon area in sandstone and conglomerate units near the base of the formation. It is common in the Castaic Creek area, and, particularly, in sandstones and conglomerates near or at the base of the formation, between Necktie and Elderberry Canyons. Specimens are most abundant in poorly sorted pebble conglomerate. Few are articulated; most of the specimens are poorly preserved as a result of abrasion before deposition, and Recent weathering. The species is restricted to coarse clastics deposited near shore.

According to Dr. David Nicol, personal communication 20 March 1959, "Glycymeris grewingki belongs to the northern Pacific group of species which is distributed today from California to northern Japan". The group occurs throughout the sublittoral zone. Glycymeridids generally live on a sandy substrate.

Crenomytilus coalingensis (Arnold)

Plate 14, Figures 4, 5.

Mytilus (Mytiloconcha) coalingensis Arnold, 1909, U. S. Geol. Survey Bull. 396, p. 73, pl. 19, fig. 5; pl. 22, fig. 6.

Crenomytilus coalingensis (Arnold), Soot-Ryen, 1955, Allan Hancock Pac. Exped., v. 20, no. 1, p. 23.

Shell large, mytiliform, unbones terminal, surface sculptured with growth lines and faint radial lines. Shell margin finely crenulate. Resilial ridge compact. Shell inflated in some specimens. Anterior margin smoothly concave; posterior margin convex, with an angle at about the midpoint, dorsal half of the posterior margin nearly straight, the ventral half, strongly curved. Anterior slope of valve approaches margin steeply, posterior slope, shallowly. Some specimens are large, the largest having these approximate dimensions in mm.:

Length - 200, width - 95, diameter - 60.

A single incomplete well preserved specimen from locality 1670 displays the characteristic hinge features. Specimens from locality 1663 have the typical shape and size, but are badly weathered and poorly preserved, but are, in general, whole, articulated individuals.

C. coalingensis has previously been reported only from Pliocene sediments of central California. Clark, 1915, p. 419, reported a questionable new variety of the species from the upper San Pablo formation of the San Francisco Bay region.

Although mytilids characteristically are found attached to a rocky shore, living in the littoral zone, this is not always the case. Specimens of normally rocky shore species have been found attached to kelp, and anchored by byssal threads to a muddy substrate. Although these examples are rarities, they illustrate the hazards of drawing ecological inferences from species of a different subgenus.

Chlamys discus (Conrad)

Plate 15, Figure 4, Plate 16, Figure 4.

Pecten discus Conrad, 1857, U. S. Pacific R. R. Rept., v.7, p. 190, pl. 3, fig. 1.

Pecten (Aequipecten) discus Conrad, Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v.1, p. 200, pl. 4, fig. 7.

Shell small to medium size, thin, equilateral except for ears, equivalve, or nearly so--the right valve appears to be slightly less inflated than the left valve. Apical angle about 100°, hinge length one-half to two-thirds of longitude, right anterior ear about 1.8 times longer than posterior ear, ears of left valve equal in length. Right anterior ear with five radial ribs; ctenolium with four teeth, deep byssal notch one-half the length of the ear. Sculpture of 19 or 20 radial, rounded, un-striated ribs. Interspaces slightly narrower than ribs, smooth. Sculpture reflected on shell interior for three-fourths of distance from shell margin to umbo. Growth lines faint. Some shells have very faint secondary rib in interspaces. Dimensions in mm. of specimens from locality 1623.

Long.	28	13	16
Alt.	25	12.5	15
Hinge Length	16	8	10

Keen, 1958, p. 68, in a key to the genera and subgenera of the Pectinidae, states that the ears of Chlamys are unequal in length whereas those of Aequipecten are equal. The species discus is placed in Chlamys because the ears are of very different length. Clark, in Kew, 1924, p. 67-69, identified material from Haskell Canyon as Pecten raynondi. This probably corresponds to what is herein referred to the species discus.

These two species and several others that are very similar have proven to be difficult to separate. Grant and Gale, 1931, p. 200, place several of these in the species *discus*. The pectinids in the Castaic formation add no light to this taxonomic problem. Where the species is most abundant, at locality 1623 in fine sandstone about 50 feet above the base of the formation, the shape and sculpture are variable. At one extreme are small, moderately ventricose valves with prominent ribs; at the other extreme are broad, nearly flat valves with very low ribs. A transition appears to exist, but cannot be proved. Only the marginal parts of the larger valves are preserved, so the possibility that the valves are originally ventricose, but become less so and ribbing becomes lower and broader with increasing size can not be validated. This same variability is present in the material from locality 232, in Haskell Canyon. A specimen from locality 234 may be *C. discus*, but it is more likely a valve of *L. estrellanus* that is too small to exhibit the secondary ribbing. The species is also found at locality 1670.

The material from locality 1623 consists of molds and gypsum casts representing unworn whole valves, a few of which were articulated when buried. At locality 232 the material consists of single whole valves and fragments in a matrix of coarse to very coarse sandstone. Locality 232 is in a sandstone bed about 85 feet above the base of the formation.

Chlamys discus has been reported from middle and upper Miocene sediments of the California Coast Ranges.

Chlamys cf. C. hastatus Sowerby

Plate 15, Figure 6.

Pecten (Pecten) hastatus Sowerby, Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 166, pl. 11, figs. 6a, b.

Shell medium size, thin, convex, nearly flat. Sculpture expressed internally but not in detail. Sculpture of strong spinose ribs, generally grouped in bundles of three with interspaces between bundles about as wide as adjacent ribs, interspaces within bundles much narrower. A small lateral riblet is present along one side of some ribs.

The sculpture is similar to that of hastatus and its varietal forms, but there is not enough material for a definite identification. This form has been found only at locality 1670.

Chlamys hodgei Hertlein

Pecten (Chlamys) hodgei Hertlein, 1925, S. Calif. Acad. Sci. Bull., v. 24, p. 42, pl. 4, figs. 1, 2.

Shell large, higher than long, equilateral, inequivalve, thin, sides approximately straight, ventral margin evenly rounded. Ears unequal, anterior ears much larger than posterior ears. Right valve: deep byssal notch, ctenidium with about 10 medium-sized teeth, ears with about five radiating ribs crossed by growth lines. Left valve: radiating ribs on ears about the same size as those on right posterior ear--smaller than on right anterior ear. Right valve ornamented with about 20 bifid ribs, interspace contains a median riblet and, in some cases, one or two additional riblets. Left valve ornamented by about 22 flatly rounded ribs, interspaces contain a median riblet about one-third to one-fourth as wide as the primary rib. In some interspaces, finer, tertiary ribs lie along the sides of the primary ribs. The primary ribs of the left valve are narrower than those of the right; the secondary riblets of the left valve, however, are wider than those of the right valve. General pattern of sculpture reflected internally to umbo. The sculpture of the right valve is variable. On one specimen, all the ribs are bifid; on another, only a few are bifid; and on a third, most are bifid, but the two parts of the ribs are not of equal width, and the posterior half of several of the ribs is split.

Dimensions in mm. of three specimens from locality 1663:

Alt.	52	49	44
Long.	49	43	40
Diam.	19	18	*8

*single right valve.

These specimens agree in all respects with the type specimens of Chlamys hodgei. Grant and Gale, 1931, p. 168, consider this species to be synonymous with *Pecten bartschi* Arnold. As they state, however, the type of *bartschi* is poorly preserved. *C. hodgei* should be considered as a separate species because it bears little resemblance to *P. bartschi* as illustrated by Arnold, 1906, pl. 41, fig. 3, and because it has now been found in sediments of equivalent age at two widely separated localities. The plasticity in sculpture, evident in the Castaic formation specimens, indicates that this and apparently closely related species might offer a good subject for an evolutionary, ecological study.

C. hodgei has been found in the Castaic formation only at locality 1663. Two articulated individuals and a single right valve have been found. None were abraded or broken before deposition.

C. hodgei has been reported previously only from the type locality of the Santa Margarita formation, near Coalinga. Species of *Chlamys* today live in the sublittoral zone of open coasts on mud and sand bottoms. If the relation between shell dimensions and degree of mobility pointed out by Yonge, 1951, p. 415, can be applied, to fossil as well as to recent *Chlamys* and *Pecten*, *C. hodgei* was sedentary, attached, no doubt, by byssus.

Chlamys parmeleei? Dall

Plate 15, Figure 1.

Pecten (*Chlamys*) *parmeleei* Dall, 1898, Wagner Free Inst. Sci. Trans., v. 3, pt. 4, p. 708, pl. 37, figs. 14, 14a.

Pecten (*Pallium*) *swiftii* Bernardi, Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 171, pl. 10, figs. 1a, b, 2, 4a, b, 5.

Medium size, altitude about 50 mm. Shell thin, sculpture reflected internally. Sculpture consists of radial rounded ribs and furrows upon which are about 7 secondary ribs per set of rib and furrow. Ribs wider than furrows.

Two fragments have been found at locality 1663.

The material is too fragmentary to be identified surely. The sculpture does not resemble that of the type, but it does resemble the specimen from the Pliocene sediments of Cresent City figured by Arnold, 1906, pl. 41, fig. 5. It resembles somewhat *Pecten wattsii* var. *morani* Arnold, and *Pecten etchegoini* Anderson. Grant and Gale, 1931, p. 171-175 consider these species to be synonymous with, or varieties of, *Pecten swiftii* Bernardi from the late Tertiary and Recent of Japan. The material can only be tentatively identified with the most similar local material.

Lyropecten estrellanus (Conrad)

Plate 16, Figure 6.

Pallium estrellanum Conrad, 1856, Acad. Nat. Sci. Phila. Proc., v. 8, p. 313.

Pecten (*Lyropecten*) *estrellanus* (Conrad), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 185, pl. 8, fig. 4.

Shell large, bi-convex, equilateral, right valve is a little more ventricose than left valve. Apical angle about 100°, 18-19 radial ribs, ribs steep sided, rounded on top with striae absent or reduced. Interspaces narrower than ribs, flat, with well developed median secondary rib, and, on some valves, two marginal tertiary ribs. Ribbing reflected internally from shell margin to umbonal area. Ears equal in size; byssal notch shallow; ctenolium of two widely spaced, low smooth bumps on thickened shell margin. Several radial ribs on exterior of ears.

Dimensions of some typical specimens; in mm.:

Long.	76	46	41	70	120	80	56	53	44	55	45	60
Alt.	74	45	41	68	110	77	55	50	50	49	45	60
Diam.of valve-	34	20	16	23	54	38	24	24	17	--	--	--
Hinge length	30	20	17	--	50	37	25	24	20	25	--	--

L. estrellanus has been found at localities 1849, 1627, 1663, and 2069, south of Soledad Canyon, at localities 232 and 233 in Haskell Canyon, at locality 2104 in Fish Canyon, and at locality F-4 north of Fish Canyon. At locality 1849, specimens are abundant but poorly preserved; most valves are disarticulated but unbroken. The specimens are in medium- to coarse-grained sandstone a few feet above the basal unconformity. At locality 1627, *L. estrellanus* is rare, occurring in pebbly sandstone as single valves. At locality 2069 it is one of the most abundant forms present, occurring as fragments throughout the unit at Locality 1663, it is of the most abundant form present, and most of the valves are articulated. This bed is composed of sandstone with occasional scattered pebbles and cobbles. At locality 233, the specimens are poorly preserved disarticulated valves in a bed of pebble conglomerate. Only a single broken valve has been found at locality 7-11-15, in the basal coarse clastics. At locality F-4, molds of L. estrellanus are abundant in a two-inch-thick layer within a sandstone bed several feet thick. The valves are all about the same size--50 mm. in altitude, and two-thirds of them are concave up. The valves were buried unworn. Johnson, 1957, has shown that a cupped shell is less stable when the concave side is up than when the convex side is up. In the unstable position it is more likely to be transported and eventually overturned to the more stable position, whereupon it will become buried if not destroyed by organisms, or mechanical wear. Therefore, if two-thirds of the valves of L. estrellanus are in an unstable (concave up) position, something might have been anomalous in the depositional environment. It is considered, though, that the orientation of the shells is more a reflection of the life habits of the organism than of the depositional enviroment. Yonge, 1951, p. 409, 415, states that among Recent species of Pectinidae the relative lengths of the anteroposterior and dorsoventral diameters (called longitude and altitude in this paper) are indicative of the degree of attachment. The longitude is greater than the altitude in those that are unattached; the altitude is greater in those that are attached, either by cement of byssus. Applying this criterion, L. estrellanus was vagile, and as is the habit of many recent pectens, probably lived partly buried lying more or less flatly on the sandy substrate. In such a position, the lower valve of a dead individual, being below the surface, could not be flipped over easily. When the muscle and ligament had decomposed, water movement could raise and flip over the upper valve so that all the valves would be concave up, but then the upper valves would be more likely to be flipped over, lying as they would upon the surface. If none of the lower valves were disturbed, about two-thirds of the upper valves were turned subsequently to a convex-up position, so that as finally preserved, two-thirds of all the valves are concave up.

The distribution of *L. estrellanus* is discontinuous but is throughout the outcrop area of the formation. At localities F-4, 1849, and 1663, the specimens are relatively undisturbed. The species lived in shallow water on or in a substrate of sand with only a small pebble content. Specimens from other localities have been broken, dissociated, and perhaps transported. In these localities the species occurs in coarse, more poorly sorted, pebbly sediments.

The reported range and distribution of *Lyropecten estrellanus* is Miocene and Pliocene in central and southern California.

Lyropecten crassicardo (Conrad)

Plate 16, Figure 5.

Pallium crassicardo Conrad, 1856, Acad. Nat. Sci. Phila. Proc., v. 8, p. 313.

Pecten (Lyropecten) crassicardo Conrad, Arnold, 1906, U. S. Geol. Survey Prof. Paper 47, p. 71, pl. 16, figs. 1, 1a; pl. 17, figs. 1, 1a, 1b; pl. 18, figs. 1, 2, 2a.

Pecten (Lyropecten) magnificus Sowerby variety crassicardo (Conrad), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 183, pl. 9, figs. 4, 5.

Shell large, thick, bi-convex, equivalve, equilateral, sides approximately straight. About 16 strongly developed ribs, ribs wider than interspaces, both with radial striae; ribs steep sided, rounded on top, interspaces rounded to almost flat. Growth lines faint, obscure on many shells except near the outer edge of the shell. Concentric ledging present on some shells but not common. Ribbing expressed internally only near the ventral shell margin. Anterior ear with about four ribs; anterior ear a little longer than posterior ear. Apical angle 100°-110°, but as great as 120° on largest shells. Resilial pit deep, with several lateral crurae on each side.

Typical dimensions, in mm.:

Long.	120	115	140	200
Alt.	115	120	135	170
Diam.	*50	*35	*40	60
Hinge length	55	--	60	90

*of single valve.

The specimens from the Castaic formation are typical of the species. Grant and Gale, 1931, p. 183, regard crassicardo as a variety of Pecten (Lyropecten) magnificus. L. magnificus, from the Recent of the Galapagos Islands, is characterized by bulbous nodes on the early part of the left valve, whereas none of the specimens from the Castaic formation are nodose. They also state that nodosity increases in lower latitudes, thus explaining the existence of a nodose descendant of *L. crassicardo* near the equator. The relationship may be valid, but no intermediate forms have been found. *L. crassicardo*, *L. magnificus*, and *L. subnodosus* are closely related species characterized by like shape, size, and general features of sculpture. The Recent species *magnificus* and the Miocene species *crassicardo* differ apparently only in nodosity. *L. subnodosus* has fewer ribs--10 or 11 instead of 16--and is more or less nodose. In other respects, however, it is very like *crassicardo* and *magnificus*. Other similar species have been described, the description based on fossil material, and a detailed study would be necessary to determine relationships. In any case, however, *L. crassicardo* clearly belongs to a warm-water group. *L. magnificus* is a Recent species from the Galapagos Islands. *L. subnodosus* ranges from Pliocene to Recent. Its northern limit of distribution has been, and is, Baja California. The distribution of *crassicardo* is in middle and upper Miocene sediments of the central and southern California Coast Ranges. *L. crassicardo* is found in the Castaic formation north of Haskell Canyon. Articulated specimens are found only north of Necktie Canyon. Whole individuals are restricted to coarse or granular sand bodies very near the basal contact. In these places, as, for example, on the sand bar exposed in Elderberry Canyon, the articulated individuals are lying parallel to the bedding. Fragments of *L. crassicardo* are abundant within the near-shore sands and conglomerates, and small scraps are found in sandstones well out in the basin. In general, the habitat of the species was apparently on fairly well-sorted sand bottoms near shore. It is abundant in more or less fragmental condition in coarser-grained, more poorly-sorted sediments that have been transported and deposited away from shore. It is rare in the most basal conglomeratic sediments that represent material reworked by the transgressing sea, or shore line talus type deposition. It is most commonly associated with *Crassostrea* titan, but where it is associated with a more varied fauna, *C. titan* is generally absent or very scarce. Fragments of *L. crassicardo* occur within massive sandstone beds of the lower part of the Ridge Route formation.

The average maximum size of *L. crassicardo* is uniform throughout its area of distribution. The largest specimens are found in Castaic Canyon, but the average size of the largest individuals is the same at any locality. The only specimens that are shelved, due to interruptions in growth, are found in Haskell Canyon--at the southern limit of distribution of the species. The diameter of shelved specimens is greater than that of normal specimens.

Sculpture is uniform throughout the formation. Many specimens contain small borings approximately 0.5 mm. in diameter that resemble those formed by clionid sponges. Shells bored are those that remained unburied after death of the individual. Unworn valves and articulated shells are not bored; worn and broken shells, on the other hand, are. Borings are not geographically limited.

L. subnodosus is found living in the inner sublittoral zone at depths of 30 to 50 fathoms. This can be applied only tentatively to *L. crassicardo* until the relationship between the species is better known.

Hinnites cf. multirugosus Gale

Plate 15, Figure 5, Plate 16, Figure 2.

Hinnites giganteus Gray, 1826, Ann. Phil., ser. 2, v. 12, p. 103.

Hinnites crassa Conrad, 1857, Pac. R. R. Rept., v. 7, pt. 2, p. 190, pl. 2, figs. 1, 2.

Pecten (Pecten) multirugosus Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 159, pl. 11, figs. 5a, b.

Shell medium size, nearly equilateral when small, ie. when altitude is less than about 15 mm. Shell growth beyond this size is irregular, so that the adult shell is inequivalve, inequilateral. Altitude greater than longitude.

Sculpture of more than 17 primary radial ribs and well developed secondary ribs occurring singly, or in a few cases, doubly between the primary ribs. Also, one or two tertiary riblets are present in a few of the rib interspaces. Shell margin smooth; sculpture not reflected on shell interior.

Hinge narrow, heavy length about two-thirds the shell longitude. Resilial pit deep.

Dimensions of whole individual: Alt. 40 mm., long. 36 mm., hinge line-25 mm. in length, diam. 15 mm. A second specimen has these approximate dimensions: Alt. 65 mm., long. 60 mm.

The specimens are only compared to H. multirugosus because they differ in sculpture from typical individuals of that species, which has a range from middle Miocene to Recent. The species is variable, however, and it is possible that with further study the specimens found may fall within the limits of variability. They are similar to some specimens of multirugosus seen in the collection of the California Academy of Sciences. The Castaic formation specimens differ from typical specimens of multirugosus in having more regular sculpture with fewer ribs in the interspaces between the primary ribs. Also, the ribs are not squamose, but this difference may be due to weathering and poor preservation.

Hinnites has been found in the Castaic formation only at locality 2069. The articulated specimen lived attached to calcareous tubes deposited by some type of worm. The presence of both valves suggests that the specimen was not transported prior to deposition. Although this is certainly not conclusive evidence, in any case, neither specimen was transported enough to be worn or broken.

The Recent distribution of H. multirugosus is from the Aleutian Islands to the west coast of Baja California. The reported Pleistocene distribution is from Tomales Bay to the west coast of Baja California. The reported Pliocene distribution is Imperial County and coastal southern California. The upper Miocene Hinnites, H. crassa, has been found in the central California Coast Ranges but differs from the Castaic material.

Living H. multirugosus is found in marine water from low tide down to 12 fms. It lives on gravel bottoms or among rocks, most commonly along open or protected outer coasts, but also in bays. Young individuals commonly set under rocks and ledges or in rock crevices.

Pododesmus? cf. P. macroschisma (Deshayes)

Plate 16, Figure 3.

Pododesmus macroschisma (Deshayes), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 241, pl. 12, figs. 3, 4a, b.

Shell large, thin, flat. No muscle scars or hinge features preserved. Sculpture of coarse uneven radiating ribs and prominent growth lines. Every third or fourth rib is several times the size of the smaller intervening ribs. Interspace width not constant, about as wide as the adjacent ribs.

This fragment is referred to Pododesmus because of its shape and sculpture. The sculpture differs from that of typical macroschisma, but the sculpture of macroschisma is variable.

This form has been found only at locality 1670. Only the ventral part of a valve is preserved.

At the present, P. macroschisma is found in bays and on outer protected coasts in marine waters. It occurs attached to rocks or shells from low tide to 35 fms.

P. macroschisma has been reported from Pliocene, Pleistocene, and Recent sediments along the Pacific Coast between California and Japan.

Spondylus sp.

Plate 17, Figure 1.

Shell large, approximately circular, thick, moderately inflated, more or less equilateral, inequivalve; right valve with prominent opithsogyrous beak, broad triangular cardinal area. Shell margins and surface sculpture not preserved, having been riddled by boring organisms. A flat shelf about one centimeter wide lies within the ventral shell margin. Hinge of right valve contains two strongly developed teeth on either side of a deep resilial pit. On the outer side of each tooth is a pit to accomodate the corresponding tooth of the left valve. A broad triangular cardinal area is situated above the dentition. The track left by the resilial pit during the life of the animal is poorly preserved. Nature of ears indeterminable from material at hand. Dimensions in mm. are based on material that is fragmental in large part, and poorly preserved in general. Therefore, all are approximate: Alt. 150, Long. 150, Thickness (center of valve) 25.

Right hinge features:

Resilial pit depth	10
Resilial pit width	11
Distance between centers of teeth	17
Width of hinge line	65
Distance from hinge line to beak	60

Shell structure: The shell material is recrystallized to coarse calcite in some specimens, but the structure is easily discernible. The shell consists of three layers: The inner two, originally aragonite, are yellowish-gray, the outer one, originally calcite, is dark gray. The two inner layers make up 80 percent of the shell near the center, a greater percent near the hinge, a lesser percent near the margin. The interior marginal shelf marks the area where little or no aragonite of the two inner layers had been deposited. The innermost layer is several times thicker than the middle one. It is composed of prisms oriented normal to the shell surface. A layering parallel to the shell surface, mainly recognizable by slight variations in color at intervals of about one mm., is also present but appears to have no effect on the length of the prisms. The middle layer is crossed lamellar. The lamellae are normal to the shell surface. This layer is the most poorly preserved of the three, its identity being most easily destroyed in the recrystallization of the shell. The outer, calcite, layer has an irregular foliated structure. The foliae are more or less parallel to the shell surface, but margin-ward, ventrally, each folia extends from the base of the layer to the surface and out into a flat spine, forming a rough squamose exterior. This outer shell layer is thoroughly riddled by borings about one-half to one mm. in diameter. Inner layers are also bored, but not to so great an extent.

Because of the poor preservation, particularly of the sculpture, the *Spondylus* from the Castaic formation can not be identified specifically. *Spondylus* has been reported from sediments of Eocene to Pliocene age in California. The genus occurred as far north as central California during the Eocene epoch. It has not been reported from Oligocene sediments. In lower Miocene (Vaqueros) sediments, it has been found in the Transverse Ranges and Channel Islands of southern California, and as far north as Monterey County. Ogle, 1953, p. 28, stated that a *Spondylus* had been found in the basal sediments of the Wildcat Group near Scotia, in northern California. He separated these basal sediments into the Pullen formation of late Miocene and early Pliocene age. The specimen identified as *Spondylus* was examined and found to be, in fact, a *pectinid* similar to *Chlamys parmeleei*. *Spondylus* is a common element of the fauna of the lower Pliocene Imperial formation of the Colorado Desert of California. It also occurs in Pleistocene and lower Pliocene sediments of the Gulf of California (Durham, 1950, p. 68). Along the west coast of Baja California, the northern-most Pliocene occurrence of the genus is on Cedros Island. The Recent northern limit of distribution of the genus on the Pacific Coast is the Gulf of California; the genus does not occur on the west coast of Baja California (Keen, 1958, p. 76). Thus, the occurrence of *Spondylus* in the Castaic formation is the only post-early Miocene occurrence in the **coastal** sediments of California, and fits into a continuous southward movement of the known northern limit of distribution of the genus from central California in the Eocene and early Miocene to within the Gulf of California at the present.

Spondylus occurs in the Castaic formation only at locality 2104. Specimens are fragmental; only one is articulated; they occur in a basal pebble-cobble conglomerate overlying the Martinez formation.

Recent *Spondylus* of the Panamic province have been reported living at depths of 15 to 45 fms. in the open ocean attached to rock, coral, or gravel substrate.

Crassostrea titan (Conrad)

Plate 17, Figures 3, 6, Plate 18, Figure 3.

Ostrea titan Conrad, 1853, Acad. Nat. Sci. Phila. Proc., v. 6, p. 199; 1857, Pacific R. R. Repts., v. 6, pt. 2, no. 2, p. 72, pl. 4, fig. 17, pl. 5, fig. 17a.

Shell large, valves more or less elongate, flat to deeply cupped; muscle scar near the ventral end of the valve and in some cases, to one side, left valve more cupped than right valve. Shell may be twisted; all those twisted were twisted clockwise looking down on the shell in living position. The distinctive features of Crassostrea titan are large size, great valve thickness, elongate shape, and muscle scar near the end of the shell. In the Castaic formation, characters of the species vary considerably, but in a systematic way:

1. North of Elizabeth Lake Canyon, the species is most abundant, and individuals are much larger than elsewhere in the formation.

2. South of Haskell Canyon the species is rare.

3. In the Haskell Canyon-Dry Canyon area, a number of valves are radially ribbed with a few irregular, round-crested ridges. These ribs are discontinuous between laminae on some shells. Ribbing is more prevalent on bottom (left) valves, and particularly on those that are deeply cupped. Top (right) valves are generally flat without ribbing. Because the ribbed forms are associated with unribbed forms and are typical in other respects, ribbing is considered to be of only ecological or local significance--not to represent specific or subspecific difference.

4. Shell preservation is good south of Elizabeth Lake Canyon--there, many shells have pearly iridescent luster. North of Elizabeth Lake Canyon, most of the shells are dull gray and more or less recrystallized.

5. Borings:

Locality		
1849	Pholad	common
1624	Clionid?	rare
234	Clionid?	common
	Pholad	common
230	Clionid?	rare
1671	Clionid?	common
1670	Clionid?	common
North of Elizabeth Lake Canyon	Clionid?	abundant
	Pholad	occasional

6. Details of the distribution of *C. titan*: Factors considered are abundance, preservation, dimensions, and variations from the general form as described above, discussed in some cases in terms of the features of charasteristic specimens. Although *C. titan* is widely distributed, few specimens are sufficiently preserved to furnish useful dimensions. Thus the measurements given reflect the general trends of size and shape, but are inadequate for any detailed conclusions. Based on comparison with the fragmental material present, the few specimens measured at a locality are considered to be typical of the population at that locality. Parameters measured are:

L. - Length of valve, maximum diameter through beak.

W. - Width of valve, normal to length.

T. - Thickness of valve, measured in the center of valve, avoiding the irregularities in thickness associated with the muscle scar.

C. - Convexity of valve, the maximum distance, normal to the plane of the valve margins, from that plane to the interior surface of the valve, again avoiding the irregularities around the muscle scar.

Ll.- Length of the ligament pit.

Lm.- Distance from beak to center of muscle scar.
Some of the measurements, prefixed "ca", were made on shells that were slightly incomplete but well enough preserved so that the original shell outline could be reconstructed with good reliability. If this was not possible, no measurement has been given for that dimension. Even on unbroken shells, early outer laminae are generally lacking. This is the most common source of error, causing all the length measurements--L, Ll, and Lm--to be too small.

Locality

1849 - Specimens uncommon, 15 percent articulated, all more or less broken. Nacreous luster moderately well preserved.

1624 - Uncommon, all disarticulated, broken; nacreous luster poorly preserved; valves relatively flat.

2069 - Rare, all valves disarticulated, broken; nacreous luster poorly preserved; valves relatively flat.

1663 - Only a few small fragments present.

230 - Uncommon, disarticulated, most are broken; nacreous luster well preserved.

231 - Uncommon, none articulated, few not broken; nacreous luster well preserved; the left valve measured bears faint irregular radial ribs. Another incomplete left valve is deeply cupped and also is ribbed. In comparison, the right valve measured is flat.

234 - Common, none articulated; nacreous luster moderately well preserved. Right valve flat; left valve deeply cupped with broad strong radial ridges which are confined to one side of the valve exterior. Small left valves of *Ostrea?* are attached to both inside and outside of left valve.

Locality

1670 - Common, none articulated, whole valves common; nacreous luster well preserved. Several valves, both right and left, bear faint irregular ribbing.

1671 - Common, none articulated; nacreous luster well preserved.

2091 - The margins of the left valve measured are crenulate.

North of Necktie Canyon - Abundant, shells large, many articulated.

A close correlation exists between the distribution of C. titan and the sediment type. No specimens have been found within mudstone. The species is most abundant in the coarser-grained, more poorly sorted sediments--pebbly sandstones and conglomerates. In these, the valves are disarticulated and commonly fragmental and the size of the fragments found is often clearly proportional to the size of the sedimentary clasts. C. titan has been found articulated at localities 1849, D-2, D-21, D-31, G-2, 2091, 2095, 2099, and 7-12-5, and 2106. At localities 7-12-5 and 2106 some of the specimens are attached to other oysters. Otherwise, at all of these localities, the object upon which the spat set is not evident. The sediment, in every case, is well-sorted, fine-to medium-grained sandstone. These localities are in sediments which were deposited very close to the basal contract. Broken and disarticulated specimens are present both near the contact as well as in tongues of coarse clastics within the center of the basin. No oysters have been found attached to the underlying sediments on the Martinez-Castaic contact.

Living C. titan were restricted to a substrate of well-sorted sand. They were further restricted to shallow near-shore water. Although they were not limited to the northern part of the Castaic formation, they were certainly largest and most abundant there. This area no doubt represented the optimum environment. *Lyropecten crassicardo* is generally found associated with *C. titan*, and its distribution is that area in which *C. titan* is largest and most abundant. Although the two species form a common association, they are not necessarily found together, indicating that their ecological requirements are somewhat different.

Locality	Valve	L	W	T	C	Ll	Lm	Remarks
1849	L.	75	40	--	15	15	---	
1624	L.	200	75	20	5	30	155	
	L.	---	110	35	0	--	---	
2069	R.	---	62	35	0	17	---	
230	R.	140	110	15	8	25	90	
231	R.	35	25	5	2	6	---	
	L.	95	65	5	12	12	63	--shows a period of deep retration
234	R.	175	90	28	12	30	---	
	L.	155	110	15	40	20	110	--radial ribs
1670	R.	---	95	--	14	--	---	-radial ribs
	R.	145	95	20	7	25	115	--radial ribs
	L.	90	60	3	18	13	55	
	L.	---	---	10	39	30	---	-radial ribs
	L.	200	100	--	32	--	160	
1671	L.	160	105	15	35	25	105	
	L.	115	75	10	23	20	90	
	R.	125	90	12	10	15	90	
		80	45	6	8	12	60	
		120	80	5	5	20	90	
		95	65	5	10	15	65	
		100	75	10	11	--	68	
		165	115	15	21	25	130	
		190	100	25	18	--	150	
2091	L.	36	25	1	6	6	23	
2071	R.	240	165	50	10	50	155	--this specimen is unusually broad
	R.	210	---	35	15	50	155	
	R.	180	120	20	15	40	130	
2071	L.	*300	130	50	50	105	225	
7-11-30	R.	*180	120	30	--	*30	125	
2106	R.	*180	90)					--articulated
	L.	*190	*90)					
	R.	230	120	30)				--articulated
	L.	*230	*125	)				

Locality	Valve	L	W	T	C	Ll	Lm	Remarks
	L.	220	130	60	40	40	150	
	L.	---	130	90				
	L.	*250	125					--strongly twisted, attached to another valve
D-31	R.	*210	*105	*40	--	*30	*160	

Taxonomy

Crassostrea versus *Ostrea*

Two distinct problems arise in the generic taxonomy of what has commonly been called *Ostrea titan*. First, what are the genera of Ostreidae? Second, on the basis of the shell alone, into which of these genera should the species *titan* be placed?

Within the last thirty years a number of zoologists, among them Orton, 1928, Ranson, 1942, and Gunter, 1950, have pointed out that recent members of the family Ostreidae can be divided into three distinct groups. Two of the groups are in what has commonly been called *Ostrea*. The third, *Pycnodonta*, is clearly distinguished by basic anatomical differences and a shell which has a cellular or vacuolate structure.

Gunter, 1950, lists ten morphological characters in which the two groups of "*Ostrea*" differ. The validity of two primary groups is confirmed by basic differences in reproductive, larval, gill, and branchial features. Of the ten characters, six should result in differences in the shell, and one is an ecological difference which, for fossil occurrences, is an interpretive matter.

One of the groups is clearly *Ostrea*. The other genus is either *Gryphaea* or *Crassostrea*. European scientists, Ranson, 1942, Piveteau, 1952, v. 2, p. 285, prefer the name *Gryphaea* for the group, and the name *Liogryphaea* for the Mesozoic oysters that, according to Ranson, 1942, p. 162-163, gave rise to *Exogyra* and *Gryphaea*. Stenzel, 1947, p. 174-177, and Gunter, 1950, p. 445-447, have shown that *Gryphaea* can not be applied to Tertiary and Recent oysters according to the accepted rules of nomenclature; that the name *Gryphaea* must be applied to the *Liogryphaea* of European usage, and, that the proper name for the other group of Tertiary and Recent oysters is *Crassostrea*. This usage is followed here. Hedgepeth, 1954, has proposed that *Gryphaea* should apply to both *Gryphaea* and to *Crassostrea* because *Gryphaea* did not become extinct at the end of the Mesozoic but continued as a single gens with a reduced tendency to coil in the manner characteristic of the typical Jurassic and Cretaceous *Gryphaea*; the various Tertiary occurrences of gryphaeoid oysters, Packard, 1923, Hertlein, 1933, being evidence that the combination of genes characteristic of the Mesozoic *Gryphaea* remained to crop up in the Tertiary.

If, as Ranson says, 1942, p. 163, *Crassostrea* has descended from *Gryphaea*, it is reasonable to assume that some of the genetic characters have carried across, as in the derivation of any group from another. If this were not so, phyllogenetic classification based on similarities that carry through successive species or larger groups would be impossible. Thus Hedgepeth is perhaps correct in assuming that there is a genetic continuum from *Gryphaea* to *Crassostrea*. However, the differences between the two are considerable even though a few Tertiary and Recent gryphaeoid forms have existed. Therefore, it is logical to separate the two different groups.

As mentioned previously, Gunter, 1950, lists six differences between *Ostrea* and *Crassostrea* that are reflected by differences in the shells of the two. Prodissoconch differences described by Ranson, 1939, are one of these. Because, however, the prodissoconch of the oysters from the Castaic formation is not preserved, this criterion can not be used. Two other of the six criteria--*Crassostrea* possesses a promyal chamber, and the muscle of *Crassostrea* is farther anterior, nearer the opening between the valves--are significant because they are directly related to physiological differences and perhaps, also, are of significance in considering the life habits of the two groups (Nelson, T. C., 1928). The other three criteria listed by Gunter--*Crassostrea* is larger, has a more cupped lower valve, and has a more elongate variable shape--are generalizations that may be valid, although particular species and certainly many individuals will prove to be exceptions as a result of the great plasticity of oysters in response to ecological variation. Therefore, these three criteria are not as valuable as the previous two, although the position of the muscle, too, may be ecologically controlled to a certain degree in individuals.

Recent material representing small, previously identified collections of the following species, belonging to H. A. Lowenstam or the Gollish collection of the California Institute of Technology, were studied: *hyotis*, *frons*, *nobilis*, *reniformis*, *lurida*, *auriculata*, *amara*, *conchaphila*, *crenulifera*, *cristagelle*, *denticulata*, *edulis*, *expansa*, *folium*, *edulis deformis*, *glomerata*, *permollis*, *palmula*, *imbricata*, *inermis*, *plicata*, *lurida rufoides*, *retusa*, *mordax*, *irridescens*. Collections were too small to be analyzed in any quantitative way, but they do represent a large number of recent species of oysters. After studying these collections and attempting to group them in *Ostrea* or *Crassostrea*, it is obvious that morphological variation within a species may exceed the variation which distinguishes the two genera. Thus individuals of certain species of *Ostrea* may have particular morphological characters of *Crassostrea* to a greater degree than do individuals of *C. virginica*, the type of *Crassostrea*.

In comparison with the specimens of *C. virginica* seen, the individuals of the species *titan* from the Castaic formation have the characteristics of *Crassostrea* to a much greater degree. The Castaic specimens are, in general, elongate and relatively large, have a cupped lower valve, and have an anterior muscle scar. The presence or absence of a promyal chamber is difficult to determine except by the reflection of it in a cupped shape and more anterior muscle scar. On the basis of the characters typical of *Ostrea* and *Crassostrea*, if *virginica* is a typical species of *Crassostrea*, and it is by definition, then *titan* is also a typical species and to an even greater degree.

Gunter, 1950, p. 442, states that *Ostrea* characteristically lives in sea water that is clear and of high salinity, and that *Crassostrea*, in contrast, lives in estuaries and brackish water - water that is turbid and of low salinity. Nelson, 1928, p. 47-52, who was the first person to describe this difference in habitat, explained it physiologically in the following way: The promyal chamber enables *Crassostrea* to cleanse itself more effectively than *Ostrea*. Therefore, *Crassostrea* could live more effectively in turbid waters. Associated with the move into more turbid water (both Nelson and Gunter equate turbidity and brackishness or low salinity) are the advantages of abundant food in brackish or estuarine environments and the absence of the predators that are present in normal marine waters. It may be that *Crassostrea* characteristically inhabits brackish, estuarine, or low-salinity environments. For three reasons, however, one is not justified in assuming that *Crassostrea* lives only in such environments, or, that the presence of fossil *Crassostrea* determines the paleo-ecological conditions. First, the promyal chamber is an advantage in a turbid situation, but there is no necessary correlation of high turbidity and low salinity, so that the presence of a promyal chamber is no indication of conditions of salinity. Second, even if turbid and brackish waters are associated, the adaptive advantage of *Crassostrea* in such an environment does not mean it is at an adaptive disadvantage in the more usual water of normal salinity--advantage and disadvantage being relative to *Ostrea*. Third, *C. virginica* has been found on an oil well rigging 5 miles out in the open Gulf of Mexico (Butler, 1954, p. 479). In addition, a small community of the same species lives in essentially a marine environment near Port Isabel, Texas (Hedgpeth, 1954, p. 207). Representatives of *Crassostrea* are not restricted to turbid and/or brackish environments.

Although *Crassostrea* is most commonly found at present in brackish water, the presence of *C. titan* in sediments does not mean that those sediments were necessarily deposited in brackish water.

The holotype of *Crassostrea titan* came from the upper Miocene Santa Margarita formation of San Luis Obispo County. Subsequently it had been described from middle and upper Miocene sediments of the central and southern California Coast Ranges. Eaton, Grant, and Allen, 1941, as a result of a study of the Miocene sediments and fossils of the Caliente Range and environs, describe a number of new species of *Ostrea* and a new subspecies of *C. titan* from material that would have been grouped previously under *C. titan*. In addition, three other varieties or subspecies of *C. titan* had previously been described. From the descriptions of these groups that are closely related to the species *titan*, it appears that, although the populations may exhibit a small amount of variability, there are distinct characters which are different than in the typical *C. titan*. In the Castaic formation, in sediments that are essentially contemporaneous, the variability is so great that, according to the illustrations and descriptions of type specimens, several of the previously described species and subspecies could be represented among the Castaic specimens. However, it is considered to be more probable that the variability is largely environmental and not genetical. It appears probable that some of the described subspecies, varieties, and closely related species are only ecological variants.

In the Castaic formation, specimens of *C. titan* are much larger north of Elizabeth Lake Canyon than south of it. Proportions, however, are relatively constant throughout the formation. The shells found in the northern part of the outcrop area are not only longer, but are also broader and thicker, and have a longer ligament pit. These most closely correspond to typical *C. titan*, although some thick specimens could be classified as the species *ligminuta* Grant and Eaton. The largest specimens from the southern part of the outcrop area of the Castaic formation are eight to ten inches long and thus would correspond to a degree with *C. titan* var. *prior* (Grant and Eaton), which, they state, 1941, pl. 4, fig. 2, differs from *C. titan* only in being about half the size, and in being presumably ancestral to *C. titan*. In the Castaic formation, the two size groups are of the same age. The variation in size is environmentally controlled in this case, corresponding closely to the two major environments present--bay and open coast. In addition to the size variability, a number of specimens from localities 234, 231, 1670, and 279 are externally radially ribbed. This ribbing is irregularly and weakly developed in general, and the number or position of ribs is not constant. Ribbing is largely confined to lower valves, and is best developed on those that are most cupped. These ribbed specimens differ from *O. bourgeoisii* Remond, as described and illustrated by Grant and Eaton, 1941, pl. 3, fig. 1, and Clark, 1951, p. 447, pl. 43, in lacking the elongate narrow ligamental pit. They differ from *O. cierboensis* Grant and Eaton in having ribs that are narrow rather than broad and rounded. These ribbed forms in the Castaic formation are the result of ecological factors for they are not the dominant form in any particular population, but occur only rarely, scattered among the normal type of shell. Perhaps the ribbing develops in response to the cupping of the lower valve, which is the primary response of the individual to a particular situation. Ribbed specimens have been found only in the central part of the Castaic formation outcrop area--this again corresponds to the area of transition between open coast and bay.

Oyster Thin Sections

Shells sectioned of Ostrea frons and O. irridescens; Crassostrea virginica, and C. titan.

From this small sample, it would appear that only Crassostrea deposits chalky shell in front of and behind muscle scar--because both C. virginica and C. titan have thick chalky deposits, whereas O. frons and O. irridescens have none. However, Korringa, 1951, illustrates O. edulis with as much chalky shell as the Crassostrea, and tabulates the chalky deposits of European oysters (which must be O. edulis)and many have much of it.

The presence or absence of chalky deposit is not of taxonomic importance but is related to shell shape.

C. virginica individuals that are long and slightly arched longitudinally have very little. Those shells, of any species that are deeply cupped, will have much chalky deposit, as will those shells which are very thick, as is C. titan.

O. irridescens is thick but flat. Flatter shells will have less chalky deposit because chalky material is laid down when a particular part of the shell is to be built up--not for a general, overall coating.

Ostrea vespertina Conrad

Plate 17, Figures 2, 4.

Ostrea vespertina Conrad, 1854, Acad. Nat. Sci. Phila. Jour., ser. 2, v. 2, no. 4, p. 300.

Ostrea vespertina Conrad, Woodring, 1938, U. S. Geol. Survey Prof. Paper 190, p. 42, pl. 8, figs. 1-4, 8, 9; pl. 9, fig. 5.

Shell small to medium size, ovate, not falcate; shape variable depending partly upon the surface of attachment. Left valve deeply cupped with a flat or outwardly concave surface where attached; marginal walls strongly plicate and rising almost perpendicularly from the margin of the attached portion of shell. The plications are numerous, nearly parallel, and sharply defined. Right valve convex but not as much as the left valve; plications mainly near the shell margins, not as sharply defined as on the left valve. Muscle scar approximately central. Ligament pit short, broad. Shell margins not well enough preserved to indicate whether they were denticulate near the hinge. One specimen is attached to a fragment of Crassostrea titan; another, to a sandstone pebble.

Two left valves and one right valve have been found at locality 279. Two articulated individuals and several single valves have been found at locality 2104. The two left valves found at locality 279 are small; one is attached to a Crassostrea titan valve. Both specimens are sharply plicate, thin, strongly cupped, ovate. The right valve is approximately the same size as the left valves. The shell margin near the hinge is denticulate. Dimensions of the three are,

in mm.:	Left		Right
Length - L.	24	24	28
Width - W.	20	25	20
Diameter - C.	6	7	3
Thickness - T.	1	1	2
Length of ligamental pit - Ll.			4
Distance from beak to muscle scar - Lm.			17

Dimensions, in mm., of specimens from locality 2104:

	L.	W.	C.	T.	Ll.	Lm.
Single right valve	55	45	9	2	15	35
Single left valve	33	21	7	3		
Paired right and	55	40	10		10	
left valve	56	38	15			
paired right and	48	14	7			
left valve	50	32	15			

The specimens agree with descriptions and illustrations of O. *vespertina* from numerous Pliocene localities in the California Coast Ranges, and from localities in the Pliocene Imperial formation of the Colorado Desert. Specimens collected from the Imperial formation at Painted Hill, east of Whitewater Creek, differ only in being more strongly plicate. *O. vespertina* var. *sequens*, Arnold, 1909, p. 79, pl. 29, figs. 5, 6, is smaller, more circular in outline, and much less plicate. It closely resembles *O. lurida*, which Woodring, 1938, p. 44, suggested might have been its descendent. Specimens of left valves of *O. palmula* collected in Panama Bay resemble the Castaic material closely. Keen, 1958, p. 66, gives the range of *O. palmula* as Scammons Lagoon, Baja California to the Galapagos Islands. *O. palmula* differs from the Castaic specimens of *O. vespertina* in having a thinner shelled, more deeply cupped left valve,and a flat to concave right valve. The first two of these factors, and perhaps the third, too, may be controlled by environmental conditions.

Keen, 1958, p. 66, states that *O. palmula* is one of the most variable oysters of the Panamic province. *O. fischeri*, a recent Panamic species, has a convex right valve, but differs from *O. vespertina* in being flatter, less plicate, and about twice as large. *O. angelica*, as illustrated and described by Keen, 1958, p. 65, fig. 117, most closely resembles *O. vespertina* among living west North American species. Its distribution is from the Gulf of California to Ecuador. Keen states that this species corresponds to what past workers have identified as *O. veatchii* Gabb among recent oysters. It probably does not correspond, however, to what Grabb originally identified.

O. vespertina has been reported from numerous localities in Pliocene sediments of the California Coast Ranges and from Baja California. It has been found, but much less commonly, in upper Miocene sediments of California. The species was originally described from the Pliocene Imperial formation of the Colorado Desert. The occurrence of *O. vespertina* in the upper Miocene Castaic formation falls well within the known time and geographic limits of the species. The limits of distribution have moved southward during the range of *O. vespertina* until, at the present, the most closely related species occur in the Panamic province. However, it should not be related to any one of these species without detailed study because of the morphological variability inherent in oysters. Recent oysters, in general, are inner sublittoral, normal marine forms.

Eucrassatella cf. E. subgibbosa (Hanna)

Plate 16, Figure 7, Plate 17, Figure 5,
Plate 18, Figure 2.

Crassatellites subgibbosus Hanna, 1926, Calif. Acad., Sci. Proc., 4th ser., v. 14, p. 463, pl. 28, figs. 1-4.

Shell heavy, large, subtriangular, inflated; anterior margin rounded, ventral margin arcuate, posterior end truncated, produced, dorsal posterior margin straight. A rounded but distinct keel extends from umbo to ventral posterior corner of shell. Inner shell margin smooth. Sculpture of concentric growth lines; beak high; lunule long, inward sloping, not deep; escutcheon broad, long, depressed but not sharply delimited. Two cardinal teeth in each valve; an anterior lateral in the right valve; a posterior and an anterior lateral in left valve. Left valve; Anterior cardinal sloping forward, high; posterior cardinal much smaller; a low narrow ridge is on posterior edge of the resilifer; a posterior lateral lies well back along the narrow extension of the hinge plate; a small anterior lateral is situated on the ventral edge of the anterior end of the hinge plate. This tooth is reduced and does not rise above the general level of the hinge plate. Right valve: The anterior cardinal lies along the edge of the inward-sloping lunule; it is long, narrow, and low; the posterior cardinal is much heavier and higher; it is straight and joins the beakward extension of the anterior cardinal rather than extending independently up to the beak; a short spur branches from the posterior side of the tooth about mid-way from beak to hinge plate edge. The spur extends down and back to the edge of the hinge plate. The anterior lateral is a small reduced bump at the anterior end of the hinge plate. The spur on the posterior side of the right posterior cardinal tooth is actually a much reduced third cardinal tooth. When the valves are closed, the ventral end of the left posterior cardinal fits between the spur and the cardinal tooth off which the spur branches. The sides of the teeth are smooth. The anterior edge of the left hinge margin, and the posterior edge of the right fit into grooves on the opposite valves. Dimensions in mm. of two specimens:

Long.	60	55
Alt.	38	35
Diam.	28	23
Shell thickness	5	4

Following the classification and discussion of Stewart, 1930, p. 134-140, the Castaic formation material is referred to Eucrassatella on the basis of the smooth internal shell margins and the large ligamental cavity. Stewart separates Recent tropical American species of Eucrassatella from the Australian species into the subgenus Hybolophus on the basis of differences in the umbo. The Castaic formation specimens are not well enough preserved to determine whether the beak is opisthogyrous as it is in Hybolophus. Hanna, 1926, p. 403, in describing the species subgibbosa, did not compare it with any actual specimens of gibbosa but only with an illustration of gibbosa by Nelson, 1870, pl. 7, fig. 9. Spieker, 1922, p. 129, however, states that Nelson's illustration is not of gibbosa, but of another species, which he refers to Crassatellites (Scambula) nelsoni (Grzybowski). Thus Hanna's distinctions between gibbosa and subgibbosa are ill applied and the validity of subgibbosa is questionable. One of the distinctions mentioned by Hanna is "that the central cardinal of the right valve of our species has a side brace, or spur, projecting into the resilium," thus inferring that gibbosa does not have such a spur. Pilsbry, 1931, p. 429, pl. 41, figs. 9, 10, illustrates a right valve of Eucrassatella gibbosa rudis (Li, 1930) from Panama Bay. This subspecies of *gibbosa* is much more slenderly rostrate than the typical species but apparently does not differ in dentition. The specimen illustrated has a short spur-like right posterior cardinal similar to that in the Castaic formation specimens, and similar to that described in *subgibbosa* by Hanna. A quick survey of several crassatellids from various parts of the world shows that the nature of this spur, actually the posterior cardinal, is probably of specific importance, and, in the few cases observed, always present. Therefore, a direct comparison should be made with *E. gibbosa* until the validity of *E.* subgibbosa is established. *Crassatellites laronus* Jordan, 1936, from Pleistocene sediments of the Gulf of California and Magdalena Bay, Baja California, differs from the Castaic formation specimens in that the right posterior cardinal is longer and joins the central cardinal near the beak, the posterior keel is double rather than single, and the shell is somewhat larger. In general, this species (*laronus*) closely resembles the species *antillarum* from the West Indies. Durham, 1950, p. 70, pl. 16, figs. 8, 14, reports *C. laronus* from Pleistocene sediments of the Gulf of California. Judging from the illustrations, the specimen resembles those from the Castaic formation. The right posterior cardinal is short as in the Castaic formation specimens and separate as in the holotype of *C. laronus*. If a study of a large number of crassatellids should show that the nature of the posterior right cardinal is constant, the specimen identified as *C. laronus* by Durham probably should not be referred to that species but to the same species as the Castaic formation specimens.

Crassatellites digueti Lamy differs from the Castaic formation material in shape, size, and dentition; the sides of the anterior and middle cardinals are vertically grooved and the posterior cardinal is obsolete. *Crassatella granti*, from the Vaqueros formation of southern California differs in shape and lacks the sulcus of the Castaic formation species. Dentition of this early Miocene species has not been described in sufficient detail for comparison.

Crassatella fluctuata (Carpenter), which occurs today off the coast of southern California, differs markedly in shape, the posterior end being narrow and drawn out, the posterior dorsal margin being concave, and the escutcheon being much deeper. In addition, according to the illustration in Keen and Frizzell, 1939, p. 12, fig. 4, the right posterior cardinal is lacking.

In summary, then, the Castaic formation species of *Eucrassatella* differs from *E. subgibbosa* in the following way:

1. The shell is less slender posteriorly with no tendency for the posterior-dorsal margin to be concave.
2. The sulcus, extending down and back from the umbo, is much more prominent.
3. The left posterior cardinal is more distant from the anterior cardinal.

It is probably most closely related to *subgibbosa*, but the validity of this species is questionable until comparison can be made with specimens of *gibbosa*.

Eucrassatella has been found in the Castaic formation only at localities 1663 and 2069, a massive sandstone unit containing scattered pebbles, cobbles, and pebble-rich lenses. Two of the specimens from locality 2069 are whole articulated individuals showing little evidence of wear. Some of the fragments, on the other hand, are worn and thoroughly riddled with borings about 0.5 mm. in diameter.

The present distribution of *Eucrassatella* on the west

North American coast is:

E. fluctuata - Santa Barbara Islands to San Pedro
E. digueti - Gulf of California to Columbia
E. gibbosa - Gulf of California to Peru.

The Castaic species appears to be most closely related to *E. gibbosa*.

Closely related fossils appear to be the specimen from Pleistocene sediments of the Gulf of California identified by Durham as *laronus*, and the Pliocene *subgibbosa* from the Imperial formation. On this basis, the Castaic formation occurrence represents the known late Miocene distribution of a group presently found only in the Panamic province.

E. gibbosa has been found on substrates ranging in texture from mud to shell-sand, at depths of 7 to 61 fms., both in the open ocean and in bays having open connection with the ocean.

Chama cf. C. pellucida Broderip

Plate 18, Figure 1.

Chama pellucida Broderip. 1835, Zool. Soc. London Proc., v. 2, p. 149; Zool. Soc. London Trans., v. 1, p. 302, pl. 38, fig. 3.

Chama pellucida Broderip, Durham, 1950, Geol. Soc. America Mem. 43, p. 73, pl. 17, fig. 12.

Fragments of a right and left valve that were articulated have been found. Hinge features of the right valve are partly preserved.

Shell small, approximately oval in plan, strongly prosogyrous; shell exterior of concentric laminae broken up into flat frills aligned in radial rows. Exposed on the right valve is a small anterior cardinal, a shallow elongate corrugated groove corresponding to the anterior cardinal of the left valve, and a larger, posterior cardinal lying along the edge of the shell interior. The anterior cardinal and the socket between the two teeth lie within the shell margin. A narrow ligament groove lies above the posterior cardinal. The beak is twisted forward to lie above the anterior cardinal. Shell margin missing behind posterior cardinal. Anterior muscle scar large, covering the interior of the shell in front of the anterior cardinal. Original shell structure preserved; interior of shell is pale yellowish gray, exterior and interior margins are a darker yellowish gray; the inside is aragonite, the outside, calcite. The shell is about 20 mm. across and about 8 mm. in diameter.

Of the Recent and Tertiary species of Chama that have been reported from the Pacific North American coast, C. pellucida most closely resembles the Castaic formation specimens. However, a number of other West American species which have been reported from Tertiary sediments have been distinguished from one another on the basis of such criteria as shape, size, and external sculpture. The Castaic formation specimen is small and could be an immature form of any of the species. Therefore size is of no use in this case. Shape is a function of the local environment and the nature of the surface upon which the individual is attached. Thus, this is not a good criterion for distinguishing species. Ornamentation is basically of specific value, but can be greatly modified by environment. Individuals of different species should have grown under like environmental conditions for a valid comparison to be made. Dentition, probably a feature of specific taxonomic value, is generally ignored in descriptions of chamids. The result is that although all the characteristics of the Castaic formation specimen are found in *C. pellucida*, they are also found in C. *squamuligera*, *C. buddiana*, and *C. echinata*, as far as one can tell from descriptions of these species by Keen, 1958, p. 108-110, Durham, 1950, p. 72-73, and Pilsbry and Lowe, 1932, p. 103, and from examination of Recent specimens of *C. pellucida*. *C. frondosa* Broderip differs in having broad fan-shaped scales much coarser than those on the exterior of the Castaic formation specimen.

Chama has been found in the Castaic formation only at Locality 1663. Although parts of both valves were found together, the hinge of the left valve was gone, so the two were not articulated, and they are not attached to any substrate. The fact that the two valves are together, and that fragile spines are present indicates that the specimen has not been transported far from its original habitat. In addition, the presence of frills indicates that the individual lived in a quiet water environment where shifting sediment that might break off the spines was absent. This would most likely indicate that the individual lived below the depthof surf action and strong turbulence. However, a sheltered but shallow situation is also a possibility, although less probable.

The range of *C. pellucida* is late Miocene to Recent. The ranges of the other species of *Chama* that are similar to the Castaic specimen are Pliocene or Pleistocene to Recent.

Living individuals of *Chama* are found attached to some object such as the rocky bottom, pebbles, dead shells, or other *Chama*. They occur intertidally and down to depths of 25 fms.

Pseudochama sp.

Plate 17, Figure 7.

Specimen small, a right valve attached to the right valve of a large, articulated Crassostrea titan. Valve is circular in plan view, worn and bored so that internal features are lacking. The valve is 8 mm. across.

P. exogyra is the only species of Pseudochama described as a fossil from the west coast of North America. It has been reported from Pleistocene and upper Pliocene sediments of Ventura County and of the southern Gulf of California. The preservation of the Castaic formation specimen is so poor, however, that comparison with P. exogyra is impossible.

A single specimen of Pseudochama, a right valve, was found at locality 2106. At this locality many large articulated Crassostrea titan are scattered in living position in a well-sorted sandstone deposited very near shore behind what appears to have been a sand bar.

This record of Pseudochama is the earliest occurrence of the genus reported for the Pacific Coast.

Recent species of Pseudochama found along the west coast of North America are littoral and inner sublittoral forms living on rocky open or protected coasts. P. granti Strong, a southern California Recent species, is found at depths of 20-40 fms. attached to pebbles and dead shells. This deeper-water species, however, is distinguished from the closely related species exogyra by well-developed spines on the right valve.

Lucina (Here) excavata Carpenter

Plate 18, Figures 6a, b.

Lucina excavata Carpenter, 1857, Cat. Reigan Coll. Mazatlan Moll. p. 98.

Lucina (Here) excavata Carpenter, Stewart, 1930, Acad. Nat. Sci. Phila. Spec. Publ. 3, p. 181, pl. 15, fig. 3; pl. 17, fig. 5.

Lucina (Here) excavata Carpenter, Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 290, pl. 14, figs. 2, 5, 10.

Shell small, circular, very inflated, thick; beak prominent, prosogyrous, turned inward, in contact with beak of adjacent valve. Sculpture of small, closely spaced concentric ribs, ribs less well developed near outer margin of valve, worn shells show underlying radial structure. Posterior fold consists of low trough extending from shell margin behind beak to the posterior ventral margin of shell; trough is curved on shell surface. Lunule deeply depressed.

Dimensions in mm.:

Long.	16	15	18
Alt.	16	14	19
Diam. (of single valve)	9	6	7
Thickness	1.5		

This material is referred to L. excavata because of the inflated, globose shape, the concentric sculpture, and the deeply depressed posterior part of the lunule.

Grant and Gale, 1931, p. 290, give the stratigraphic range of L. excavata as Oligocene to Recent. Loel and Corey, 1932, give the range as early Miocene to Recent. The only occurrence of the species in the Oligocene is in the upper part of the San Emigdio formation at the south end of the San Joaquin Valley, Wagner and Schilling, 1923, p. 243, 244. This formation is lower Oligocene or upper

Eocene, Weaver et al, 1944, pl. 1. The species is found in lower Miocene sediments between Monterey and Orange Counties. Upper Miocene and Pliocene distributions have similar geographic limits. The known Pleistocene distribution is Baja California and southern California. The Recent distribution is between San Pedro, California and Mazatlan, Mexico.

L. excavata has been found at localities 1849, 1663, and 2069, in fine- to medium- grained sandstone. No specimens are articulated; all are single whole valves. Those from locality 1849 are badly weathered; those from localities 1663 and 2069 are well preserved.

The species is found at present offshore in the open ocean at depths of 3 to 11 fms.

Miltha sanctaecrucis (Arnold)

Phacoides (*Miltha*) *sanctaecrucis* Arnold, 1909, U. S. Geol. Survey Bull. 396, p. 57, pl. 6, fig. 6.

Lucina (*Miltha*) *xantusi* (Dall), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 291, pl. 14, figs. 20a, 20b.

Two broken fragments have been found at locality 1849, and a single large articulated specimen at locality 1663.

Shell medium to large, flattish, orbicular. Sculpture of concentric growth lines; posterior edge of shell set off by a narrow furrow extending down and back from behind the umbo; behind the furrow is a ridge of comparable width and amount of relief, followed posteriorly by a broad shallow furrow occupying the remaining part of the shell. The elongate, narrow, anterior muscle scar lying approximately parallel to the anterior shell margin can be seen on an incomplete internal mold of one of the specimens. Hinge features are poorly preserved. Two cardinal teeth are present; lateral teeth absent; shell margin behind beak straight. Neither escutcheon nor lunule is present. The shells are about 45 mm. in longitude, a little less in altitude; diameter of single valve about 10 mm.

This species is referred to *M. sanctaecrucis* because of the characteristic muscle scar, shape, and sculpture. The illustration of the type, and an illustration of another specimen by Loel and Corey, 1932, pl. 36, fig. 5, show only the external features of the shell. The hinge of the species has not been described. Comparison of the specimens with material in the collection of Stanford University, however, confirms the tentative identification made from the literature.

Grant and Gale, 1931, p. 291, have grouped together *M. sanctaecrucis* and several other species within the species *xantusi*. Considering *sanctaecrucis* to be synonymous with *xantusi* has much merit--no distinct differences can be seen to separate the two. Because they have not been studied in detail, however, the Castaic formation material is referred to *sanctaecrucis*. If not identical, the two species are very closely related. The two names seem to merely separate living and fossil specimens of the same form.

M. sanctaecrucis is abundant and widely distributed in the lower Miocene Vaqueros formation from Monterey County southward to Orange County. It also occurs in the middle Miocene Temblor formation in the Coast Ranges west of the San Joaquin Valley, in the upper Miocene Castaic formation of the eastern Ventura Basin (this report), in the upper Miocene Santa Margarita formation north of Coalinga, and in the lower Pliocene sediments in the eastern Ventura basin. *Miltha xantusi* has been reported from Pliocene and Pleistocene sediments in the Gulf of California. Its recent distribution is within the Gulf of California, at depths greater than 30 fms., on bottoms of sand and weed. Both occurrences of this species, at localities 1849 and 2069, are in fossil-rich sandstone near or at the base of the Castaic formation.

Lucinoma acutilineata Conrad

Plate 18, Figure 4.

Lucina acutilineata Conrad, 1849, U. S. Explor. Exped. Geol., v. 10, p. 725, pl. 18, figs. 2, 2a, 2b.

Lucina (Myrtea) acutilineata Conrad, Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 286, pl. 14, figs. 22a, 22b.

Lucina acutilineata Conrad, Weaver, 1942, Univ. Wash. Publ. Geol., v. 5, p. 143, pl. 34, figs. 8, 11, 16.

Shell medium-size, orbicular, flattish, equivalve, thin; beak small, prosogyrous, slightly posterior of center, shell margins smoothly rounded, lunule small, flat, without sculpture, not depressed or circumscribed; escutcheon absent. Sculpture of concentric ridges about two to three mm. apart; interspaces flat, with fine concentric ribs. Little evidence of a posterior plication or change in sculpture. No posterior lateral tooth at end of ridge-like nymph plate running back from beak. Dorsal shell margin straight behind beak, curving sharply around posterior end of nymph plate into broad smooth curve of posterior part of shell; anterior dorsal shell margin straight beyond end of lunule, to anterior lateral, around which it curves sharply into broad smooth curve of anterior shell margin; anterior lateral small, not connected to central part of hinge. Two cardinal teeth present, posterior cardinal heavy, straight; anterior cardinal smaller, curves forward parallel to adjacent shell margin; teeth too worn to determine if they were bifid. The long narrow anterior muscle scar is seen on an internal mold of a right valve. Internal features of left valve not exposed. Dimensions in mm. of specimens from several localities:

Locality	231	1627	1849				
Long.	40	38	34	33	30	26	25
Alt.	35	32	31	33	27	25	21
Diam.	*10	18	11	12	12	*5	9

*of a single valve.

The Castaic specimens agree with the description and various illustrations of Lucinoma acutilineata and can be referred with confidence to that species. The generic or subgeneric classification of the species has varied in the past. It had usually been referred to Phacoides previous to Grant and Gale, 1931; in a number of these early papers, it was placed in the subgenus Lucinoma. Chavan, 1952, shows that Phacoides is not a satisfactory name and recommends that it be abandoned. The result is that the species is within Lucina s. l, and within the group Lucinoma. Depending upon whether Lucinoma is a genus of Lucinidae or a subgenus of Lucina, the species acutilineata is either in Lucinoma or in Lucina (Lucinoma). Keen, 1958, p. 97, and Woodring, 1938, p. 52, and 1950, p. 86, consider Lucinoma to be of generic rank, and their judgement is here followed.

Lucinoma acutilineata was originally described from the Miocene sediments of Astoria, Oregon. Lucinoma annulata was originally described from the Recent of California. The two species are so similar, however, that they may be conspecific. Grant and Gale, 1931, p. 287, consider them the same, and state: "The supposed specific differences between the teeth of annulata and acutilineata is a delusion." From the discussion by Woodring, 1938, p. 53, and by Stewart, in Tegland, 1933, p. 116, it appears that comparisons involving the holotype of L. acutilineata may indicate differences between the two species, but that study of large samples of both might well indicate that the two are conspecific. The two represent a single gens, and any evolutionary change has been slight since the Oligocene epoch. The common practice has been to divide the two species at the Miocene-Pliocene boundary. Older specimens are referred to acutilineata, younger ones to annulata. The lineage actually may be somewhat more complicated. Among specimens from the Castaic formation and from about 10 other Miocene and Pliocene localities, two shapes have been noticed. One is broad and thin; the other is distinctly more inflated. Thus, the specimens from locality 1849 are less inflated than those from the other localities. In a general way, the more inflated forms can perhaps be referred to acutilineata, the less inflated ones to annulata. However, a detailed study of large populations would be necessary to show, initally, that there were even two distinct shape groups.

On the basis of published occurrences, the area of distribution of the acutilineata - annulata gens has gradually increased since the Oligocene epoch. The extension has been both to the north and to the south, but primarily to the south. The gens has been found in Oligocene sediments only in and near western Washington. Its Miocene distribution is from Alaska to the Ventura Basin (the Castaic formation localities here discussed). The known Pliocene and Pleistocene distribution is from northern California to San Diego. The Recent distribution is from Alaska to the Gulf of California. Thus, if the fossil record is adequate, the southern limit has moved progressively southward; the northern limit, except for restriction in the Pliocene and Pleistocene, has moved northward.

This species is found most abundantly at locality 1849 and locality 1663. It has also been found northward as far as the Haskell Canyon area. Most of the specimens from locality 1663 are articulated, as are about two-thirds of those from locality 1849. The single specimen from locality 1627 is articulated; those from localities 1624 and 231 are not. In general, the shells show no evidence of predeposition wear, but most are not well preserved because of Recent weathering.

The specimens of L. acutilineata from different localities in the Castaic formation are morphologically the same except as noted above. At localities 1627, 1663, and 1849, where it is abundant, and where many specimens are articulated, the species is found only in fine-grained sandstone. The specimens from the Haskell Canyon area are in less well-sorted sediments - granular to pebbly sandstones and pebble conglomerates. The material from this area has probably been transported with the coarser sediments before final deposition. Etherington, 1931, p. 77, states that in the Miocene Astoria formation of western Washington, "the best individuals" of the species came "from the finer grained muddy sandstones rather than from the coarser sediments" - a relation similar to that in the Castaic formation.

The habitat of L. annulata is in the open ocean in fine-grained sands at a depth of 8 to 200 fms.; it is most common in water 30-50 fms. deep. Collecting data presented by Burch, 1944-1946, indicate that there is no significant change in depth range with latitude.

Trachycardium cf. *T.* (*Dallocardia*) *quadragenarium* Conrad

Cardium quadragenarium Conrad, 1837, Acad. Nat. Sci. Phila. Jour., v. 7, p. 230, pl. 17, fig. 5.

Laevicardium (*Trachycardium*) *quadragenarium* (Conrad), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 306, pl. 19, fig. 15.

Shell medium size, oval, sub-equilateral. Beak slightly prosogyrous. Posterior margin is longer than anterior margin and forms a rounded angle at its juncture with the ventral margin. Ribs about 35, prominent, wider than interspaces; no sculpture seen on ribs, but all specimens are badly weathered. Hinge curved, with well developed lateral teeth. Approximate dimensions in mm.:

Long.	25	23	25	35	75
Alt.	25	22	25	35	?
Diam. (of single valve)	7	8	6	9	23

This material is too fragmentary and poorly preserved to be identified surely. It resembles *T. quadragenarium* var. *fernandoense* Arnold, 1907, p. 535, pl. 48, figs. 2, 2a, 3 in that it is smaller and has fewer ribs than *T. quadragenarium*. Even if the material were well preserved and could be identified as the species *quadragenarium*, the variety *fernandoense* is based on too few specimens to be well established (see Woodring, 1938, p. 54).

Fragments of the species have been found at localities 1663 and 2069.

T. quadragenarium has a stratigraphic range of middle Miocene to Recent. Grant and Gale, 1931, p. 306, give the late Miocene distribution as central California; the Pliocene, as central California south to Ventura. The Recent distribution is Santa Barbara south to Todo Santos Bay, Baja California. Thus, from the meager record, the Castaic formation occurrence represents a southward extension of the late Miocene distribution.

Living individuals of *T. guadragenarium* occur in sediments ranging in texture from mud to gravel, but are most common in sand. They are found in shallow water of the Pacific Coast both in bays and in the open ocean, intertidally and to depths of 75 fms., but most abundantly in water shallower than 10 fms. Burch, 1944-46, part I, no. 41, p. 21, reports the species from upper Newport Bay and the Estero of Todos Santos Bay.

Nemocardium (Keenaea) centifilosum (Carpenter)

Plate 18, Figure 5.

Cardium var. centifilosum Carpenter, 1864, British Assoc. Adv. Sci. Rept. for 1863, p. 642.

Laevicardium (Nemocardium) centifilosum (Carpenter), Grant and Gale, 1931, San Diego, Soc. Nat. Hist. Mem., v. 1, p. 311, pl. 19, fig. 9, 10.

Nemocardium (Keenaea) centifilosum (Carpenter), Palmer, 1958, Geol. Soc. America Mem. 76, p. 91, pl. 10, figs. 7-11.

Twenty-one specimens, one articulated, have been found at locality 1849; about 12 specimens, none articulated, at localities 1670, 279, 2097, and 2098. Preservation is poor, particularly at localities 279 and 2097, where identification is largely on the basis of molds. The specimens from locality 1849 are best preserved and differ somewhat from the specimens collected at the other localities. Therefore, they will be described first and then the other material will be compared with them.

Shell small, ovate, beak only slightly prosogyrous. Shell margins smoothly rounded. Sculpture consists of about 60 to 65 fine radial ribs. Rib interspaces are wider on the posterior part of the valve, but the ribs are of constant width over all the shell. The posterior part of the shell that has different sculpture contains about twenty ribs. There, ribs and interspaces are approximately equally wide. On the main body of the shell, interspaces are less than half as wide as the ribs. Hinge relatively short, slightly arched, anterior and posterior lateral teeth well developed. Dimensions in mm. of specimens from locality 1849: Range of dimensions- Long. 12-22, Alt. 10-23, Diam.* 4-8.

$\frac{\text{Long.}}{\text{Alt.}}$ 1.0-1.2, 1.08 avg. for six specimens

$\frac{\text{Long.}}{\text{Diam.}}$ *2.45-3.20, 2.81 avg. for six specimens

*of single valve.

There is no noticeable change of shape with size.

The specimens from localities 1670, 279, 2097, and 2098 differ from those from locality 1849 in having about 75 ribs instead of 60 to 65, in being a smaller, uniform size, in having a different, more elongate shape, and, in having fine concentric laminae across the posterior part of the shell. This concentric sculpture might be equally characteristic of the specimens from locality 1849, but has been destroyed by weathering. Dimensions in mm. of material from localities 1670, 279, 2097, and 2098; Range of dimensions - Long. 12-14, 13.3 avg. of six specimens, Alt. 9-12, 10 avg. of six specimens, Diam.* 4-5, 4.4 avg. of six specimens.

$\frac{\text{Long.}}{\text{Alt.}}$ 1.15-1.45, 1.3 avg. for six specimens

$\frac{\text{Long.}}{\text{Diam.}}$* 2.6-3.25, 3.0 avg. for six specimens

*of single valve.

Therefore, in these specimens, longitude is greater relative to both altitude and diameter than it is in the specimens from locality 1849.

The subgenera *Keenaea* and *Arctopratulum* are separated on differences in hinge length, shape, and sculpture, Keen (1954) p. 317. A significant difference in hinge length is not obvious from illustrations of representatives of the two subgenera in: Keen (1954) pl. 1, figs. 12, 14, 17, text figs. 3, 4; Oldroyd (1925) v. 1, pl. 34, figs. 2a-d; Grant and Gale (1931) pl. 19, figs. 9, 10. The illustrations do show, on the other hand, that *Arctopratulum* has a trigonal shape, *Keenaea*, a subquadrate one. Secondary concentric lamellae are present over the whole shell of Arctopratulum but are restricted to the posterior part of Keenaea. The Castaic material was referred to Keenaea on the bases of shape, and distribution of secondary sculpture. It closely resembles Nemocardium (Keenaea) lorenzanum (Arnold) (1908) Weaver (1942) v. 5, p. 160, pl. 35, fig. 22, pl. 36, figs. 3, 5, from the upper Oligocene sediments of California, but it differs in that it is larger and the posterior ribs are relatively finer, whereas, on N. lorenzanum, the posterior ribs are coarser than on the rest of the shell.

The specimens from locality 1849 are sufficiently different from those found elsewhere in the formation that it is probable that two subspecies are present. The specimens from locality 1849 being typical of the species, the other specimens being a distinct variant. For the purposes of this paper, however, it is sufficient to merely point out the variations within the species.

Localities 279, 2097 and 2098 are close together and stratigraphically approximately equivalent. These localities are within a relatively coarse-grained tongue of sediments within a section that is composed largely of mudstone. Within this tongue , sediment types vary from mudstone to pebble conglomerate. In general, the section consists of sandstone beds with graded texture, sandstones of uniform texture, and mudstone partings of variable thickness. Locality 279 is in a ten foot thick section of fine- to medium-grained sandstone, even textured, thin-bedded (3-8 inches). Localities 2097 and 2098 are in units with graded texture from pebbly sand at the base to fine sand at the top. The disarticulated and uniformly sized material from this area might indicate that some transportation and sorting **have** taken place. On the other hand, none of the thin delicately sculptured shells show any signs of wear. Locality 1849, about twelve miles southeast of the other localities is in pebbly to fine sandstones within the basal few feet of the formation. The specimens have come from fine-grained sandstone. The intermediate locality, 1670, is in sediments similar to those localities to the north, but a little coarser-grained and with less evidence of graded bedding.

Keen (1954) p. 317, states that N. centifilosum ranges from Pleistocene to Recent. Grant and Gale (1931) p. 311, report that the species is found also in Pliocene and questionably in Miocene sediments. Therefore the Castaic occurrence represents the earliest definite occurrence of the species. The occurrence lies within its Pliocene distribution of Kern County to San Diego County. Its Recent distribution is central California to the Pacific Coast of Baja California.

At present, N. centifilosum lives in the open ocean off California at depths of 20 to 80 fms., but most commonly, at depths of 35 to 50 fms. on a bottom of muddy sand or sand.

Tivela _diabloensis_ Clark

Plate 19, Figures 1a, b.

Tivela (_Pachydesma_) _diabloensis_ Clark, 1915, Univ. Calif. Publ. Geol. Sci. v. 8, p. 462, pl. 54, figs. 5, 6; pl. 55, fig. 1.

Shell large, heavy, trigonal, only slightly inequilateral; beak prominent, pointed, slightly prosogyrous; anterior and posterior dorsal margins straight; anterior, posterior and ventral margins not preserved on specimens. Shell thick, surface smooth, except for faint concentric growth lines. Nymph plate strongly developed, escutcheon well defined, deeply set. Right valve contains two anterior lateral teeth, three cardinal teeth. A III, along shell margin, small; A I large, elongate; groove between the two laterals is deep and broad. 3A is very small, close along the shell margin; 1 and 3b are of equal size. Only a fragment of left hinge present. Posterior left lateral, 4b, large, heavy.

Dimensions of right valve:
Alt. 60 mm., long. 75 mm., diam. 19 mm., shell thickness 4 mm.

The specimens agree well with _T._ _diabloensis_ from the lower San Pablo Group, as described and figured by Clark. They differ from _T._ _gabbi_ in being proportionately more elongate, and in having a straighter, almost concave dorsal posterior margin. They differ from _T._ _trigonalis_ in being more equilateral, relatively more elongate, and in having a less well developed right anterior cardinal. The material from the Castaic formation resembles the Recent _T._ _stultorum_ in shape. The recent species, however, has a well developed right anterior cardinal which is practically obsolete in the Castaic formation species. Clark (1915) p. 462, emphasizes the presence of a posterior carina on _T._ _diabloensis_, and the relative lack of one on *T. gabbi* and *T. stultorum*. Although the Castaic formation specimen has been slightly crushed, it does not appear to have had a carina more prominent than does *T. stultorum*. This feature on the type specimen is not so well defined as to be of diagnostic importance compared to the less plastic, more stable, dentition.

T. diabloensis has been found at localities 1849 and 1663--a single, nearly complete right valve at locality 1849, several fragments at locality 1663. Both occurrences are in similar sediments--pebbly, poorly-sorted sandstone containing a large variety of other fossils.

Recent species of *Tivela* characteristically burrow in sand on beaches and bars along open exposed coasts. They have been found within the mouths of sloughs and bays, but not back within them. They occur most commonly in the littoral and very shallow inner sublittoral zones, but some species have been found at depths of 30 to 40 fms. Of the recent West Coast species of *Tivela*, *diabloensis* is probably most closely related to *stultorum*. This species has been reported only from very shallow depths.

Pitar (*Lamelliconcha*) sp.

Plate 19, Figures 2a, b, c.

Shell medium size, elongate-ovate; beak prosogyrous, slightly anterior of center; margins rounded, smooth internally. Sculpture of coarse, irregular, rounded, concentric ridges. Left valve: three cardinal teeth; posterior cardinal long, thin, parallel to narrow nymph plate; middle cardinal short, heavy; anterior cardinal short, thinner than middle one. Anterior lateral elongate, close to cardinals. Right valve: a prominent elongate posterior cardinal; middle and anterior cardinals close together under beak, small; deep anterior socket with small laterals above and below. Lunule incised, slightly depressed; escutcheon not defined. Dimensions in mm. of a single articulated individual; Long. 42, Alt. 31, Diam. 23.

Only one specimen has been found at locality 1663. It is articulated, unworn, but it has been bored through on the umbo of the left valve. In addition, a *Crepidula adunca* is attached to the left valve. The specimen is placed in the subgenus *Lamelliconcha*. It can not be specifically identified because suitable material for comparison is not at hand. It is well preserved and should be identifiable.

Recent species of *Lamelliconcha* from the Panamic marine province are found at a variety of depths, from sand beaches and bars and mud flats to depths of 60 fms. Most of the species occur in the open ocean at depths less than 40 fms.

Dosinia arnoldi Clark

Plate 18, Figures 7a, b, 8.

Dosinia arnoldi Clark, 1915, Univ. Calif. Publ. Geol. Sci., v. 8, p. 459, pl. 51, figs. 1, 2.

Shell large, circular; beak prominent, prosogyrous. Shell margins broadly rounded except for beak and short concave arc anterior to it. No excutcheon, lunule strongly depressed but not circumscribed. Sculpture of fine concentric ribs which are rounded in cross section. Left hinge: AII small; anterior cardinal narrow, sloping down and slightly forward from under beak; middle cardinal broad and heavy; posterior cardinal long and relatively narrow sloping back and down along the edge of the nymph plate. Right hinge: Anterior lateral teeth small, AIII only slightly anterior of AI; anterior cardinal narrow, short; middle cardinal heavy, short; posterior cardinal long, large, grooved and separated from nymph plate; a fine ridge marks the anterior margin of the nymph plate. Dimensions: of mature specimen--long. 80 mm., alt. 80 mm., diam. of single valve 24 mm.; of immature but well preserved articulated specimen--long. 21 mm., alt. 19 mm., dia. of individual 8 mm.

Clark (1915) p. 459, in his description of D. arnoldi, figured only a left valve. Arnold (1909) p. 67, pl. 16, fig. 5, in his description of D. jacalitosana, figured only the exterior of a right valve. Nomland (1917) p. 219, pl. 10, fig. 1, 1a, illustrates a right valve of D. jacalitosana. On the basis of the descriptions and illustrations, there is little difference between the two species. Grant and Gale (1931) p. 352, group the two, along with D. merriami Clark in D. ponderosa (Gray) variety jacalitosana Arnold. As Grant and Gale note, these three species are very similar. However, the Castaic forms are referred to D. arnoldi for the following reasons: The left anterior cardinal tooth of the type of *D. merriami*, as illustrated by Clark (1915) pl. 52, fig. 2, turns backwards ventrally, and the anterior lateral is close under the beak. Thus, the anterior part of the hinge is compressed backwards relative to *D. arnoldi* and the Castaic specimens. The differences in shape are small between *D. jacalitosana* on the one hand, and *D. arnoldi* and the Castaic forms on the other. These distinctions are made on the basis of only a few illustrations, so Grant and Gale may very well be correct in combining these species. Keeping this possibility in mind, it is probably best to be conservative taxonomically until Pacific Coast Tertiary *Dosinia* are studied in more detail.

D. arnoldi has been reported only from the upper Miocene sediments of the central California Coast Ranges between the San Francisco area and the southern San Joaquin Valley. Thus its occurrence in the Castaic formation represents a small southward extension of its distribution. It has been found in the Castaic formation at two widely separated localities and in somewhat different sediments. At both localities the sediments are sandstone with scattered pebbles. At locality 1849, however, the sand is fine-grained, well-sorted, well-cemented, whereas, at locality 2093, the sand is poorly-sorted, medium- to coarse-grained with scattered granules, and is calcareous but relatively much less hard and cemented. Except for one small specimen from locality 1849, all the fossils are disarticulated and broken. Two valves from locality 1849 had been bored through on the umbo.

Dosinia ponderosa, which is a living species probably closely related to *D. arnoldi*, lives from Baja California to Peru in bays and offshore in water 4 to 33 fms. deep. It has been dredged from bottoms of mud, sand and mangrove leaves, and mud and shell. Pleistocene occurrences of D. ponderosa are in the Gulf of California, Oaxaca, and Ecuador. Pliocene specimens have been found only in the Gulf of California. Thus the known distribution from Pliocene to Recent has been strictly Panamic.

Amiantis callosa (Conrad)

Plate 20, Figure 6.

Cytherea callosa Conrad, 1837, Acad. Nat. Sci. Phila. Jour., v. 7, p. 252.

Callista (Amiantis) callosa Conrad, Arnold, 1907, U. S. Nat. Mus. Proc. v. 32, p. 544, pl. 49, fig. 2.

Amiantis callosa (Conrad), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 348, pl. 17, figs. 7, 9, 11 - 14.

Three specimens of this species have been found in the Castaic formation, all at locality 1849. All are fragments of left valves. Hinge characters and sculpture are preserved on all of them. The shape inferred is a composite of the three specimens. The fragmental nature of the material is not the result of pre-depositional abrasion, but of weathering and collecting.

Shell medium size, subovate; beak prominent, prosogyrous, slightly anterior of center. Margins of shell smoothly rounded; anterior dorsal margin descends moderately from beak. Sculpture of well developed concentric ribs which are rounded in cross section but are irregular in that some widen, narrow, or bifurcate. Grooves approximately the same width as the ribs. Escutcheon is long and narrow; lunule is circumscribed by a fine line, is not depressed and extends anteriorly about as far as the anterior edge of the lateral tooth. Left anterior lateral tooth well developed, more or less parallel to adjacent shell margin; left anterior cardinal straight, thin, sloping slightly anteriorly from under beak; left posterior cardinal heavier, sloping posteriorly. Dimensions (approximate) in mm. of specimens from locality 1849:

Long.	45	30	32
Alt.	30	22	23
Diam. (of left valve)	14	8	7

These specimens were originally identified by L. A. Wright (1951) as *Marcia* (*Compsomyax*) cf. *subdiaphana* Carpenter. However, he had not prepared the material sufficiently to expose the anterior lateral tooth. Grant and Gale (1931) divided *A. callosa* into two varieties, *callosa*, s.s., and *stalderi*, on the basis of the shape of the anterior dorsal margin. In the variety *stalderi*, the anterior dorsal margin supposedly descends more abruptly than in *callosa* s.s. This distinction, based on slight shape differences alone, is perhaps not valid, because Grant and Gale (1931) p. 349, state "This variety (*stalderi*)will prove of value if the character of its outline is sufficiently constant to allow identification in the majority of the cases". However, in any growth series of recent *Amiantis callosa* there is a pronounced change in shape with size. As the shell becomes larger, it becomes less elongate, more round; the posterior dorsal margin becomes more curved; and the anterior dorsal margin descends more abruptly. This trend is towards the shape observed in *stalderi*. Arnold (1907) p. 544, pl. 49, fig. 2, illustrates a specimen of what he identified as *Callista* (*Amiantis*) *callosa* Conrad. If this specimen is a typical *A. callosa*, as Grant and Gale (1931) p. 348, 349, regard it to be, var. *stalderi* lies well within the range of variability of *A. callosa*, for the specimen figured by Arnold has a rounder outline and more abruptly descending anterior dorsal margin than does the typical *A. callosa* var. *stalderi*. The Castaic specimens most closely resemble Arnold's figured specimen, which is from the lower Pliocene of Elsmere Canyon, and the type specimen of *A. stalderi*, described by Clark (1915) p. 468, pl. 53, fig. 5, 6, as *Pitaria stalderi*.

Specimens of *A. callosa* from the Pleistocene upper San Pedro formation, C. I. T. locality 265, are identical with recent specimens, whereas the upper Miocene specimens grouped by Grant and Gale (1931) p. 349, in var. *stalderi*, and the similar lower Pliocene specimen of *A. callosa* figured by Arnold are somewhat different from Pleistocene and Recent specimens of *A. callosa*. Whether this difference rates taxonomic distinction can only be determined by a detailed study of the genus. It seems most proable that the shape differences perhaps represent an evolutionary trend, but material of intermediate age would be required in order to prove this.

A. callosa is found in the Castaic formation at locality 1849. There it occurs in the basal few feet of the formation in a pebbly coarse-grained, moderately sorted sandstone. The valves are all separate, but show no evidence of the abrasion that might result from transportation.

The stratigraphic range of *A. callosa* is from upper Miocene to Recent. It's known geographic distribution is (from Grant and Gale 1931, p. 348, 349):
Late Miocene - San Francisco area to Newhall
Pliocene - Ventura Basin
Pleistocene - San Pedro, California to San Quintin Bay, Baja California
Recent - Santa Monica, California, to Tehuantepec, Mexico.
Therefore, the Castaic occurrence is early in the known history of the species. Geographically, it is the southermost known late Miocene occurrence, but upper Miocene sediments are so rare farther south that the actual southern limit of the species at that time must be considered as unknown.

Living *A. callosa* are found along sandy beaches of the open ocean. It occurs most abundantly just below the low tide.

Clementia (*Egesta*) *pertenuis* (Gabb)

Venus kennerlyi Reeve?, Gabb, 1866, Geol. Survey California, Paleontology, v. 2, p. 22, pl. 5, fig. 37.

Venus pertenuis Gabb, 1866, Geol. Survey California, Paleontology, v. 2, p. 22, pl. 5, fig. 37.

Clementia (*Egesta*) *pertenuis* (Gabb), Woodring, 1926, U. S. Geol. Survey Prof. Paper 147-C, p. 40, pl. 16, figs. 1-6.

This species is found only at locality 1849. The identification is based on material that is largely fragmental. Size, shape and sculpture features are well preserved. Hinge features are composite from a number of specimens. None of the shells are articulated.

Shell large, inequilateral, thin, ovate, beak prominent, prosogyrous. Dorsal posterior margin approximately straight from beak back and down to relatively sharp ventral-posterior arc. Anterior margin broadly rounded. Sculpture consists of broad concentric swells and fine concentric ribbing on both swells and troughs. Near the ventral margin the swells are less well defined and irregular in cross section, and the fine concentric ribbing is the dominant type of sculpture. Internal margin edge smooth. Dentition consists of three cardinal teeth in each valve, no lateral teeth. Right valve contains a slender anterior cardinal, a heavier middle cardinal, and an elongate posterior cardinal that is poorly preserved in all the specimens; left valve contains heavy anterior and middle cardinals and an elongate posterior cardinal. Lunule is depressed but not circumscribed. Dimension: material collected ranges from small to large. The longitude of mature specimens is about 90 mm.; altitude, about 80 mm., diameter of single valve, about 30 mm. The shell is only 1-2 mm. thick.

From the discussion, descriptions, and figures by

Woodring (1926) it appears that the species of *Egesta* form a closely knit group. *C. pertenuis* differs from *C. conradiana* in having a more extended anterior margin and in having a less depressed lunule. It differs from *C. martini* in being less elongate and less inequilateral. Woodring mentions no differences in dentition. The known range of *C. pertenuis* is from early Miocene to early Pliocene. *C. martini* is known from sediments of late Miocene age, *C. conradiana*, from sediments of early to late Miocene age. Because the main variation in these three species is in shape, *C. martini* and *C. conradiana* may only represent local or ecological variants of *C. pertenuis*. A study of these species in terms of population variability would, of course, be necessary to test this supposition. Loel and Corey (1932) have noted that in the Vaqueros formation, there is a wide variety in *Clementia* shape at any locality, and they refer all the material to *C. conradiana* as a variety of the earlier described *C. pertenuis*.

All the Tertiary Pacific Coast *Clementia* so far found have come from Miocene and Lower Pliocene sediments in California in or south of the San Francisco region. No middle or late Pliocene or Pleistocene *Clementia* have been reported from the Pacific Coast of the United States or Baja California. Recent *C. solida* from the Gulf of California is referred to the sub-genus *Egesta* by Woodring (1926) but Keen (1958) p. 138, states that this species is based on a single valve, and that no additional material has since been found, so that the valve may only represent a chance introduction. If so, there are no recent Pacific Coast *Clementia*. Woodring (1926) p. 30, believes that *Clementia* s. s. is a tropical group, whereas *Egesta* is sub-tropical to warm temperate. The data from California are not sufficient to show any climatic control of distribution during the Cenozoic era.

Clementia pertenuis is found in the Castaic formation only at locality 1849. None of the shells are articulated; most are broken, but not much abraded. They occur in well-sorted coarse-grained sandstone.

Chione fernandoensis English

Plate 19, Figures 5a, b.

Chione fernandoensis English, 1914, Univ. Calif. Publ. Geol. Sci., v. 8, p. 215, pl. 23, figs. 9, 10.
Chione (*Anomalocardia*) *fernandoensis* English, Parker, 1949, Jour. Paleontology, v. 23, p. 585, pl. 95, figs. 7, 8, 13, 14, 16, 18.

Shell medium-size to small, equivalve, inequilateral, sub-trigonal. Posterior dorsal margin slopes from beak in a relatively straight line; margin curves abruptly at posterior and anterior ends of ventral margin; anterior dorsal margin concave, short. Beak prominent, strongly prosogyrous. Sculpture of strong concentric rounded ribs spaced about 3 mm. apart (measured down the center of a valve). Fine radial ribbing between the concentric ribs apparently is made visible only as a result of weathering of the shell. Posterior hinge narrow, ligament attached very close to the shell margin. Lunule depressed, lanceolate; escutcheon large, broad, flat, sloping towards hinge margin. Dentition: Three cardinal teeth in each valve, no lateral teeth, teeth smooth. Right valve: 3a short; 1 curves down and anteriorly from under beak; 3b long, straight, perhaps grooved along the crest.

Dimensions in mm.:

Locality	1663			1627			1849		
Long.	23	26	23	20	23	23	29	35	19
Alt.	20	23	18	17	19	18	22	28	15
Diam.	15	16	14	11	12	14	*7	*9	*5

*Diameter of single valve.

The Castaic material is identified as *C. fernandoensis* on the basis of size, shape, sculpture, and nature of escutcheon and lunule. The hinge of the type of *C. fernandoensis* is unknown because the type specimen is articulated. Grant and Gale (1931) p. 321, pl. 17, figs.

4a, b, 5, 6, neither illustrate nor discuss the hinge features of the species. Parker (1949) p. 585, states that the hinges of specimens, identical in external form with the holotype, are the same as the hinge of *C. mariae* "except for slightly wider angles between teeth and longer anterior cardinals". Parker's illustration of the hinge of *C. fernandoensis* is unsatisfactory for comparison. The hinge of *C. mariae* illustrated, Parker (1949) pl. 92, figs. 7, 10, is very close to the hinge of the material here referred to *C. fernandoensis*. The two species of *Chione* found in the Castaic formation can be easily separated in the following ways: *C. fernandoensis* has a broad flat escutcheon and sculpture consisting of widely spaced concentric rounded ribs, whereas *C. elsmerensis* has a poorly defined narrow escutcheon and sculpture in which the concentric element is more prominent than the radial. However, the concentric folds are more closely spaced and lamellar and tend to give a more reticulated appearance to the exterior of the shell. The teeth of *C. fernandoensis* are smooth, whereas the right posterior and right middle and left middle cardinal teeth of *C. elsmerensis* are grooved. The position of ligament attachment in the two species is very different. In *C. fernandoensis*, the hinge plate is narrow, and the ligament attachment is close to the shell margin; in *C. elsmerensis* the hinge plate is wide and the ligament attachment is more deeply placed on the plate.

Chione fernandoensis has been found only in the southern part of the Castaic formation outcrop area, at localities 1627, 1663, and 1849, in fine-grained sandstone. Articulated specimens occur at localities 1627 and 1663, and, in general, the material is little broken or weathered, although the exterior is eroded enough that it is difficult to determine the original sculpture. The distribution of *C. fernandoensis* does not overlap with that of *C. elsmerensis*. *C. fernandoensis* has been found only in fine-grained sandstone. The specimens from localities 1627 and 1663 were probably buried where they lived, considering that they are articulated, closely shut, unworn, and that the ligament is still well preserved in most of them. The two species of *Chione* thus differ in geographical distribution, state of preservation, the type of sediment in which they occur, and in gross ecologic setting- *C. elsmerensis* being within an embayment, whereas *C. fernandoensis* occurs along what was an open coast.

C. fernandoensis has been reported from lower Pliocene, middle Pliocene and lower Pleistocene sediments of the Transverse Ranges. Thus, the occurrence of the species in the Castaic formation is within the area in which it has been previously found, but represents an extension of its stratigraphic range into upper Miocene sediments.

Chione (Securella) elsmerensis English

Plate 20, Figure 5.

Chione elsmerensis English 1914, Univ. Calif. Publ. Geol. Sci., v. 8, p. 214, pl. 23, fig. 1.

Securella elsmerensis (English) Parker, 1949, Jour. Paleontology, v. 23, p. 590, pl. 93, fig. 14, 16; pl. 94, fig. 9.

Shells small to medium size, equivalve, inequilateral, ovate sub-trigonal, outline rounded. Sculpture varies with degree of weathering; no really fresh, well-preserved sculpture seen among specimens; concentric more prominent than radial sculpture, but from the material at hand, it is impossible to determine what the sculpture was initially like. Escutcheon long, narrow, not sharply defined; lunule lanceolate, bordered by impressed line. Posterior part of hinge plate broad, ligament attachment area deeply seated between valves. Three cardinal teeth in each valve, no lateral teeth. Right valve: 1 and 3b bifid, posterior part of 1 larger than anterior part, 3a small; left valve: 2b bifid, posterior part of 2b larger than anterior part. None of the specimens are well enough preserved to be accurately measured. The approximate average dimensions in mm. are: Long. 23, Alt. 17, Diam. of single valve 5.

C. elsmerensis has been found in the Castaic formation at localities 231, 232, 233, 279, 1670, B-4, 2077, 2081, 2093, 2096, 2097, 2098, 9-8-1, and 2104. No articulated specimens have been found. Many of the shells were broken before burial but were not greatly worn or rounded. This species occurs characteristically in pebbly sandstone and pebble conglomerate. It has been found most commonly in sediments deposited within one-half mile from the then-existing shore line. The material is, in general, more or less weathered, so that the exact nature of the sculpture is in doubt. Other features of the shells are satisfactorily preserved.

Left valves are much more abundant than right valves in the Castaic Canyon area. The result of studies by Lever (1958) would explain the relative abundance of left valves by the sorting action of currents below the littoral zone. Along the Castaic formation shore, which trended approximately north, a longshore current from the north would have sorted out left valves and transported them on to the beach. Conversely, a longshore current from the south would have tended to sort out right valves, leaving behind the left valves below the effective wave base. Thus, the preponderance of left valves of Chione in the Castaic formation can be interpreted in two ways, depending upon whether the deposit represents littoral or sublittoral accumulation. In support of a sublittoral deposit, the littoral segregation would be more likely to be destroyed by the rough abrasive wave action. If the shells represent a littoral deposit, the sublittoral one should be found basinward, but is not. The specimens are associated with Turritella, which indicates deeper water than does Crassostrea, which is represented by abundant fragments with the Chione, but by whole shells nearer the basal contact and the contemporaneous shore. Concluding that the predominance of left valves represents the lag from current sorting, the direction of longshore transport was northwards.

According to Parker (1949) p. 579, Securella is a North Pacific group first recorded from the upper Oligocene of Alaska, Washington and northern California. Its occurrence in the Castaic formation is at the southern limit of its known geographical range. The group appears to have become extinct during the late Pliocene. C. elsmerensis has been previously reported from the lower

Pliocene sediments of Elsmere Canyon, and from the lower Pliocene Jacalitos formation of the San Joaquin Valley. Thus, the Castaic occurrence is an extension of the stratigraphic range of the species to late Miocene.

Spisula albaria (Conrad)

Plate 20, Figures 1, 2.

Mactra albaria Conrad, 1848, Am. Jour. Science, ser. 2, v. 5, p. 432, fig. 4.

Spisula albaria (Conrad), Packard, 1916, Univ. Calif. Publ. Geol. Sci., v. 9, p. 290, pl. 23, fig. 5, pl. 24, fig. 1, pl. 25, figs. 1-8.

Spisula (*Mactromeris*) *albaria* (Conrad), Weaver, 1942, Univ. Wash. Publ. Geol., v. 5, p. 239, pl. 57, figs. 5, 10.

Shell medium size, equivalve, inequilateral, trigonal, thick; beak prosogyrous, prominent, slightly anterior of center. Dorsal areas broad; lunule and escutcheon not circumscribed, lunule depressed so that anterior dorsal margin concave. Posterior margin more broadly curved than anterior margin. Sculpture of strong growth lines. Chondrophore deep, inclines down and back obliquely under beak. Cardinal teeth large. Right anterior cardinal short, nearly parallel to shell margin, joined to margin at dorsal end; right posterior cardinal long, thinner than anterior cardinal, extends to ventral edge of hinge plate. Right anterior lateral parallel to, and in line with, anterior cardinal. Rest of dentition not preserved.

Dimensions in mm.:

Long.	70	62
Alt.	53	40
Diam.	20*	18*
Thickness	3	1.5

*Diameter of single valve.

The specimens agree well with illustrations of *S. albaria*. *S. abscissa* is less elongate and more equilateral than *S. albaria* in general, although Packard (1916) pl. 24, fig. 1, illustrates a specimen of *albaria* that is shaped very much like *abscissa*. *Spisula catilliformis*, middle Miocene to Recent, is much larger than *S. albaria*, is relatively thinner, and possesses a right anterior lateral which is less nearly parallel to the adjacent shell margin. *Spisula albaria* is variable in shape both from locality to locality and within a locality. Packard (1916) p. 291, states, however, that dentition remains constant.

Spisula albaria has been found only at locality 1849 in the Castaic formation. Specimens are well preserved but disarticulated.

Spisula is found along the open coast in the inner sublittoral zone, most commonly between 5 and 10 fathoms below low tide. Specimens of the genus are found on mud, sand, or gravel substrate.

Apolymetis biangulata (Carpenter)

Plate 20, Figures 3a, b.

Tellina alta Conrad, 1837, Acad. Nat. Sci. Phila. Jour. v. 7, p. 258.

Apolymetis biangulata (Carpenter), Grant IV and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 363, pl. 20, fig. 16.

Apolymetis biangulata (Carpenter), Palmer, 1958, Geol. Soc. America Mem. 67, p. 107, pl. 14, fig. 5.

Shell medium size, ovate, moderately thin; beak slightly anterior of middle of shell, only slightly prosogyrous. Sculpture poorly preserved, of weak radial lines and concentric growth lines. The growth lines bend sharply at the posterior fold which runs from behind beak obliquely down and back. Dentition: Hinge plate broad, ligament area bordered by slight ridge. Two cardinal teeth, no lateral teeth, posterior cardinal slightly larger than anterior. Long. about 55 mm.; Alt., about 40 mm.; Diameter of right valve about 14 mm.

This specimen agrees with the original description and with recent specimens of A. biangulata from Corona Del Mar except that the hinge plate is considerably broader and heavier than in recent specimens. In terms of hinge plate size, the late Miocene Castaic formation specimen is similar to specimens from the Pleistocene San Pedro formation (C.I.T. locality 265) so the decrease in hinge plate size relative to shell size occurred post-Pleistocene.

Apolymetis biangulata is rare in the Castaic formation. One whole individual has been found at locality 1627 in fine-to very-fine sandstone, and one right valve has been found at locality 2093 in poorly-sorted, pebbly coarse-grained sandstone.

From the published occurrences of this species, the distributional limits appear to have moved southward since early Miocene time. During late Miocene, its known distribution was from central California south to these Castaic formation localities; the latter representing a southward extension of the distribution. The early Miocene distribution (Loel and Corey (1932)) was from the Santa Cruz Mountains to the Santa Monica Mountains. The present distribution is from Santa Barbara to San Quintin, Baja California.

The species occurs both in bays and open ocean in shallow water littorally and sublittorally to about 40 fms. and most commonly on a substrate of sand or gravel. Burch (1946) part 1, no. 43, p. 10, notes that it has collected in upper Newport Bay, in fine sand in Mugu Bay, in Mission Bay, and in the Estero of Todos Santos Bay south of Ensenada, Baja California. G. E. MacGinitie, personal communication (1959) believes that there is no salinity gradient within Newport Bay. The bay habitat may not necessarily mean that it can live in water of abnormal or fluctuating salinity.

Macoma sp.

Three broken valves have been found at locality 1849.

Shell medium size, compressed, oval; beak small, central, slightly opithsogyrous. Margins not preserved. Shell smooth with only faint growth lines. Posterior fold broadly curved, not sharp or angular. Lateral teeth absent; a single bifid cardinal tooth in left valve; two cardinal teeth in right valve. No lunule or escutcheon. Approximate dimensions in mm.:

Long.	70	50
Alt.	50	40
Diam. (of single valve)	15	12

The material described here was referred by Wright (1951) p. 11, 28, to two different genera and species--- Macoma indentata Carpenter, and Cryptomya cf. ovalis Conrad. Wright had not prepared the hinge of the "Cryptomya"sufficiently to expose the hinge; the dentition is that of Macoma. The identification of Macoma indentata is based on a single broken specimen. The shape can not be determined, and again Wright had not prepared the hinge. There is not sufficient material well enough preserved to be identified specifically.

The species has been found in the Castaic formation only at locality 1849. It is in fine-grained sandstone near the base of the formation. Associated with it are a variety of other mollusks.

Macoma? sp.

Shell small, thin, equivalve, slightly inequilateral, compressed, elongate-oval; margins smoothly rounded. Sculpture of faint growth lines. Lateral teeth absent or poorly developed, two small cardinal teeth. Hinge line short. Average dimensions in mm.:
Long. 15, Alt. 10, Diam. 3.

Dentition and general shape are suggestive of *Macoma*; however, hinge features are poorly preserved, and so the identification is only tentative.

This species occurs widely through the Castaic formation. It has been found only in mudstone. If the sediment is weathered, only molds are found; specimens with original shell material are found only in freshly exposed sediments. The species has been found at localities 277, 7-6-8, 7-6-9, 7-11-24, 7-11-33, 9-4-4, 7-11-27, B-5-B, 7-11-19, 7-7-12, H-5, 232, 277, and 1626.

Sanguinolaria cf. S. nuttallii Conrad

Plate 20, Figure 7, Plate 21, Figure 1.

Sanguinolaria nuttallii Conrad, 1837, Acad. Nat. Sci. Phila. Jour., v. 7, p. 230, pl. 17, fig. 6.

Sanguinolaria nuttallii Conrad, Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 383, pl. 20, figs. 15a, b.

Shell medium size, ovate; margins smoothly rounded; beak small, approximately central. Shell exterior smooth or with faint growth lines, no posterior fold. Dentition consists of two cardinal teeth in each valve. The right posterior cardinal is bifid, other features of dentition not preserved. A groove separates beak and teeth from prominent nymph plate which forms a ridge externally above the shell margin. Hinge plate broad and flat both anterior and posterior of dentition.

Dimensions in mm. of right valve (approximate):
Long. 50, Alt. 38, Diam. 8, Thickness 3.

Sanguinolaria alata Gabb, as described and figured by Clark (1915) p. 476, pl. 61, fig. 14, pl. 62, fig. 4, differs from the specimens in having a more prominent beak, a larger nymph plate with a longitudinal groove on it, and a more pronounced sculpture. S. nuttallii Conrad closely resembles the two specimens found in the Castaic formation. It is larger, but with so small a sample, size differences can not be diagnostic. The only real difference between the specimens and S. nuttallii is that the anterior hinge plate of S. nuttallii is much less broad. The material from the Castaic formation belongs to a closely related but different species.

Sanguinolaria has been found in the Castaic forma- only at locality 2093. There it occurs as single valves and fragments in pebbly coarse-grained sandstone at the base of the formation.

The range of S. nuttallii is from late Miocene to Recent. This species is found living buried 6 to 8 inches deep in mud or loose sand in estuaries, sand flats, or in the open ocean. It occurs intertidally and to depths of 7 fms. The Castaic formation species is similar enough to S. nuttallii that the two probably required similar ecological conditions. S. nuttallii is found in both bays and the open ocean, being, however, most typically a bay form. This is in agreement with the distribution of Sanguinolaria in the Castaic formation, and perhaps partly explains its absence from localities south of Soledad Canyon where suitable substrate was much more abundant.

The bays in which S. nuttallii is found at present have good connection with the ocean and contain water of normal marine salinity.

Solen perrini Clark

Plate 20, Figure 4.

Solen perrini Clark, 1915, Univ. Calif. Publ. Geol. Sci., V. 8, p. 477, pl. 44, fig. 2.

Valves elongate, dorsal and ventral margins parallel, straight; posterior and anterior edges bluntly rounded. Hinge features or position not preserved; sculpture of very faint growth lines, surface nearly smooth. Approximate dimensions in mm. of single valve:

Long. at least 100, Alt. 20-25, Diam. 5-8, Thickness 0.5.

Clark (1915) p. 477, separated S. perrini from S. sicarius Conrad on the bases of the straightness of margins and the presence or absence of a flexure of the anterior shell end. The specimens are referred to S. perrini because the dorsal and ventral margins are straight, not curved, and a slight flexure is seen at the end of one fragment. A distinction cannot be made on the basis of roundedness of the anterior ends of the valves. Grant and Gale (1931) p. 386, consider S. perrini to be only a variety of S. sicarius. Clark (1915) p. 478, considers perrini to be of greater taxonomic rank and says that most of the upper Miocene and Pliocene Solen of California belong in it. The Castaic formation material is too fragmentary to shed any light on the problem, except that it is more evidence for the late Miocene existence of S. perrini as a distinct form.

S. perrini is abundant at locality 1849 as fragments of disarticulated valves. It is in a coarse-grained sandstone within a few feet of the basal contact of the formation. Although the fossils are in a sediment that might well have been a suitable substrate in which to live, there has clearly been some reworking of the shells before deposition and burial. Therefore, the presence of

Solen gives no indication of the water depth at locality 1849. At locality 2069, a single fragmentary specimen of an articulated *S. perrini* has been found. It is in poorly sorted pebble conglomerate. Thus, although articulated, this specimen too has been reworked because it is in a sediment in which it would probably not have lived. Fragments of the species have been found at locality 1627.

Present-day species of *Solen* live at depths of less than about 20 fathoms, burrowing in sand or mud. They live in bays and estuaries or along the open coast. They have been found where the salinity of the water was as low as 25^{o}/oo.

Corbula (Caryocorbula) luteola Carpenter

Plate 19, Figures 3, 4.

Corbula luteola Carpenter, 1864, British Assoc. Adv. Sci. Rept. for 1863, p. 637.

Corbula (Lentidium) luteola Carpenter, Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 421, pl. 19, figs. 2, 7.

Corbula (Caryocorbula) luteola Carpenter, Keen, 1958, Sea shells of Tropical West America: Stanford, Stanford Univ. Press, p. 209, fig. 525.

Corbula (Lentidium) Luteola Carpenter, Palmer, 1958, Geol. Soc. America Mem. 76, p. 117, pl. 15, figs. 13-18.

Shell small, trigonal, elongate; beak not prominent, slightly anterior of center. Anterior end of shell rounded, posterior end truncate; posterior dorsal margin straight; fold extends from umbo to posterior ventral margin. Sculpture of fine growth lines which change direction sharply at posterior fold. Left hinge contains indentation in shell margin below and slightly in front of beak; rounded extension of margin present just behind indentation.

Dimensions in mm.:

Long.	7	-
Alt.	4	4
Diam. (of left valve)	2	2

The material from the Castaic formation is referred to C. luteola, and not to other species, on the basis of shape, sculpture and dentition. The specimens are distinguished by their elongate shape, simple sculpture, and the nature of the posterior truncation. No other described Tertiary or Recent form matches in all respects. C. luteola is reported to range from Late Miocene to the present time, Grant and Gale, 1931, p. 422, the previously reported late Miocene occurrence being from a locality near Bakersfield.

No Pliocene occurrences have been reported. Its published Pleistocene and Recent distribution is from southern and central California to the Gulf of California and La Paz, Baja California, respectively. Thus, little is known of this species concerning changes in its distribution during late Cenozoic time. Grant and Gale (1931, p. 421), and Keen (1958, p. 209), both give the average size of *C. luteola* as about 30 percent greater than that of the specimens from the Castaic formation, although Grant and Gale (1931, p. 421) state that the size is variable. The sample is too small to indicate whether this size difference is significant. Arnold (1903, p. 181) collected specimens from the Pleistocene San Pedro formation which are intermediate in size between these late Miocene specimens and the Recent specimens. Without more extensive collections, size trends through time can be neither proved nor disproved.

C. luteola has been found in the Castaic formation only at locality 2093. It is in calcareous medium-grained sandstone which is interbedded with pebbly sandstone and conglomerate. These sediments were deposited within several hundred feet of the shore line.

Neither of the specimens show any evidence of abrasion or transportation; both are single valves.

At the present, *C. luteola* is found in shallow water of the open ocean intertidally and to depths of 25 fms. on a rocky bottom. Keen (1958, p. 208) states that "most specimens (of the family Corbulidae) are to be found intertidally clinging by byssus under rocks and among gravels."

Panope generosa (Gould)

Mya abrupta Conrad, 1849, U. S. Exploring Expedition (Wilkes), v. 10, p. 723, Geol. Atlas, pl. 17, fig. 5.

Panopaea generosa Gould, 1850, Boston Soc. Nat. History, v. 3, p. 215.

Panope generosa Gould, Weaver, 1942, Univ. Wash. Publ. Geol., v. 5, p. 262, pl. 60, figs. 2, 4.

Shell large, elongate, ventricose, more or less rectangular, inequilateral, equivalve; hinge slightly anterior of center; ends of valves bluntly rounded, posterior margins flare out, widely gaping. Sculpture of coarse, irregular, concentric, rounded, undulose ribs. Dentition not exposed.

Dimensions in mm. of two specimens:

Locality	1627	1849
Long.	100	ca.120
Alt.	65	65
Diam.	40	45

A number of middle and late Tertiary species of Panope have been described which differ from one another primarily in size and shape. Grant and Gale (1931, p. 425) suggest that since this genus burrows in sediment, the shell may vary considerably depending on the nature of the substrate. No quantitative data on this subject have been published; the collections from the Castaic formation are too small, and the specimens too fragmentary to determine variability of the species within a population or between localities. MacGinitie (1939) has noticed that Schizothaerus nuttallii, also a burrower, varies considerably in size and shape in substrates of different consistency and texture. The same seems likely for Panope, so that the status of the several similar species might well be reviewed. In the absence of such review of the genus, P. generosa is used in a broad sense for the identification of the Castaic material.

Panope specimens are found only in the southern part of the outcrop area of the Castaic formation. At locality 1849 they occur in medium-grained sandstone deposited within a few feet of the basal unconformity. Most of the specimens are articulated and may well have been living where buried. A single articulated specimen has been found at locality 1627 occurring in fine-grained sandstone overlying poorly consolidated basal conglomerate. This specimen, too, may well have been buried and preserved without being transported. At locality 2069 a single articulated specimen has been found in living position, within Mint Canyon sandstone, a few inches below the angular unconformity at the base of the Castaic formation. This indicates two things: 1. The sandstone which is now moderately consolidated must have been much less so when it was overlapped by the Castaic seas. Probably the Mint Canyon sediments, in general, were poorly consolidated then---they had only been deposited relatively recently themselves, and also there are few clasts of Mint Canyon origin within the Castaic formation. 2. The basal Castaic sediment consists of cobble-pebble conglomerate containing fragments of Panope. This would not have been a suitable substrate for the individual burrowing into the Mint Canyon sand. Therefore, in this locality, if any sediment were initially deposited as the sea encroached over the land, it was fine-grained, fairly well-sorted sand. P. generosa burrowed within this sediment in much the same position as they have been found at localities 1627 and 1849. Some individuals burrowed down into the underlying Mint Canyon sediments where they were preserved when the loose Castaic sand, including inhabitants, was swept away, and conglomerate, containing fragments of Panope, was deposited. An alternative supposition would be that there was originally no sediment present at all and that the Panope larva settled and burrowed directly into the soft Mint Canyon sediment. This is equally probable. The important point is that, in either case, the conglomerate was not deposited for some time after the area was flooded. It does not represent a winnowing or reworking by the transgressing sea. Higher in the section, at locality 1663, in pebbly sandstone, very rare fragments of Panope are found. These are probably introduced, considering their fragmentary nature, and considering that this would not be an ideal substrate in which for them to live.

The geologic range of P. generosa is Miocene to Recent. It has been found in the Coast Ranges from Washington to Baja California and in the Imperial formation of the Colorado Desert. Its occurrence in the Castaic formation lies at the southern limit of its known late Miocene distribution. Its recent distribution is from Washington to Baja California.

Recent P. generosa are found in bays, estuaries, and the open ocean, in water of normal salinity. It commonly burrows deeply in loose mud or sand at water depths as great as 25 fms.

Pholadidae

Plate 21, Figure 2.

Burrowing pelecypods are found in oyster shells at many localities throughout the Castaic formation, particularly in the northern part of the outcrop area. They are found most commonly in shells that are broken and worn, but also in thick articulated shells.

Shell elongate, inflated, equivalve, thin. Longitude about 20 mm., altitude and diameter about 8 mm. Nothing else is known of the shells, which are thin, poorly preserved, and imbedded in very well cemented pebbly sandstone. The holes bored are about 10 mm. in diameter. Most are lined with a variable number of carbonate layers. The lining generally is not of uniform thickness around a burrow.

At locality 2069, a rounded tuff pebble, probably derived from tuffaceous sediments of the Mint Canyon formation, is pitted by several shallow borings about 3 mm. in diameter. The borings resemble those made by Recent pholads.

Periploma cf. P. discus Stearns

Plate 20, Figures 8a, b, c.

Periploma discus Stearns, 1890, U. S. Nat. Mus. Proc., v. 13, p. 222, pl. 16, figs. 1, 2.

Shell medium size, oval, inequilateral, inequivalve; umbo of right valve higher than that of left valve; diameters of the two valves approximately equal. Anterior dorsal margin of shell slopes downward gradually from umbo; posterior dorsal margin extends horizontally at a level slightly below beak, then curves downward sharply at the dorsal posterior corner (at which the shell may be slightly gaping). Anterior end of shell flexed slightly to the left; posterior end to the right. Shell thin, subnacreous, with fine concentric growth lines. Teeth lacking; a chondrophore extends down and forward from slightly behind the beak. The chondrophore is braced by a fine ridge on the interior of the shell which extends from the base of the chondrophore down and backwards for a short distance. No lithodesma found.

Dimensions, in mm.:

Alt.	20	24	17
Long.	30		25
Diam.	10	10	

Except for a small fragment of one valve, all specimens are molds. The hinge description is based on internal molds of articulated shells. Shell material is preserved only in unweathered freshly exposed rock.

Buffington (1947) considered this material to represent a new species. However, he described the holotype as a natural cast of an external mold, whereas it is actually an internal mold. The material is not sufficiently diagnostic to be described as a new species. It most closely resembles P. discus Stearns, which occurs presently from Monterey, California, to El Salvador, and has been reported from Pliocene sediments in downtown Los Angeles, Woodring (1938, p. 57). The shape of the dorsal margin of the Castaic formation specimens is the same as that of *P. discus*, and different from that of any other described *Periploma* from the west coast of North America. The specimens also are similar to *P. discus* in having only a short buttress beneath and behind the chondrophore, in having the beak position more central, and in being less inequivalve than other Pacific Coast *Periploma*. The specimens differ from P. *discus* in only one characteristic-they are oval rather than nearly circular.

Periploma cf. *P. discus* is found in the Castaic formation only at locality 1671. It occurs in moderately well-sorted, fine-grained sandstone. Most of the specimens are articulated.

The present habitat of *P. discus* is on mud flats and in shallow water to depths of at least 5 fms.

Scaphopoda

Dentalium sp.

Plate 29, Figure 4.

Shell medium size, slightly curved, features of either extremity not preserved, sculpture of 12 ribs, interspaces wider than ribs, ribs rounded; no finer ribs intercalated towards the anterior end of the shell, the 12 ribs are strongly developed from one end of the shell to the other. Length of shell about 30 mm.; anterior diameter 3 mm., posterior diameter about 1.5 mm., wall thickness about 0.3 mm., maximum perpendicular distance from the concave side of the shell to a line connecting the two ends of the shell on that side, 1 mm.

The sculpture of this species is different than that of any species previously described. All those species that have about 12 ribs have a variable number from one end of the shell to the other, adding new ribs between the old as the shell becomes longer.

Dentalium has been found only in the Dry Canyon-Haskell Canyon area, at localities 232 and 1670. The specimens occurs in pebble-granule sandstone containing, in addition, much fragmental molluscan material.

The genus Dentalium is widely distributed in tropical and temperate oceans at the present time. It is represented throughout the Cenozoic Era in sediments of the west North American Coast. It is a strictly marine group, living for the most part in clean sand, avoiding mud with much decomposing matter. Few species of the group are littoral; different species of the genus occurring in water a few to over 1000 fathoms deep. Thus the presence of a species of Dentalium tells little about the depth of water. It is an indication that water circulation was probably not restricted. The occurrence of the fossils in coarse, poorly-sorted sediments suggests that they had been transported before burial.

Brachiopoda

Terebratalia occidentalis Dall
Plate 30, Figures 3, 4.

Terebratalia occidentalis Dall, 1871, Calif. Acad. Sci. Proc., v. 4, p. 182, pl. 1, fig. 7.

Terebratalia occidentalis Dall, Hertlein and Grant, 1944, Univ. Calif. Los Angeles Publ. Math. and Phys. Sci., v. 3, p. 127.

Shell medium size, generally wider than long, more or less sulcate with sulcus on pedicle valve, fold on brachial valve. The shape and sculpture of the specimens are variable. Shells vary in sculpture from nearly smooth individuals only faintly sulcate to individuals with clearly defined fold and sulcus and numerous distinct sharp radial ribs over the whole shell, fold and sulcus included. Shells range in shape from broad and short to equant to elongate oblique.

Dimensions in mm.:

Locality	1663						231					1670	
Length	27	29	15	35	38	23	34	23	20	37	19	26	28
Width	36	35	25	40	39	30	34	22	22	32	22	26	27

The species has been found at localities 1663, 1624, 231, 233, and 1670. In general, the specimens from 1663 and 1670 are more strongly ribbed; those from localities 231 and 233 are smoother and less broad. The range of variability includes forms that could be identified as *T. occidentalis*, *T. obsoleta*, *T. arnoldi*, and *Miogryphus willetti*. However, Mattox (1955) has shown that similar variability is present within a single population of living *T. occidentalis*. The variability is probably due to micro-environmental differences. When these differences become known they can perhaps be applied to the Castaic formation to explain the general segregation of different forms to different localities.

Most of the specimens are articulated. All occur in coarse to pebbly sandstone.

The range of occidentalis is Oligocene to Recent. The late Miocene distribution is Oregon to southern California; the Pliocene distribution, central and southern California; the Recent, San Francisco to Cape San Lucas, Baja California. Living specimens are found in the open ocean at depths of 30 to 120 fms., but most commonly, at depths of 30 to 50 fms. Those living off the northeast shore of Catalina Island occur on a substrate of rock and gravel with patches of sand and sandy mud. The temperature at which they live there is 10-12 C. with little seasonal fluctuation. They occur singly or in clusters, attached to one another.

Echinodermata

Astrodapsis cf. A. fernandoensis Pack

Plate 30, Figures 1, 2.

Astrodapsis fernandoensis Pack, 1908, Univ. Calif. Publ. Geol. Sci.; v. 5, p. 279, pl. 24, figs. 3, 4.

Astrodapsis fernandoensis Pack, Grant and Hertlein, 1938 Univ. Calif. Los Angeles Publ. Math. and Phys. Sci., v. 2, p. 72, pl. 25, figs. 4, 5.

Test small, sub-circular to oval, thin, margins not thick, posterior margin slightly pointed, lower surface flat, upper surface slightly convex. Apical system approximately central. Ambulacral areas broaden rapidly from apex to one-half the distance to the test margin; then broaden gradually to shell margin; numerous large tubercles set in well defined broad pits on the upper and lower surfaces. Spines are one-half to three fourths mm. in diameter, up to five mm. in length, are faintly ribbed longitudinally reflecting the fascicle-like internal structure. The spine ends are not well preserved. Large tests are about 40 mm. long, 30 mm. wide, 7 mm. thick.

Astrodapsis occurs throughout the northern and central part of the Castaic formation, but specimens are in general poorly preserved. Only molds have been found at locality 1671, but surface details are well preserved on these. Fragments and whole tests from localities 232, 2084, 2087, 2092, 2100, and 2070 indicate the shape and size of the species, but surface features are poorly preserved. In addition to these occurrences of tests, at some of which spines have also been found spines have been found at localities 2074, 2075, 2102, 2073, 2085, 2093, 2103, 2083, 2086, 1670, 2095, 2091, 2099, and 2105.

Astrodapsis specimens collected by geologists in the past from the Castaic formation in the Haskell Canyon-Dry

Canyon area have been compared by them both with *A. tumidus* and with *A. fernandoensis*. In this particular study, however, all the specimens sufficiently well preserved appear to be closely similar to *A. fernandoensis*. They have been compared to *fernandoensis* rather than *tumidus* on the basis of the large tubercles; the relatively large, oval size; the slightly pointed posterior margin; and the relatively flat, uninflated test. Positive specific identification is not made because general preservation is not sufficiently good.

Although the genus *Astrodapsis* is extinct, some evidence of its habitat can be gained from noting the sediments in which it is found. Complete tests and large fragments of tests have been found only in fine to coarse well-sorted sandstone beds. At locality 2084 fragments are abundant, but the sandstone is less well sorted and contains scattered small pebbles. Spines are found in a variety of sediments, including very poorly sorted pebble-cobble conglomerate.

Tests have been found at relatively few localities in the formation, but where found, they are common or abundant. Thus, it would seem that in several respects the *Astrodapsis* of the Castaic formation had habits similar to the present day *Dendraster* of the California Coast; they lived in colonies, in a fine-grained, well-sorted substrate.

The stratigraphic range and distribution of *Astrodapsis* is middle Miocene to lower Pliocene, in California. Those of *A. fernandoensis* are lower Pliocene of southern California; *A. tumidus*, middle Delmontian or upper Miocene of central and southern California.

Cidarid spines

Plate 30, Figures 6, 7.

Large echinoid spines have been found at localities 1670, 2094, 2105, and 2069. Two types of spines are represented. Those from locality 2069 are characterized by few large nodes in annular clusters. The spines from the other localities are alike, and have many, smaller spinose nodes arranged in longitudinal rows, but in no transverse pattern. Both types of spines are 3 to 4 mm. in diameter. All are incomplete; the length of the longest is 27 mm. They are cylindrical.

Bryozoa

Encrusting bryozoa have been found at two localities. At locality 1663, they line part of the interior of the body whorl of a large gastropod, probably *Ficus* (*Trophosycon*). At locality 2076 they cover the inside of a large *Lyropecten crassicardo* valve and several gastropod shells within the *Lyropecten*. Impressions of the other valve indicate that the pelecypod was articulated, contained several gastropod shells, and a flourishing bryozoan colony before being filled with coarse sand. The bryozoa on the gastropods are several zooecia thick.

Arthropoda

Barnacles

Plate 30, Figure 5.

Barnacles have been found at localities 2074, 2082, 2104, 2105, 1663, and 2069. They consist of: 2074, a single individual, plates together, but somewhat broken, in a pebbly very coarse sandstone, diameter about 10 mm., height about 10 mm.; 2082, two individuals side by side, connected at edge of base, plates together, in a pebble conglomerate, diameter 20 mm., height 20 mm.; 2104, and 2105, a few small fragments scattered in pebbly sandstone; 1663, a single minute whole individual attached to an articulated Glycymeris grewingki, diameter and height about 2 mm.; 2069, a single imcomplete compartment, probably a rostrum, incomplete height and width 4 mm.. No opercular plates were found. From the internal structure of the compartments observed, all the individuals would seem to be Balanus. The true relations can not be known, however, until the internal structure has been studied in detail.

Vertebrate

Vertebrate remains

The following vertebrate fossils have been found in the Castaic formation:

Two shark teeth, both non-serrate; elongate, triangular. The one from locality 2093 is 24 mm. high including the base, 23 mm. wide at the base. That from locality 1663 has corresponding measurements of 21 and 17 mm.

Fish vertebra, 20 mm. long, 23 mm. in diameter, from locality 2069.

Bone fragments from localities 1663, 1670, 2069 (one foot stratigraphically above the basil, mollusk-rich horizon), and 2089.

Fish skeleton, incomplete, poorly preserved, locality 1626, length at least 40 mm.

Fish scales are common throughout the formation in the mudstones.

Borings

Borings are common in pelecypod shells throughout the formation but are most abundant in the northern part of the outcrop area. They are one-half to 1 mm. in diameter. The organism causing them is unknown, although they are not unlike the borings formed by clionid sponges. The borings are most abundant in large valves of *Crassostrea titan*, but also occur on large *Lyropecten* valves. The boring organism was active on the shells of living pelecypods. Whether it was also on loose or empty shells is not clear.

Gastropoda

Patellid gastropods

Two patellid gastropods have been found in the Castaic formation. They can not be identified, even to the family level.

Shell cap-shaped, oval in plan view, apex slightly eccentric, the specimen from locality 2081 is sculptured with radial ridges and faint growth lines. Nothing can be determined about the specimen from locality 1670 beyond the shape and size.

Dimensions in mm.:

Locality	1670	2081
Length	17	7
Width	15	6
Height	7	3

Both specimens are imbedded in coarse-grained pebbly sandstone.

Calliostoma coalingense Arnold

Plate 21, Figures 3a, b.

Calliostoma coalingensis Arnold, 1910, U. S. Geol. Survey Bull. 396, p. 83, pl. 27, fig. 7.

Calliostoma coalingense Arnold, Woodring, Stewart, and Richards, 1940, U. S. Geol. Survey Prof. Paper 195, p. 83, pl. 11, figs. 2, 3, pl. 15, figs. 15, 16.

Shell small, turbinate, nacreous. Sculpture of four primary ribs on upper surface of whorl; the upper-most rib is just below the suture, the second forms a slight shoulder, the fourth (lowest) is at the sharply curving part of whorl between side and base. Upper two primary ribs noded, lower two may or may not have been, for shell is somewhat weathered. Single secondary ribs between primaries, uppermost secondary is noded. Ribs on base of whorl equal to secondaries in size. Suture appressed. Whorl profile more flat-sided than that of the other species of Calliostoma found in the Castaic formation; the shell is almost conical in shape. Alt. about 11 mm., diam. 9 mm.

Two specimens have been found in the Castaic formation--one from locality 1849, the other from locality 2069. Both specimens are broken but have moderately well preserved sculpture.

The specimens are identified as C. coalingense rather than C. etchegoinense because nodes on ribs are very likely restricted to the upper part of the whorls rather than occurring on all the ribs. In general, however, the two species are very similar. The illustration of the type of coalingense by Arnold (1910) is not clear in detail. The Castaic formation specimens seem to more closely resemble the specimen illustrated in Woodring, Stewart, and Richards (1940, pl. 11, figs. 2, 3).

C. coalingense has been reported previously only from the Pliocene Etchegoin formation of the Coalinga-Kettleman

Hills area.

Living Calliostoma are most abundant in the littoral and inner sublittoral zones of rocky open coasts exposed to considerable wave action.

Calliostoma splendens Carpenter diabloense Clark
Plate 21, Figure 4.

Calliostoma splendens Cpr. var. diabloensis Clark, 1915, Univ. Calif. Publ. Geol. Sci., v. 8, p. 482, pl. 65, fig. 1.

Shell small, turbinate, nacreous, about six whorls. Sculpture of spiral ribs, those on the upper surface of the whorl possibly noded. Whorl profile only slightly angulated by two primary ribs which divide whorl into top, side, and basal elements; top of whorl contains three secondary ribs with single tertiaries in interspaces; side of whorl marked by four or five ribs stronger than the secondaries but slightly finer than the two primary ribs; the base of the whorl sculptured with alternating secondary and tertiary ribs. The top part of the whorl profile is nearly straight, but the whorl profile is rounded overall. Suture appressed. Aperature obliquely oval; columella smooth. Alt. 10 mm., diam. 8 mm.

A single specimen of this form has been found at locality 1849. It is moderately well preserved, imbedded in well-cemented, fine-grained sandstone. The illustrations of specimens of diabloense by Clark (1915, pl. 65, fig. 1), and Loel and Corey (1932, pl. 64, fig. 2), do not illustrate the sculptural details of the subspecies sufficiently. The description by Clark, however, fits the Castaic formation specimen very well in terms of the number, size, and distribution of the spiral ribs. The whorl profile of the Castaic formation specimen, however, is perhaps not so angulated as is that of the type specimen, tending thus towards splendens s.s. in sculpture.

C. splendens diabloense has been reported from lower Miocene (Vaqueros) sediments of southern California and from upper Miocene sediments of central California. C. splendens is found at present between Monterey, California and Guadalupe Island, Mexico. A specimen from the Pleistocene deposit of Potrero Canyon, Pacific Palisades has been compared to the species.

Living individuals of *C. splendens* are found in water 10 to 50 fms. deep on rock and shell or on kelp.

Calliostoma sp.

Plate 21, Figure 5.

Shell small, turbinate, nacreous. Sculpture of spiral ribs, coarser on side and upper part of whorl than on base. Whorl profile smoothly rounded. Suture slightly appressed. Aperture obliquely oval, columella smooth. Alt. about 10 mm., diam.8 mm.

Four specimens have been found in the Castaic formation--two at locality 1849 and two at locality 2096. None are well preserved, all being broken and weathered so that the sculpture is interpreted from the impression on inner shell layers. The specimens are found in well-cemented medium-grained sandstone.

These specimens are too poorly preserved to be identified specifically.

The genus Calliostoma is found in marine water of the littoral and inner sublittoral zones on rocks, shells, and kelp, along shores with considerable wave action.

Tegula gallina (Forbes)

Plate 21, Figures 6a, b.

Trochus (Monodonta) gallina Forbes, 1850, Zool. Soc. London Proc., p. 271, pl. 11, figs. 8a, 8b.

Tegula (Chlorostoma) gallina (Forbes), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 827, pl. 32, figs. 30, 31.

Shell medium to large, conical, nacreous, imperforate. Whorl base nearly flat, whorl side gently convex; peripheral margin sharply rounded but not keeled. Growth lines protractive at about 45° angle to shell axis. Sculpture of dark brown low retractive ridges on whorl side. The ridges are almost perpendicular to the growth lines. Suture not preserved. Aperture holostome, sub-circular, with two teeth on inner lip, the posterior tooth is larger than the anterior one.

Dimensions in mm.:

Locality	1624	2093	
Alt.	ca.20	45	40
Diam.	17	40	32

The specimens are like recent specimens of gallina from San Diego in all morphological features.

T. gallina has been found in the Castaic formation only at localities 1624 and 2093.

The species has been reported previously from Pliocene sediments of the Elsmere Canyon area and from Pleistocene sediments between Santa Monica, California and Magdalena Bay, Baja California. The Recent distribution is from San Francisco, California south to Baja California.

Living individuals are found in the rocky littoral zone along the open or protected coast.

Astraea sp.

Plate 21, Figures 7a, b, Plate 22, Figures 1, 2.

Shell medium to large, conical, about six convex whorls; apical angle 75°-80°. Periphery of body whorl is a prominent noded undulating carina; sculpture above the carina consists of two rows of nodes similar in size to those of the carina; the nodes on the lower row are more numerous and slightly smaller than those on the upper row. The upper nodes are elongate, retroactive; the number of nodes on the upper and lower rows are in the proportion 14:19, respectively, on the body whorl. Sculpture on the flattened base of the body whorl consists of a prominent noded spiral rib lying next to the carina and of almost equal strength; inside this outer noded rib, are about three finer ribs, unnoded, but crossed by thread-like growth lines. There is an arcuate depression on the planar outer surface of the columella comparable to that in *A. undosa*. Aperture ovate; opercula, found associated with the specimens but not in place, are ovate, nucleus sub-marginal near the left side of the thinner, less broadly rounded end (viewing the interior of the operculum with broad end down); the exterior of the operculum is granulose, with a single broad low spiraling ridge and a small crescentic depression spiraling out from the nucleus. Granulose texture most concentrated on the area of the slight depression. Dimensions in mm. of specimens from several localities:

Locality	2077			2069	1849			
Alt.	12	20	25	18	35	30	23	20
Diam.	15	22	31	22	39	35	23	22

Of the west North American species of *Astraea* that have been described, the Castaic formation specimens most closely resemble *Astraea* (*Pomaulax*) *gradata*. They differ from *A. gradata* however, in the following respects-- smaller, larger apical angle, more strongly nodose carina, an outer basal nodose rib, and a less angular whorl profile. In addition, the operculum of A. gradata is typical of the subgenus Pomaulax, the opercula found in the Castaic formation are not. Although the opercula from the Castaic formation were not in place within the shell aperture, there is no other species found with which they can be placed. This is the same situation as for the operculum of A. gradata that Grant and Gale described. Also, the ribbing of the umbilical area is not nearly so strong as it is in A. undosa, the type of Pomaulax. Thus, the specimens from the Castaic formation must represent a new species of a subgenus other than Pomaulax, if Pomaulax is restricted to those species having an operculum "with four strong granulose ribs radiating from the nucleus", Pilsbry (1888, p. 243). However, Keen (1958, p. 262), states that the operculum of Pomaulax is smooth-surfaced, which clearly can not apply to A. undosa. The operculum of the Castaic formation species is like that of A. undosa in shape and position of the nuclear whorl. It differs however in having two low broad ridges instead of four sharply defined ones. The umbilical area of the Castaic formation specimens resembles that of the subgenus Pachypoma, but the operculum differs in shape, position of the nucleus, and sculpture. The operculum resembles most closely the opercula of A. americana and A. cubana, both in the subgenus Astralium. The net result is that the Castaic formation species can not be placed in any of these subgenera because of conflicting characters. The opercula of turbinids would be useful in taxonomy if they were better documented and more closely correlated with the generic and subgeneric groups.

Astraea occurs in the Castaic formation at localities 1849 (abundant), 2069 (common), 1670 (rare), 1663 (rare), 1624 (rare), and 2077 (rare). The sediment is well-indurated fine-to medium-grained sandstone at 1849 and 1670, uncemented pebbly sandstone at 2069, and indurated pebble conglomerate at 2077.

Recent Astraea occur in normal marine water both along rocky outer coasts and in estuaries and embayments, littorally and to about 15 fms. most commonly, but in some cases to 50 fms. The genus is herbivarous.

Astraea? sp.

Plate 22, Figure 3.

Shell large, heavy, conical, spire moderate; suture not preserved but tangent or slightly impressed. Whorl profile slightly convex; whorl sharply carinated; whorl base flat. Spiral sculpture absent. Outer part of shell dark brown. Shell smooth except for faint protractive ribs sloping down and forward at an angle of 30° to the shell axis. Aperture not preserved, but apparently holostome; columella is callus covered and smooth. Shell not umbilicate. Diameter 31 mm., Altitude (of remains of body whorl and part of preceding whorl only) 24 mm.

A single imcomplete specimen has been found at locality 2104 in pebbly sandstone. Identification is impossible because the shell apex and most (perhaps all) of the body whorl is missing. The lack of umbilicus, the sharply keeled whorl, and the conical shape are features indicative of Astraea. If so, however, it must be referred to a species with little or no spiral sculpture, and with apparently an unsculptured whorl base, unless the base is modified before the shell of the succeeding whorl is deposited.

Arene, n. sp.

Plate 21, Figures 8a, b.

Shell small, depressed, turbinate, umbilicate; whorls approximately circular in cross-section. Sculpture of beaded spiral ribs and fine axial threads. The ten ribs on the penultimate whorl are all of about equal width except that the rib at the base of the whorl and at the top of the whorl are slightly larger. Two ribs lie along the side of the umbilicus, on the inner side of the basal rib. The inner side of the whorl does not contain an angular umbilical cord as in Architectonica. The periphery of the whorl is not carinate. Interspaces between ribs are slightly wider on the dorsal side of the whorl. The suture between body whorl and penultimate whorl is about 1/3 of the whorl height above the base of the penultimate whorl. The body whorl is missing - only a mold of part of the dorsal exterior of it is present. The whorl broke off without apparently altering the sculpture on the base of the preceding whorl. The fine axial threads connect adjacent nodes. Alt. 4 mm., Diam. 6 mm., Diam. of last whorl 2 mm. The approximate altitude and diameter of the specimen, with body whorl present, were 5.5 mm. and 8 mm., respectively.

This shell is referred to Arene for the following reasons. Architectonica differs in being depressed; the basal part of the whorl tends to be flattened with one or more broad spiral ribs; the periphery of the shell is carinate and a prominent umbilical cord is generally present. Heliacus differs, as does Architectonica, in shape, in having a more or less flattened whorl base, a carinate periphery, and an umbilical cord. The beaded spiral sculpture of Heliacus is similar to that of the specimen. Antillachelus Woodring (1928) differs in being conical and in having reticulate sculpture.

Solariella differs in lacking the prominent beading. Circulus differs in being low spired, in having a keel at the base of the body whorl, and in lacking the axial element in the sculpture. *Liotia* and *Arene* are closely related, *Arene* having been considered a subgenus of *Liotia* in the past. The two genera are distinguished on the basis of sculpture--in *Arene*, axial and spiral ribs are of about equal prominence; in *Liotia*, axial sculpture is reduced or absent. Therefore, the specimen from the Castaic formation fits into *Arene*.

Both *Liotia* and *Arene* are scarce in the Pacific Coast fossil record. *Liotia weaveri* Effinger has been described from the middle Oligocene Gries Ranch Beds of the lower Cowlitz Valley, Washington. It is a small planorbid form that bears little resemblence to the Castaic formation specimen, of for that matter, to other members of Liotidae. The only other fossil record of *Liotia* is that by Jordan (1936, p. 113). He reported *Liotia rammata* from the Pleistocene deposts of Magdalena Bay, Baja California. This species however is very different from the specimen from the Castaic formation. It has a very narrow umbilicus and much different sculpture. Among recent west Pacific Coast species of *Arene*, *winslowae*, *hindsiana* and *carinata* most closely resemble the specimen being described. Of these, *carinata* (?*Liotia carinata* Carpenter 1857, Mazatlan Catalogue p. 248, no. 313) is the least similar. Its umbilicus is narrower and its sculpture is different, consisting of spiral beaded ribs of two distinct sizes, the larger ones being restricted to the peripheral and umbilical sides of the whorl. *Arene hindsiana* differs in being more narrowly umbilicate and in having a different sculpture--a prominent peripheral keel, and greater variation in rib size. *A. winslowae* is most similar to the Castaic formation specimen--it has the same number of spiral ribs, and very similar sculpture. However, *A. winslowae* has a more elevated shell, a narrower umbilicus, and a more pronounced peripheral keel. These three Recent species are Panamic in distribution--*A. carinata* occurs in the Gulf of California; *A. hindsiana*, at Manzanillo, Mexico, and *A. winslowae*,from Nicaragua to Panama. The latter two species have been collected living under rocks at the low tide line. Only a single specimen has been found in the Castaic formation--at locality 1663. It is in a matrix of well-cemented pebbly sandstone.

Nerita sp.

Plate 23, Figures 1a, b.

Shell medium size, globose; spire very low, slightly crushed. Shell low; rapidly expanding body whorl with semicircular aperture; broad callus deposit on inner lip extends as shelf out into body whorl. Callus thickest at posterior corner of aperature. No detail preserved on callus. Outer lip probably not thickened, margin broken so no details preserved. Shell thick, with 15 to 20 coarse spiral flatly rounded ribs, narrow interspaces, coarse growth lines. Dimensions in mm.: Alt. 25, diam. 28.

A single specimen has been found at locality 2072, from the uppermost bed of a series of fossiliferous sandstones and conglomerates deposited as a tongue from the basal contact out into predominantly mudstone section within the basin. The specimen is associated with fragments of Crassostrea titan and Lyropecten crassicardo, as well as abundant carbonized plant fragments.

No post-Eocene occurrence of Nerita has been reported from California. Nerita (Ritena) scabricosta Lamarck has been reported from Pleistocene sediments of Magdalena Bay, Baja California; the present distribution of scabricosta is from the west coast of Baja California to Peru. Nerita (Theliostyla) funiculata Menke has been found in Pleistocene sediments of the Gulf of California and Magdalena Bay, Baja California. Its present distribution is from San Roque Island, Baja California to Punta Penasco, Sonora, and south to Peru, Judging from its low spire, the Castaic formation specimen is probably in the subgenus Theliostyla. It is larger and has fewer spiral ribs than the Pleistocene specimen of N. bernhardi Recluz from the Gulf of California illustrated by Durham, (1950), pl. 35, figs. 6, 9. N. bernhardi is considered synonymous with N. funiculata. It has about the same number of ribs as the middle Pliocene Nerita sp. from the Gulf of California, Durham (1950), pl. 35, fig. 5, but the sculpture differs in several other respects. The Castaic formation specimen probably represents a new species. It is not well enough preserved, however, to be described as such, nor to be surely separated from N. funiculata.

This occurrence of Nerita is the only one reported from west North American sediments younger than Eocene and older than middle Pliocene.

Living specimens of N. funiculata, probably the most closely related living species, are found intertidally on rocky shores.

Turritella cooperi Carpenter
Plate 22, Figure 4.

Turritella cooperi Carpenter 1864, Brit. Assoc. Adv. Sci. Rept. for 1863, p. 612, 655.

Turritella cooperi Carpenter, Merriam, 1941, Univ. Calif. Publ. Geol. Sci., v. 26, p. 117, pl. 33, figs. 1, 2, 3, 4; pl. 34, figs. 9, 12, 13, 14, 15, 16; pl. 35, figs. 14, 15.

Turritella cooperi Carpenter, Palmer, 1958, Geol. Soc. America Mem. 76, p. 168, pl. 20, fig. 7.

Shell medium to large, turreted, no specimens whole. Sculpture of two primary spiral ribs that divide the whorl approximately into thirds; the lower rib is a little larger than the upper one. One or two secondary ribs are between the primaries, and a secondary lies at the base of the whorl. Several tertiary ribs lie between the primaries and above the upper primary. Whorl profile straight to slightly convex; aperture more or less triangular with sharp angle at junction of side and straight basal margin. Pleural angle 13°; diam. 15 mm. alt. greater than 50 mm.

The specimens possess a sutural secondary rib at the base of the whorl which is similar to that of T. margaritana. Such a rib, however, may also be present in T. cooperi. They differ from T. margaritana in having, in most cases, only one secondary rib between the two primary ribs.

T. cooperi is found throughout the outcrop area of the formation. However, it is abundant only at locality 1849; it is common at locality 1625, and rare elsewhere. At the two localities where specimens are numerous, they are in well-sorted, fine-grained sandstone. According to Merriam (1941, p. 13), "the vast majority of fossil turritellas in the Pacific North American region are found in moderately fine to fine sandstones". Their commonness at these two localities in fine-grained sediment suggests that they were buried where they lived. At the other localities, however --1663, 1675, 1677, 279, 2077, 2096, 2098, and 2074, the specimens are in coarser, more poorly sorted sediment which is pebbly sandstone to pebble conglomerate. Their rarity (and turritellas are generally very gregarious) and their presence in coarse sediments make it likely that the individuals at these localities were transported before burial.

The previously reported distribution of T. cooperi is:
upper Miocene--central California
Pliocene--Monterey County to San Diego
Pleistocene--Ventura County to San Quintin Bay, Baja California
Recent--Monterey Bay to Scammons Lagoon, Baja California.
Thus the occurrence of the species in the Castaic formation extends the previously reported upper Miocene southern limit of distribution.

Recent specimens of T. cooperi are dredged from depths of 10 to 60 fms. The species is most commonly found in water deeper than 25 fms. It has been dredged from mud, sand, and gravel bottoms. It has been found only in the open ocean, never in bays or estuaries.

Turritella aff. T. freya Nomland
Plate 22,Figure 5.

Turritella freya Nomland, 1917, Univ. Calif. Publ. Geol. Sci., v. 10, p. 312, pl. 19, fig. 2.
Turritella freya Nomland, Merriam, 1941, Univ. Calif. Publ. Geol. Sci., v. 26, p. 124, pl. 37, figs. 14, 15.

Shells broken, specimens consist only of several whorls each, sculpture on most obliterated by weathering. Suture appressed to impressed; whorl profile shallowly convex. Pleural angle about 15°. Sculpture variable, possessing elements of both T. freya and T. vanvlecki. Five specimens have well preserved sculpture which is different on each. The five patterns are:

1. Primary median rib and basal sutural rib. Secondaries at anterior 1/8 and 3/8 and posterior 1/8. Tertiary ribs as follows: one below median primary, two between the anterior secondaries,one above the basal primary, five above the median primary and one above the secondary at posterior 1/8. Quaternary ribs on primary ribs.
2. Primary median rib. Secondary basal sutural rib and posterior 1/4 rib. Tertiary ribs as follows: three on anterior half of whorl, two between median primary and posterior 1/4 secondary, three above posterior 1/4 secondary.
3. Primary median rib. Secondary ribs at base of whorl, anterior 1/4, posterior 1/4 and 1/8. Two to three tertiary ribs between each of the primary or secondary ribs, a single tertiary rib above posterior 1/8 secondary.
4. About 11 ribs comparable in size to the secondary ribs on the other specimens. These are distributed evenly over the whorl except for a slight clustering at the center; one rib is at the base of the whorl. Between most of these ribs are single finer ribs.

5. Primary median rib. Secondary ribs at basal and upper margins of whorl and at anterior 1/4. Three ribs on posterior half of whorl are slightly smaller than secondaries,the central one, at posterior 1/4 is a little larger than the other two. Tertiary ribs in interspaces on anterior half of whorl. Basal primary with a shallow median groove. Diameter of largest whorl 11 mm.

On the basis of the more or less prominent median primary, the specimens belong in the *T. broderipiana* stock described by Merriam (1941, p. 50). They are considered closely related to *T. freya* on the basis of the general pattern of sculpture, in particular, the presence of a basal rib. They differ from *T. freya*, however, and tend toward *T. venvlecki* in that the basal rib is not so well developed as in the typical *T. freya*, and a posterior 1/4 secondary is present on some of the specimens. This differentiation of the ribs on the posterior part of the whorl is absent in the typical *T. freya* but characteristic of *T. vanvlecki*. Therefore, the specimens are close to *T. freya* but are probably transitional to *T. vanvlecki*.

Specimens have been found in the Castaic formation at localities 1849 and 2069. Those from 1849 are in a matrix of fine-grained sandstone, are common, and are associated with abundant individuals of *T. cooperi*. Only a few specimens have been found at locality 2069, in the basal, poorly consolidated, fossiliferous pebble conglomerate.

T. freya has been reported only from the upper Miocene Santa Margarita formation of the Coalinga and Santa Margarita areas. *T. vanvlecki* has been reported from middle Pliocene sediments of the Coalinga area, and from Pliocene, and perhaps upper Pliocene, sediments near El Rosario, Baja California.

The recent members of the *T. broderipiana* stock would be the living species most closely related to the fossils from the Castaic formation. Those occurring on the Pacific Coast are: *T. banksii*, *T. gonostoma*, and *T. broderipiana*. Ecological comparisons would be dangerous, however, because the relationship is only at a sub-generic level within a genus, the species of which live in a great variety of habitats. Furthermore, little is known of the ecology of these three species except that *T. banksii* has been collected living at the base of the littoral zone, and has been dredged between 6 and 9 fms., and thus presumably lives in such shallow water. These three related species are now found in Panamic waters, none occurring north of Scammons Lagoon.

Irregularly coiled gastropod

Patches and small masses of twisted tangled tubules have been found at the following localities: 279, 2093, 2083, 2105, 2099, 2081, and 2088. These are in the northern part of the outcrop area of the formation. In all cases, the fossils occur in more or less pebbly sandstone. They generally are associated with abundant fragmental pelecypods. The tubules have an outside diameter of about 1.5 mm., an inside one of about 1.2 mm. The nucleus and juvenile part of the tubules are not exposed.

These fossils are identified as irregularly coiled gastropods rather than worm tubes because transverse thin sections of the shells indicate that they are three-layered rather than two-layered, as are worm tubes.

Specimens from localities 1663 and 1670 contain tubes that are much larger than those described above. Inside diameter is 3.5 mm., outside diameter, 4.7 mm. These too appear to have more than two shell layers and are tentatively classified as gastropods. The tube exterior is smooth.

In the absence of nuclear whorls, none of the specimens can be classified beyond the class except to place them tentatively in the family Vermetidae. Of interest is the presence of two forms with distinctly different distributions.

?Bittium arnoldi Bartsch

Plate 22, Figure 6.

Bittium arnoldi Bartsch, 1911, U. S. Nat. Mus. Proc., v. 40, p. 411, pl. 56, fig. 1.

Shell small, turreted, high-spired, whorl profile flatly convex, suture appressed, whorls 5, nucleus 1-1/2 whorls. Aperature oval, anterior and outer lip not preserved. Sculpture of 4 strong spiral cords-one is just below the suture, two are close together on the center of the whorl, and the fourth is low on the whorl; on the larger whorls finer cords lie between the primary cords and below the lowest one. Closely spaced, broader, axial ribs are also present (about 20 on the penultimate whorl). The intersection of the axial and spiral ridges forms nodes elongate in the direction of the spiral cording. Alt. 15 mm., diam. 5.5 mm.

A single specimen has been found at locality 279.

The size and sculpture of this individual are very close to those of B. arnoldi. However, the aperture is poorly preserved so that the specimen can not be identified generically within the Cerithiidae.

Calyptraea filosa (Gabb)

Plate 22, Figure 7.

Trochita filosa Gabb, 1866, Geol. Surv. Calif., Paleo., v. 2, p. 15, pl. 2, figs. 25, 25a.

Calyptraea filosa (Gabb), Clark, 1915, Univ. Calif. Publ. Geol. Sci., v. 8, pl. 65, figs. 23, 24.

Shell large, patelliform, approximately circular in plan view, apex nearly central. Shape variable but in general the sides of the shell are straight in profile view. Sculpture consists of fine radial ridges and coarser, uneven, concentric growth lines. Early whorls of the spire are not filled in with shell material as in the case of Calyptraea (Trochita) sp. Maximum dimensions: Alt. 20 mm., diam. 40 mm. Apical angle is variable, being less for smaller shells than for larger ones. It averages about 95° ranging from 80° to 120°. In conjunction with this, larger shells tend to be relatively broader and lower.

The Castaic formation specimens agree in all respects with C. filosa.

The reported range of the species is Miocene and Pliocene. It is found in lower Miocene, Vaqueros, sediments between Baja California and Monterey, California. In addition to the Castaic formation occurrence, it has been reported from upper Miocene sediments of central California. Pliocene occurrences have been reported from central and southern California. There does not appear to be any Recent West North American species that possesses similar fine radial ribbing.

C. filosa has been found in the Castaic formation only at locality 1849, where it is abundant in a fossil-rich, well-sorted, medium-grained sandstone, within a few feet above the basal contact of the formation.

Calyptraea (*Trochita*) sp.

Plate 24, Figure 2.

Shell large, low, patelliform. Early whorls of spire have been filled in so that living chamber consists of 1 1/3 whorls. Surface of shell much bored so that sculpture of coarse more or less axial ridges is largely obscured. Shell margin crenulate. Diameter about 90 mm., altitude about 35 mm.

No *Calyptraea* of similar size has been reported from the Cenozoic or Recent of the west North American Coast. A number of species of *Calyptraea* found in Miocene and Pliocene sediments of California have similar coarse radial sculpture, but are much smaller--in most cases, the diameter is only 20 to 30 mm. These species are: *C. diabloensis* Clark, from the upper Miocene of central California; *C. martini* Clark, from the upper Miocene of central California; and *C. radians* Lamarck and *C. costellata*(Conrad), both reported from Miocene and Pliocene sediments of southern California. The taxonomic status of these species is not clear for two reasons. *C. costellata* is poorly described and illustrated, and fossil specimens are variable and poorly preserved because of the habitat and life history of the species. As one solution, Grant and Gale (1931, p. 795), have considered the species *radians*, *costellata*, and *martini* to be synonymous with *C. trochiformis* (Gmelin) which occurs at present from Panama to Peru. This grouping may not be valid, but certainly points out the lack of distinctive specific features. Another Recent species that belongs in this group of coarsely ribbed *Calyptraea* is *C.* (*Trochita*) *spicata* (Forbes) from the Pacific coast of southern Mexico. In some cases, this has been grouped with *C.* (*T.*) *trochiformis*. Strangely enough, no Pleistocene species of *C.* (*Trochita*) from the Pacific Coast have been reported. In summary, then, the known distribution of this group, to which the Castaic formation specimen belongs,is: Miocene-central and southern California; Pliocene-southern California; Recent-Mazatlan, Mexico to Peru. _C_. (_T_.) _spicata_ is found attached to the most surf-beaten rocks on exposed coasts (Keen, 1958, p. 312).

The only specimen found in the Castaic formation came from locality 1663. It is imbedded in a matrix of granule-pebble sandstone.

Crepidula adunca Sowerby

Plate 22, Figure 8.

Crepidula adunca Sowerby, 1825, Cat. Tankerville, Appen., p. 7.

Crepidula adunca Sowerby, Clark, 1915, Univ. Calif. Publ.Geol. Sci., v. 8, p. 422, pl. 70, fig. 6.

Shell medium size, thin-shelled, oval. Apex terminal, untwisted, situated above plane of aperture and extending as a prong beyond aperture margin. Sculpture of concentric growth lines and coarse but faint radial ribbing. Internal features not exposed. Aperture margin irregular, depending on the surface to which attached. Length 25 mm., width 18 mm., height 10 mm.

The identification of this species as adunca is based on general shape and size, and particularly upon the nature of the apex or beak.

C. adunca has been found in the Castaic formation only at localities 1624, 1849, 1663, and 9-8-1. It is common, in a fine-grained sandstone, at locality 1849. Many of the specimens are broken or badly weathered. A single specimen has been found at locality 1663.

The published range of C. adunca is Miocene to Recent. Its distribution is:

Late Miocene: Coos Bay, Oregon and central California
Pliocene: Central and southern California
Pleistocene: Ventura, California to Magdalena Bay, Baja California
Recent: British Columbia to Cape San Lucas, Baja California.

The Castaic formation occurrence thus represents the known southern limit of the late Miocene distribution of the species.

Living specimens of adunca are found in the littoral zone and in the inner sublittoral zone to a depth of 20 fms., attached to rocks or other shells in bays and along protected outer coasts. The species occurs only in marine water.

Crepidula princeps Conrad
Plate 23, Figure 3.

Crepidula princeps Conrad, 1856, Pac. R. R. Surv. Repts., v. 5, p. 326, pl. 6, figs. 52, 52a.

Crepidula princeps Conrad, Weaver, 1942, Univ. Wash. Publ. Geol., v. 5, p. 358, pl. 73, figs. 4, 13, 14.

Shell large, heavy, elongate oval; aperture smoothly rounded; apex close to side of shell, nearly terminal. Sculpture of prominent growth lines; shelf not exposed, shell high, sides nearly parallel. Length 100 mm., width 45 mm., height 40 mm.

The single large specimen from locality 1663 is a typical example of *princeps* both in size and shape. A number of smaller individuals, averaging about 20 mm. in length, are similar to *C. princeps* in shape and are considered as *Crepidula* cf. *C. princeps*. These are common at locality 1849, and rare at locality 1663 where the large specimen was found. Many of the small specimens are badly weathered and broken. A few, however, have faint indications of a radial sculpture. *C. princeps* has been described as lacking any radial sculpture, but this may be the result of large more or less worn shells having been described.

The known range of *C. princeps* is Miocene to Pleistocene. The Castaic formation occurrence is a southward extension of the Miocene distribution, the species having been previously reported from the northwest Pacific coast south to the San Francisco Bay Area. The Pliocene distribution of the species is central California south to the Ventura Basin. The Pleistocene distribution is Santa Barbara County to Los Angeles County. The Recent species, *C. grandis*, from Alaska and Siberia, is similar in size to *princeps*. Grant and Gale (1931, p. 790), consider it a direct descendent of *princeps*; however, Woodring, Bramlette and Kew (1946, p. 70) state that a close relationship is doubtful.

The large princeps, from locality 1663, is extensively bored and contains an internal incrustation of Bryozoa.

The genus is found in the littoral and inner sublittoral zones along the open coast and in bays and estuaries in both marine and brackish water.

Crepidula sp.

Plate 23, Figure 4

Shell medium size, depressed, beak approximately terminal; sculpture of radial ribs. Shell thin, oval. Nature of the shelf is not clear, but appears to extend over about half of the base, extending from side to side. Length 27 mm., width 25 mm., height 7 mm.

This form is characterized by its flat, broad shape and radial sculpture.

L. A. Wright (1951), had identified the specimen from locality 1849 as being in the subgenus Crepipatella. This is considered unlikely because the shelf on the specimen is different than that characteristic for Crepipatella (Woodring, Bramlette, and Kew, 1946, p. 71).

This species of Crepidula is rare--a single specimen has been found at locality 1849, two, at locality 1663.

The genus is found in the littoral and inner sublittoral zones along the open coast and in bays and estuaries. It is found both in marine and brackish water.

Polinices (Polinices) uber (Valenciennes)

Polinices uber (Valenciennes), Hertlein and Strong, 1955, Am. Mus. Nat. Hist. Bull., v. 107, p. 288.

Shell small, globose, smooth except for faint growth lines, umbilicate; callus on inner lip along entire side of aperture and filling in posterior aperture angle; callus partly fills in umbilicus; sutures tangential; shell profile smoothly rounded from apex to base; spire moderately low. Alt. 13 mm., diam. 9 mm.

The specimen is placed in the subgenus Polinices rather than Euspira or Neverita on the basis of the shape and amount of callus on the inner lip and in the umbilicus. The specimen is small and is probably an immature individual. Although this perhaps makes the identification a little doubtful, in addition to the fact that only a single individual has been found in the Castaic formation, the specimen agrees closely with recent P. uber in all respects except size, and agrees also with specimens from the Imperial formation of Carrizo Mountain, that Hanna (1926, p. 451) has identified as P. uber. The specimen is similar to Natica (Neverita) arnoldi Clark (considered by Grant and Gale, 1931, p. 800, more probably to belong in the sub-genus Polinices)from the San Pablo Group of central California, but is different in having tangential rather than strongly appressed sutures and in having a body whorl more than three times as high as the spire.

Polinices uber has been found in the Castaic formation only at locality 2093. The single specimen was in calcareous medium-grained sandstone deposited near the basal contact of the formation.

The Recent distribution of the species is from Scammons Lagoon, and perhaps San Diego, through the Gulf of California to Paita, Peru. It has been found in Pleistocene sediments at Magdalena Bay and in the Gulf of

California. The only Pliocene occurrence of the species is in the Imperial formation of the Colorado Desert. Thus, its presence in the Castaic formation is much farther north than any later distribution, and represents as well an extension of the age of the species.

Living individuals are found rarely intertidally, more commonly in water of less than 15 or 20 fm., and occasionally to 50 fm. The species occurs both offshore and in bays, commonly on mud or sand substrate.

Polinices (Neverita) reclusianus (Deshayes)
Plate 24, Figures 4a, b.

Natica reclusiana Deshayes, 1839, Rev. Zool. Soc. Cuv., p. 361.

Polinices (Neverita) reclusianus (Deshayes), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 800-803, text figures 13a, b, c, 14.

Shell medium size, ovoid, spire low, sutures tangential to slightly appressed, shell smooth except for faint retractive growth lines slanting down and back at angle of 40° to shell axis. Aperture subovate, acute posteriorly, straight along inner lip, smoothly rounded on outer lip and anteriorly. Outer lip simple, inner lip with heavy callus more or less filling umbilicus and extending to and filling posterior angle of aperture. Callus is broader posteriorly and in the umbilicus than it is between; a narrow shallow groove divides the umbilical lobe of callus.

As might be expected in the case of a relatively long-ranged, widely distributed species, Polinices reclusianus has been split into several varieties to segregate individuals that vary slightly in shape-primarily in spire height- and in sutural character. These varieties are probably not of any genetic significance, having, as they do in the Recent fauna, a common distribution. Although P. reclusianus is found throughout the Castaic formation and presumably, therefore in a variety of ecological situations, little variation in shell morphology is discernible, except that specimens from locality 2069 are perhaps slightly lower spired in general than individuals from other localities. In terms of the varieties described by Grant and Gale (1931, p. 800-803), most of the individuals from the Castaic formation should be referred to the variety andersoni Clark, some to the typical variety reclusianus s. s.

Well preserved, easily identified specimens have been found in the Castaic formation at localities 1849, 1663, and 2093. Specimens from localities 1670, 57-12-20, 2090, 2103, and 1627, are certainly in the subgenus *Neverita* and are probably *reclusianus*. Other specimens, from localities 279, 233, and 232, are poorly preserved, only internal molds in many cases, and although they resemble *P*. (*N*.) *reclusianus* in shape, can not be identified as such. Specimens of *reclusianus* occur in sandstone, pebbly sandstone, and pebble conglomerate.

The range of *P*. (*N*.) *reclusianus* is Oligocene to Recent. Its known distribution is:

Oligocene--central California and southern San Joaquin
Valley, California
Lower Miocene--central, southern, and Baja California
Middle Miocene--central California
Upper Miocene--central California and this occurrence in
the Soledad Basin
Pliocene--central and southern California
Pleistocene--Santa Barbara south to Baja California and
the Gulf of California.
Recent--Northern California to Tres Marias Islands.

Thus, this occurrence of the species in the Castaic formation represents a southward extension of the upper Miocene distribution. The species is so widely distributed that its presence in the Castaic formation tells little concern-the late Miocene marine climate.

Living individuals are found both along the open coast and in estuaries and lagoons. Although primarily a littoral to very shallow water species, it has been found living in water as deep as 25 fms.

Polinices cf. P. (Euspira) lewisii (Gould)
Plate 25, Figure 2.

Natica lewisii Gould, 1847, Boston Soc. Nat. Hist. Proc., v. 2, p. 239.

Polinices (Euspira) lewisii (Gould), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 804, text figs. 15a, 15b.

Shell large, thin, globose, whorls about six; sutures appressed, whorl profile smoothly convex except for a slight shoulder near the suture, the profile above the shoulder being straight or slightly convex. Surface smooth except for growth lines which are faint on the exterior of the shell but prominent within the umbilicus. Callus on inner lip thin, extending over the upper part of the umbilicus but leaving it essentially open. No evidence of plugs within the umbilicus. Average dimensions in mm. are: Alt. 40, Diam. 29. The altitude of the largest of 13 specimens is about 60 mm.

Thus, the specimens are much smaller than the largest recent specimens of P. lewisii. They differ also from lewisii in having a relatively higher spire, and a somewhat more open umbilicus. They differ from P. draconis in having a relatively higher spire and a less pronounced shoulder. In addition, umbilical lobes are present in draconis, but are not evident in lewisii nor in the Castaic formation specimens. Although they most closely resemble P. lewisii, they can not be identified as such because of the differences in shell thickness and callus deposits.

This form of Polinices has been found in the Castaic formation only at locality 1671. There it is common, occurring in medium-grained sandstone.

The range of P. lewisii is Miocene to Recent. Its distribution is:

Miocene--central California
Pliocene--central and southern California
Pleistocene--southern and Baja California
Recent--British Columbia to Scammons Lagoon, Baja California.

P. lewisii is found living both in estuaries and offshore at depths less than 25 fms.

Sinum scopulosum (Conrad)

Plate 24, Figures 3a, b.

Sigaretus scopulosus Conrad, 1849, U. S. Expl. Exped., Geol., p. 727, pl. 19, figs. 6, 6a.

Sinum scopulosum (Conrad), Weaver, 1942, Univ. Wash. Publ. Geol., v. 5, p. 349, pl. 71, figs. 12, 14, 17, 18.

Shell medium size, thin, body whorl rapidly enlarging, spire low, shell somewhat depressed, sutures appressed; aperature oblique, inner walls of spire not resorbed. Sculpture of fine spiral grooves separated by flat ribs several times as wide as the grooves. Growth lines faintly visible. Outer lip not preserved, inner lip curls over to form a narrow umbilical chink. Alt. 25 mm., diam. about 20 mm.

The material from the Castaic formation, although fragmentary, agrees in all respects with S. scopulosum.

Only two specimens have been found in the Castaic formation: a small specimen from locality 1849, the apertural half of which is not preserved, and a specimen from 279, the shape of which is evident, but much of the shell of which is missing. The specimen from 1849 is in fossiliferous medium-grained sandstone; that from 279 in granule-pebble conglomerate.

S. scopulosum ranges from Oligocene to Recent. Its distribution has been: Oligocene-Central California and possibly Washington; early Miocene (Vaqueros)-Monterey County to Ventura County; middle Miocene-Oregon; late Miocene-Central California and this occurrence in the Castaic formation; Pliocene-Washington, central and southern California; Pleistocene-southern California; Recent-Monterey, California to Todos Santos Bay, Baja California. Its occurrence in the Castaic formation constitutes a southward extension of the late Miocene distribution. The general distribution of the species during the Miocene and Pliocene epochs was from Washington to southern California, corresponding to the present distribution of Monterey to Baja California. If the actual middle to late Tertiary distribution was as suggested by the fossil record, the Castaic formation occurrence was near the southern limit of distribution.

Living specimens of *S. scopulosum* are commonly found in marine water both in the open ocean and in bays. In the San Pedro Basin, it is most abundant on bottoms 8 to 20 fms. deep.

Ficus (*Trophosycon*) *ocoyana* (Conrad)

Plate 25, Figures 1a, b, c.

Sycotopus ocoyanus Conrad, 1855, House Document no. 129, p. 19.

Ficus (*Trophosycon*) *ocoyana* (Conrad), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 743, pl. 30, figs. 3, 7, 8a, 8b, 11.

Shell large; spire low; aperture elongate, three-fourths the altitude; apical angle 115; body whorl sculptured by two spiral rows of nodes and by a cancellate arrangement of fine spiral and axial ribs. The upper row of nodes forms a prominent shoulder dividing the main part of the body whorl from the upper margin and the spire; the shell profile above this shoulder is straight to slightly concave. About nine large nodes are on the upper row. The lower row is situated one-half to one-third of the distance from the upper row to the anterior end of the shell. The nodes are similar in number and size to those of the upper row. The fine axial ribs are uniform in size, the spiral ones are of several orders, first order ribs are separated by about three second order ribs, which in turn are separated by ribs of higher order. Columella smooth, curving inwards and then outwards, forming an elongate open canal. Immature shells characterized by a more smoothly rounded profile and less well developed nodes. Dimensions in mm.:

Locality	279	1849		
Alt.	65	80	45	23
Diam.	40	45	27	14

There are several modifications of the basic *ocoyana* form represented among the specimens from the Castaic formation. The specimens from localities 1849, 279, and 1624 are similar to *ocoyana* s. s. as described by Grant and Gale (1931, p. 746). A single fragment found at locality

2069 differs from the typical form in having double-pronged nodes. Specimens from localities 1670 and 231 differ in yet another manner, being very low spired with relatively low, rounded, but more numerous, nodes on the whorl shoulder. The lower row of nodes appears to be absent, the whorl side being smooth and gently curved. Grant and Gale (1931, p. 743-749), described two new varities of *ocoyana*. The specimen from locality 2069 is assignable to the variety *contignata*, reported previously from Pliocene sediments of southern California. The form found at localities 231 and 1670 is as different from *ocoyana* s. s. as either of the varieties Grant and Gale described. However, preservation is not good--all the specimens from localities 231 and 1670 are thin-shelled and have been deformed--so they will be considered only as variants of a morphologically plastic group, and will not be given a formal varietal name. Perhaps *ocoyana* is too inclusive a species and should be split, as Grant and Gale have done. The present material is not well enough preserved for such work.

The Castaic formation material represents an extension of the range of *ocoyana* s. s. from the middle Miocene into the late Miocene age, and an extension of the range of *ocoyana* variety *contignata* from the early Pliocene back to the late Miocene age. Thus the ranges of these morphological varieties a re overlapping.

The species is common at localities 1624 and 1849. Elsewhere it is rare, with only single specimens having been found at localities 231, 279, and 2069.

Ocinebra cf. O. topangensis Arnold
Plate 26, Figure 2.

Ocinebra topangensis Arnold, 1907, U. S. Nat. Mus. Proc., v. 32, p. 530,pl. 43, fig. 4.

Shell large, spire moderately high; whorls with axial ribs culminating in strong nodes near the posterior edge of the whorl; ribs more or less reduced below the nodes; about 12 nodes on body whorl. Suture tangential. Spiral sculpture of flatly rounded ribs separated by narrower interspaces; ribs of variable thickness because of bifurcation. Aperture not preserved. Diameter 25 mm., Altitude about 50 mm.

Several incomplete specimens from locality 2105 are in coarse sandstone. Preservation is too poor for positive identification. The sculpture, however, is very like that of O. topangensis.

This species has been reported from the middle Miocene Topanga formation of the Santa Monica Mountains.

Forreria carisaensis (Anderson)

Chorus carisaensis Anderson, 1905, Calif. Acad. Sci. Proc., ser. 3, v. 2, p. 206, pl. 17, figs. 90, 91.

Forreria carisaensis (Anderson), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 727.

Shell medium to large, heavy; spire moderately high; aperture about one-half the shell length. Sculpture of seven or eight prominent axial ribs on each whorl; the ribs culminate in broad spines high on the whorl. Suture appressed. Aperture oval, outer lip and canal not preserved; columella smooth, callus-covered. No constriction at the base of the body whorl.

Approximate dimensions in mm.:

Locality	1849	
Alt.	50	40
Diam.	35	28

Three imcomplete specimens have been found in the Castaic formation; two at locality 1849 and one at locality 2090. The specimen from locality 2090 is in a pebbly very coarse-grained sandstone; those from locality 1849, in fine-grained sandstone.

These specimens are identified as *F. carisaensis* because of their general shape and sculptural features. They are distinguished from other species by the absence of spiral sculpture and the absence of any constriction around the base of the body whorl.

F. carisaensis has been reported previously from middle and upper Miocene sediments of central California. These occurrences in the Castaic formation thus represent a southward extension in the distribution of the species.

Living species of *Forreria* along the California and Baja California coast are found in the inner sublittoral zone both within bays and in the open ocean.

Jaton eldridgei (Arnold)
Plate 24, Figure 1.

Murex eldridgei Arnold, 1907, U. S. Nat. Mus. Proc., v. 32, p. 537, pl. 50, fig. 12.

Purpura (Jaton) eldridgei (Arnold), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 708, pl. 32, figs. 1, 2a, 2b.

Shell medium size, broadly fusiforn, spire moderately high, whorls about 5; whorl profile convex. Axial sculpture of six prominent rounded varices; varices vertical, connected to varices of preceding whorl but offset to the right so that varices slant sinistrally from apex down to body whorl. Spiral sculpture of strong spiral ribs with finer ribs between. Suture tangent on varices but strongly impressed between, forming deep pits. Aperture oval; outer lip simple, columella smooth, callused. Canal long, narrow. Dimensions in mm.:

Alt.	28	15
Diam	16	8

Four specimens have been found at locality 1849.

J. eldridgei has been reported previously only from lower Pliocene sediments of the Newhall-Elsmere Canyon area. Thus the Castaic formation occurrence represents a slight extension of range of the species to the late Miocene.

Pyrene sp.

Plate 23, Figure 2.

Shell medium-size, biconic, spire moderately high, apical angle about 70°. Posterior part of body whorl curves upward at aperture. The two specimens referred to this genus are internal molds. Dimensions in mm.:

Locality	2077	2096
Alt.	25	11
Diam.	12	7
Altitude of spire	8	3

The specimens are referred to Pyrene on the basis of shell shape and the upward flare of the aperture.

The two specimens were found at localities 2077 and 2096. Both localities are in fossil-rich conglomerate and pebbly sandstone.

No Pyrene species has been reported previously from Cenozoic sediments of California. Three species have been found in Pliocene, Pleistocene, and Recent sediments of Baja California. The Recent northern limits of distribution of the species (fuscata, strombiformis, and major) are Magdalena Bay, the central Gulf of California, and the southern Gulf of California, respectively. All are found littorally under rocks.

Kelletia vladimiri Kanakoff

Plate 26, Figure 1.

Kelletia vladimiri Kanakoff, 1954, S. Calif. Acad. Sci. Bull., v. 53, p. 114-117, pl. 29, 30, 31.

Shell large, fusiform, spire moderately high, aperture about one-half the total length of the shell, about seven whorls. Suture appressed, slightly undulating. Whorl profile convex. Axial sculpture of elongate nodes which are more or less prominent, nodes are reduced to low undulations on the body whorl of some large specimens. Nodes 10 to 12 on body whorl; spiral sculpture of narrow incised grooves. Aperture elongate-oval; outer lip lirate internally. Columella smooth, covered with sharply limited callus deposit. Anterior canal moderately long and narrow. Dimensions in mm. of specimens from locality 1849:

Alt.	61	53	52	45	38	38	30
Diam.	25	22	21	19	17	16	13

The specimens agree in all respects with *K. vladimiri* which has previously been reported only from lower Pliocene sediments at a locality less than two miles from the major Castaic formation occurrence. The species is abundant at locality 1849 and rare at localities 2069, 2090, and 2092, where it is represented by single incomplete specimens. Several of the specimens from locality 1849 have been bored by some species of predatory gastropod.

The living species *Kelletia kelletii* is found abundantly off the coast of southern California at depths of 10 to 35 fathoms.

Calicantharus fortis (Carpenter) *angulatus* (Arnold)

Plate 26, Figures 3a, b.

Pisania fortis Carpenter var. *angulata* Arnold, 1907, U.S. Nat. Mus. Proc., v. 32, p. 536, pl. 50, figs. 6, 7.

Shell large, broadly fusiforn, whorls angulated with obtuse shoulder near posterior suture. Suture appressed, marked by band at top of body whorl. Faint broad axial undulations on shoulder. Prominent spiral sculpture of coarse ribs alternating with deeply set secondary ribs. Aperture oval, inner lip smooth, callused, twisted at junction of the aperture and the moderately long, twisted canal. Interior of outer lip finely grooved. Umbilicus subperforate. Dimensions in mm. of two specimens from locality 1849:

Alt.	60	60
Diam.	30	27

The sculpture, shape, and whorl profile of the specimens agree very closely with those of the holotype of the variety as figured by Arnold (1907, pl. 50, fig. 7). The specimens differ from the illustrations in Stewart (1926, pl. 32, figs. 2, 3) of *Neptunea humerosa* Gabb, in having a more definite shoulder and in having the two orders of spiral sculpture more clearly defined. The scultpure of the specimen of *Calicantharus humeroaus* (Gabb) figured by Grant and Gale (1931, pl. 28, fig. 3), is more like that of the Castaic formation specimens, but is also less bimodal. Woodring, Bramlette, and Kew (1946, p. 75) discuss the generic taxonomy of *C. fortis* and closely related species. They apparently refer the variety *angulatus* to the species *humerosus*. Grant and Gale consider the variety gradational into *humerosus*. Although this may be, the specimens from the Castaic formation have the strong bimodal sculpture characteristic of *fortis* and differ only in the angularity of the whorl profile, whereas they differ from *humerosus* in both of these respects. The late Miocene species *pabloensis* differs in having a broadly rounded whorl profile.

Two specimens of *angulatus* have been found at locality 1849, in fine-grained sandstone. The spire of each is incomplete but the preservation otherwise is good.

C. fortis angulatus has been reported previously only from lower and middle Pliocene sediments of central and southern California. The genus became extinct in the Pleistocene epoch.

Colus (*Anomalosipho*) n. sp.

Plate 27, Figures 1, 2, 3.

Shell large, fusiform, thin, spire high, whorls six, whorl profile smoothly rounded. Nucleus of 1 1/2 smooth inflated whorls. Apical angle 30°. Sutures appressed. Sculpture of sharp narrow spiral ridges separated by broad shallow interspaces several times as wide as the ridges. About 20-25 ridges on body whorl. No axial sculpture. Growth lines inconspicuous in most cases, but stronger on a few shells, particularly on the body whorl. Aperture elongate, oval, canal short, columella straight, smooth, with thin callus covering. Inner lip recurved slightly on the anterior part of the columella; outer lip simple. Sculpture reflected slightly on interior of shell. Dimensions in mm.:

Alt.	40	32	43	43	52
Diam.	15	12	15	16	ca.18

This species is abundant at locality 1671 in very fine-grained sandstone. Associated with it are *Periploma* and plant remains consisting of leaf impressions and fragments of carbonized wood less than 1 cm. in maximum dimension. Most of the fossils are imcomplete molds.

This species differs from the west North American species of *Colus* in having a relatively higher spire. The shells thus are very similar to *Anomalosipho altus* (Wood), found in Pliocene sediments of Europe as illustrated by Harmer (1914) p. 150, pl. 15, fig. 6.

The subgenus *Anomalosipho* occurs along the west North American Coast from the Bering Sea south to southern California. It is in general restricted to depths of several hundred fathoms. It has been found in Pleistocene sediments in Oregon and at San Pedro, California, and in Pliocene sediments in northern California and near Ventura, California. The single species found as a fossil in southern California, Colus riversi (Martin), differs from the Castaic formation species in being larger and relatively broader, and in having a relatively lower spire.

Nassarius cf. N. stocki Kanakoff

Plate 25, Figure 3.

Nassarius stocki Kanakoff, 1956, S. Calif. Acad. Sci. Bull., v. 55, p. 110-112, pl. 30, figs. A, B, C.

Shell small, ovate-conical, whorls six, convex. Sculpture cancellate with strong rounded, slightly retractive axial ribs, and fine overlying spiral ribs. About 11 axial ribs and 10 spiral ribs on body whorl and four spiral ribs exposed on preceding whorl. Apical angle about 35°. Suture impressed. Aperture oval, inner lip reflected with several approximately horizontal folds-one near the posterior and two near the anterior ends of the lip are preserved-the central part of the inner lip is weathered. Outer lip thickened internally, with 8 or 9 denticles distributed evenly over the length of the lip. Canal short, siphonal notch deep. Constriction at base of body whorl deep. Dimensions in mm. of three specimens from locality 2069:

Alt.	12	11	11
Diam.	5.5	5.5	6

The Castaic formation specimens differ from N. stocki in only minor ways: N. stocki is sculptured with a greater number of axial ribs; there are 4 denticles on the interior of the outer lip of N. stocki, whereas there are 8 or 9 on the Castaic formation specimens; N. stocki is slightly smaller. In all other respects, the specimens from the Castaic formation are identical with N. stocki. The sculpture of this species is very similar in gross aspect to that of N. hamlini, reported from lower Pliocene sediments of the Los Angeles Basin. The species differ, however, in the more critical features of the aperture.

N. cf. N. stocki has been found at locality 2069 in a fossiliferous pebbly sandstone at the base of the formation, at locality 1670 (a single specimen), and at locality 1849 (several specimens). Locality 2069 is about one-half mile from the only reported occurrence of the species, in the lower Pliocene Towsley formation. The Castaic formation occurrence thus is older than the known range of the species.

Representatives of the genus Nassarius live intertidally and in water as deep as several hundred fathoms. They are carnivorous, predatory on other mollusks.

Nasaruis sp. A

Plate 25, Figures 4, 5.

Shell small, ovate-conical, whorls six; sculpture cancellate, axial and spiral ribs of about equal strength; axial ribs retractive, 25 to 30 on body whorl, half as wide as interspaces; spiral ribs slightly more prominent, 8 or 9 on body whorl, 4 or 5 exposed on preceding whorl; suture impressed. Aperture oval with narrow posterior notch; both inner and outer lips denticulate, about 7 teeth on outer lip, probably not more than 6 on inner lip. Canal short, siphonal notch deep. Constriction at base of body whorl deep. Dimensions in mm. of five specimens from locality 1849:

Alt.	14	14	15	13	14
Diam.	7.5	7	8	7	7

The sculpture is very similar to that of N. californianus as illustrated by Oldroyd (1927) pl. 26, fig. 13. The aperture, however, is different from that of N. californianus, but is similar to that of N. stocki, a species with which it is associated. It differs from N. stocki in being larger and in having more numerous, finer axial ribs. Considering that external sculpture is probably more plastic than apertural features, this species is more closely related to N. stocki.

N. sp. A. has been found only at locality 1849, in medium-grained sandstone.

Cancellaria cf. *C. fernandoensis* Arnold
Plate 26, Figure 5.

Cancellaria fernandoensis Arnold, 1907, U. S. Nat. Mus. Proc., v. 32, p. 535, pl. 50, fig. 4.

Shell medium size, only body whorl preserved, sculpture of about 18 low rounded axial ribs and finer, uniform, equidistant spiral ribs with interspaces slightly wider than the ribs. Aperture narrow, oval; canal short, narrow; columellar lip with two oblique folds on callus. Diameter of body whorl 14 mm.

This specimen is too incomplete to be positively identified. Its sculpture however is like that of *C. fernandoensis*.

Only one specimen has been found in the Castaic formation, at locality 2101. It was imbedded in well-cemented, calcareous, medium-to very coarse-grained sandstone.

C. fernandoensis has been reported previously from the lower Pliocene sediments of Towsley Canyon.

Cancellaria hemphilli Dall

Plate 27, Figures 6a, b.

Cancellaria hemphilli Dall, 1909, U. S. Geol. Survey Prof. Paper 59, p. 30, pl. 14, fig. 5.

Cancellaria hemphilli Dall, Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 621, pl. 27, figs. 3, 15a, 15b.

Shell medium size, whorls about six; whorls sharply angulated at a nodose shoulder. Sculpture of sharp axial ribs (12 on body whorl) separated by interspaces about twice as wide as the ribs; ribs terminate in sharp nodes at the shoulder. Spiral ribbing reduced, of faint uniform ribs below the shoulder. A broad concave spiral channel lies between shoulder and suture. Aperture elongate, oval, anterior canal narrow, relatively long for the genus. Columellar lip callused with two oblique folds; outer lip not preserved.

Dimensions in mm.:

Alt.	15	22 (approx.)
Diam.	8	8

Two incomplete specimens have been found at locality 1849, in fine-grained sandstone.

C. hemphilli previously has been reported from middle Pliocene sediments of southern California. The Castaic formation occurrence thus represents an extension of the range back to late Miocene.

Cancellaria tritonidea Gabb
Plate 26, Figure 4.

Cancellaria (Euclia) tritonidea Gabb, 1866, Geol. Surv. Calif., Paleo., v. 2, p. 11, pl. 2, fig. 18.

Cancellaria tritonidea Gabb, Arnold, 1909, U. S. Geol. Survey Bull. 396, p. 31, pl. 26, fig. 10.

Shell medium to large; spire moderate, conical; aperture more than one-half the shell length; apical angle 75°; suture appressed; shoulder near posterior margin of whorl, broad axial ribs (about 11 on body whorl) form nodes at shoulder, nodes reduced on shoulders of spire on most specimens; spiral sculpture of alternating coarse and fine ribs. Aperture oval, anterior canal short, rounded; columella with two strong folds, callus deposit on inner lip. Dimensions in mm. of specimens from locality 1849:

Alt.	45	33	30	32	38	32	18	17
Diam.	25	18	16	17	23	19	10	9

Several species of Cancellaria have been described that are more or less like C. tritonidea, varying only in height of spire and prominence of shoulder on the spire whorls. In addition to the three species tritonidea, altispira, and rapa, which represent forms with respectively relatively low to high spire and more-to less-shouldered whorls, Carson (1926), described several new species of Cancellaria- hamlini, newhallensis, perrini, and elodiae - falling within the same range of features, without fully comparing them to the previously described species. Grant and Gale (1931) p. 616-618, synonymized Carson's species under a few varieties of tritonidea but further confused the situation by using as illustrations of the varieties tritonidea s.s. and altispira, figures of the type specimens of species placed within the synonomy of the two varieties, thus making it difficult to check on the classification. The Castaic formation specimens are very similar to the C. tritonidea specimen from the Pleistocene of San Pedro illustrated by Arnold (1910), pl. 26, fig. 10. They are lower spired than the holotype of tritonidea illustrated by Gabb (1866), pl. 2, fig. 18, or the individual illustrated by Woodring et al (1946), pl. 35, fig. 21. Woodring et al (1940), p. 88, state that C. tritonidea can be distinguished perhaps from C. altispira because a shoulder is better developed on the spire whorls of C. tritonidea. In this respect however, the holotype of tritonidea is not typical, being intermediate between the specimen of tritonidea figured by Arnold (1910), pl. 26, fig. 10 and the holotype of altispira, Stewart (1926), pl. 31, figs. 9, 9a. The Castaic specimens are similar in shape to C. perrini Carson, but have more prominent shoulders on the spire whorls. Within this group of closely related forms, the presence of a shoulder on the whorl may be a genetic variable, or may be a character evolving through time. In no case are the first few whorls shouldered. The distinction has been made between forms with no shoulders, those with a shoulder on the body whorl of mature individuals, and those with a shoulder on the body whorl and on the preceding one or two whorls. The group should be studied as a whole to arrive at meaningful sub units.

This species has been found in the Castaic formation only at locality 1849, where it is common. It occurs in a medium-grained sandstone.

C. tritonidea has been previously reported from Pliocene sediments of central a nd southern California and Pleistocene sediments of southern California. The Castaic formation occurrence thus represents an extension of the species to the late Miocene.

Recent Cancellaria is most common in the inner sublittoral zone in marine water on a sand substrate.

Cancellaria aff. C. tritonidea Gabb

Plate 27, Figures 4a, b, Plate 28, Figure 3.

Cancellaria (Euclia) tritonidea Gabb, 1866, Geol. Survey Calif., Paleo., v. 2, p. 11, pl. 2, fig. 18.

Cancellaria tritonidae Gabb, English, 1914, Univ. Calif. Publ. Geol. Sci., v. 8, p. 218, pl. 23, fig. 2.

Shell medium size, spire moderate, aperture about one-half shell altitude. Whorls strongly shouldered on body and spire whorls. Strong axial ribs (about 12 on body whorl) culminate in sharply pointed nodes at shoulder; axial ribs comparatively faint above shoulder, on ramp. Spiral ribbing consists of alternating coarse and fine ribs. Spiral ribbing slightly weaker above shoulder. About six ribs (three coarse, three fine) are exposed below shoulder on nearly vertical side of spire whorls. Aperture elongate-oval; inner side of outer lip faintly lirate, columella with two strong folds; canal short and narrow. Dimensions in mm. of three specimens from locality 1849:

Alt.	33	30	25
Diam.	19	16	13

The specimens agree with the illustration by English (1914), pl. 23, fig. 2, of an individual of Cancellaria tritonidae Gabb (mistake for tritonidea) from the Pliocene sediments of Elsmere Canyon. This specimen and those from the Castaic formation differ considerably from the holotype of C. tritonidea, the specimens of tritonidea from the Castaic formation, or the illustrations of tritonidea by Woodring et al (1946), pl. 35, fig. 21, and Arnold (1909), pl. 26, fig. 10. They differ in having a higher, more slender spire, and more strongly shouldered, angulated whorls. They agree in spiral sculpture. They are certainly closely related to, or conspecific with C. tritonidea, representing the extreme in whorl profile angularity of the whole group of forms closely related to tritonidea.

Specimens have been found in the Castaic formation at localities 1849, 2069, and 2090. They are rare at localities 2069 and 2090, common at locality 1849. The specimens from localities 1849 and 2069 are moderately to well preserved. That from locality 2090 is poorly preserved in sculptural details, but nevertheless can be grouped surely with the others.

The only previously reported occurrence of this form is the Pliocene sediments of Elsmere Canyon. Thus, the Castaic formation occurrences do not affect the distribution materially, but extend the range to late Miocene.

Cancellaria aff. C. rapa Nomland
Plate 27, Figure 5.

Cancellaria rapa Nomland, 1917, Univ. Calif. Publ. Geol. Sci., v. 10, p. 240, pl. 11, figs. 1, 1a.

Cancellaria tritonidea Gabb var. rapa Nomland, Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 617.

Cancellaria rapa Nomland, Woodring, Stewart, and Richards, 1940, U. S. Geol. Survey Prof. Paper 195, p. 88, pl. 15, figs. 1, 7.

Shell medium size, spire moderate, aperture a little more than one-half the shell altitude; spire conical; sutures appressed, nearly tangent; whorl profile rounded, no shoulder on spire whorls, a very faint shoulder on body whorl. Axial ribbing only on body whorl, very low, faint. Spiral ribbing on body whorl, absent or not preserved on spire, of rounded ribs, narrow interspaces, ribs of approximately uniform strength. Aperture elongate oval; canal short, narrow; outer lip with faint lirations internally; columellar lip with thick callus, two strong folds. Dimensions in mm. of two specimens from locality 1849:

Alt.	35	27
Diam.	20	15

Two specimens have been found at locality 1849 imbedded in fine-grained sandstone. Both are moderately well preserved, one has been bored by a gastropod. These specimens are similar to C. rapa in shape and whorl profile. They differ, however, in having finer, uniform spiral sculpture.

They differ from C. hamlini in lacking the well developed axial sculpture. They are very similar to C. elodiae, which is probably a form of C. rapa, but differ in having more rounded, inflated spire whorls, and finer spiral sculpture.

C. rapa has been reported only from Pliocene sediments of central and southern California. The Castaic formation occurrence thus represents a slightly older, closely related form.

Cancellaria sp.

Shell medium size, fusiform; spire moderately high; suture appressed; whorls about 5. Sculpture of axial nodes near the posterior margin of the body whorl and fine spiral ribs of uniform size and spacing. Shell weathered so sculpture is poorly preserved, but spire whorls appear to be node-free. **Aperture** elongate narrow; canal narrow, moderately long; outer lip poorly preserved, columella straight with two oblique folds. Alt. 40 mm., Diam. 17 mm. x

A single specimen has been found in the Castaic formation at locality 2090 in pebbly coarse-grained sandstone.

The shell is similar in many respects to C. perrini Carson (1926), p. 56, pl. 3, fig. 4. It is too poorly preserved however to identify specifically. C. perrini has been reported from Pliocene sediments of the Santa Maria area and of Elsmere Canyon.

Cancellaria is most common in the inner sublittoral zone in marine water on a sand substrate.

Olivella (*Olivella*) *pedroana* (Conrad)

Strephona pedroana Conrad, 1855, U. S. 33rd Cong., 1st. Sess., House Ex. Doc. 129. Appendix to Prelim. Geol. Rept. of W. P. Blake, p. 17, 1855; 1856, Pacific R. R. Repts., v. 5, p. 327, pl. 6, fig. 51.

Olivella pedroana (Conrad), Weaver, 1942, Univ. Wash. Publ. Geol., v. 5, p. 501, pl. 95, figs. 25, 30.

Shell small, smooth, slender, two and one-half whorls of spire preserved; probably not more than one whorl missing from apex. Suture channeled. Aperture narrow, outer lip simple, inner lip with thin callus extending above the aperture. A single fold at the base of the inner lip bears a central groove, thus giving the appearance of two closely set folds. Canal not preserved. Dimensions in mm. of specimen from locality 2097:

Alt. of shell	12
Alt. of spire	3
Diam.	4

This species is represented in the Castaic formation by a single specimen, which is an external mold, from locality 2097, and by single, poorly preserved specimens from localities 279, 1670, 1849, 2069 and 2093.

The best preserved specimen was identified on the bases of the shell shape and the nature of the columellar folds. The only species of *Olivella* reported from late Cenozoic sediments of the west North American coast that have a single, moderately-large, grooved fold at the base of the inner lip are *O. pedroana*, *O. biplicata*, *O. baetica*, and *O. porteri*. However, *porteri* is probably only a variant of *baetica*, and *baetica* is probably synonymous with *pedroana*, Burch, v. 2, part I, No. 49, p. 20-21. The Castaic formation specimen is much more slender than *O. biplicata*, having the shape typical of Recent individuals of *O. pedroana*. See Olsson (1956).

The stratigraphic range of O. pedroana is middle Miocene to Recent. Its previously reported geographic distribution is:

middle Miocene--Washington and perhaps central California
late Miocene--central California (San Pablo formation)
Pliocene--Oregon to southern California
Pleistocene--southern California to San Ignacio Lagoon, Baja California
Recent--Puget Sound to Cape San Lucas, Baja California.

If the record is adequate, and it probably is except for the pre-Pleistocene of Baja California, it appears that the southern limit of distribution of the species has moved southward since the middle of the Miocene epoch. The northern limit has remained fairly constant except for a southward move during Pleistocene time. The Castaic formation occurrence here described constitutes a southward extension of the late Miocene range.

O. pedroana is found at present both in bays and along the open coast, on beaches and to a depth of 40 fathoms, although it is uncommon below about 20 fathoms. It is usually found on a sand or muddy sand substrate.

Oliva spicata (Bolten)
Plate 28, Figure 1.

Oliva spicata (Bolten), Durham, 1950, Geol. Soc. America Mem. 43, p. 103, pl. 29, fig. 1.

Shell medium size, spire moderately high. The lower three-fourths, and perhaps more, of the inner lip lightly callused, with more than ten plications of about equal strength. Outer lip slightly thickened. Shell slender, elongate, with inconspicuous shoulder and nearly parallel sides that taper in very little towards the base of the shell. Dimensions: Alt. 37 mm., diam. 15 mm.

A single specimen has been found at locality 230. Preservation is good; only the apex of the spire is missing.

This specimen differs from *O. simondsi*, found in the Briones formation of the San Francisco Bay region, in being more slender with less prominent shoulders, and in having many more columellar folds all of about equal strength. It differs from both *O. californica* and *O. futheyana*, found in lower and middle Miocene sediments of central and southern California, in being more slender and straight-sided and in having a higher spire and more, uniform, plications. Leol and Corey (1932), p. 239, consider that *O. futheyana* is only a variant of *O. californica*. *O. simondsi* is similar to and probably closely related to *O. californica*. In contrast, the Castaic formation specimen is much more like the warm water species *O. spicata* and *O. incrassata*. These two species have similar shapes, spires, and columellar plications. Immature individuals of *O. incrassata* are difficult to distinguish from *O. spicata* on the basis of shell form. Adult *O. incrassata* are distinguished by having a much more angular shoulder that is relatively low on the body whorl. Individuals of both species attain a size somewhat larger than the Castaic formation specimen: It is referred to O. spicata because it lacks the shoulder characteristic of O. incrassata, and because it is indistinguishable from specimens of O. spicata from the Imperial formation collected at Carrizo Mountain. It is considered unlikely that it is an individual of O. incrassata so immature as to completely lack the low, prominent shoulder. The published geographic distribution of O. spicata is:

Pliocene--The Colarado Desert and the Gulf of California.
Pleistocene--Magdalena Bay and San Ignacio Lagoon areas, Baja California
Recent--North end of the Gulf of California to Panama.

The distribution of O. incrassata is:

Pleistocene--Magdalena Bay, Baja California; Gulf of California, and Oaxaca.
Recent--Magdalena Bay through the Gulf of California to Peru.

O. spicata has been found in the Castaic formation only at locality 230.

The occurrence of O. spicata in the Castaic formation extends the range of this species back to the late Miocene, and the distribution northward from within the Gulf of California during the Pliocene epoch.

Recent specimens of Oliva are found most abundantly burrowing just beneath the surface of sandy substrates either in bays or along the open coast. They are found in the inner sublittoral zone from low tide line to 25 fms., but most commonly in the upper part of this depth range.

Marginella sp.

Plate 28, Figures 4a, b.

Shell medium size, sub-cylindrical, ovoid, thick, smooth; spire very low. Apex of shell barely extends above broadly rounded shoulder of body whorl. Outer lip not preserved, inner lip incomplete, three heavy horizontal plications just below the middle of inner lip. Aperture elongate, narrow, open anteriorly, extending posteriorly over shoulder to suture. Alt. 25 mm., Diam. 19 mm.

A single specimen has been found at locality 2069. It is not well preserved enough to be identified specifically. Nevertheless, it is of great interest, because fossil marginellids of any sort are rare on the west coast of North America. The specimen is clearly distinct from any of the marginellids, recent or fossil, that have been reported from California. Five species of marginellids have been reported from Pleistocene localities along the northwest coast of Baja California and Recent and Pleistocene localities in southern California. Only four other species have been reported as fossils from the west North American coast: *Marginella sapotilla* Hinds, *Cystiscus minor* (Hinds), and *Cystiscus margaritula* (Carpenter), from Pleistocene, and *Marginella* sp. nov. from Pliocene sediments of the Burico Penninsula of Panama and Costa Rica, Olson (1942), p. 11, 12, 17, 21. All of these differ from the Castaic formation specimen. Thus, this specimen is distinct from any described west North American fossil marginellid, and from any of the Recent californian species. It can not be identified generically in detail because of poor preservation. In general features, however, it is similar to *Marginella albuminosa* Dall, Keen (1958), p. 433, fig. 668, from the west coast of Mexico.

Living marginellids are largely confined to tropical waters, living in the littoral zone or at only a few fathoms depth on sandy bottoms. The family is relatively poorly represented in the east Pacific fauna, being much more abundant in the Caribbean, the western Pacific, and along the west African coast.

Conus californicus Hinds

Plate 28, Figure 2.

Conus californicus Hinds in Reeve, 1844, Conch. Icon., v. 1, pl. 42, fig. 224.

Conus californicus Hinds, Hanna and Strong, 1949, Calif. Acad. Sci. Proc., v. 26, p. 308, pl. 5, figs. 14, 15.

Shell medium size, biconical, shoulder rounded, apical angle 82°. Suture marked by a fine groove, but this may be a weathering effect. Shell smooth except for about twelve fine spiral grooves on the anterior half of the body whorl. Aperture narrow, straight. Sides of shell above and below shoulder straight. Dimensions in mm. of two specimens from locality 1624:

Alt.	25	12
Alt. of spire	7	3
Diam.	12	6

The Castaic formation specimens differ from Conus owenianus in having rounded rather than angular shoulders, in having spiral sculpture only on the lower part of the body whorl, and in having a higher, more acute spire. They differ from C. juanensis in having spiral sculpture rather than a smooth exterior and in having a straight-sided, rather than a concave-sided, sharply-pointed, spire. They resemble C. puncticulatus Hwass, from a Pleistocene locality in the Gulf of California, as illustrated by Durham (1950), pl. 32, fig. 2. However, the spire of C. puncticulatus differs in being lower and sharply pointed with concave sides. Recent C. californicus, as illustrated by Hanna and Strong,(1949), pl. 5, figs. 14, 15, and by Keen (1958) fig. 924, are somewhat higher spired than the specimens from the Castaic formation. However, the difference is slight, and judging from a survey of a collection of Recent and Pliocene specimens the range of variability of the species includes the Castaic formation specimens.

Two specimens of *C. californicus* were collected at locality 1624, one at locality 1849, and one at locality 2069. Poorly preserved specimens probably belonging to this species have been found at localities 2093, 2096, and 2105.

The known reported distribution of *C. californicus* is: Recent-Farallone Islands to Cape San Lucas, Baja California; Pleistocene-Ventura to Turtle Bay, Baja California, Pliocene-Ventura and Los Angeles Basins. The Castaic formation occurrence thus represents an extension of the range into the late Miocene age.

C. californicus lives along protected outer coasts and in bays containing water of normal marine salinity. It is most abundant on a sand or gravel substrate, but is also found on mud, and along rocky shores. It occurs littorally and down to 25 fathoms.

Conus sp. A

Shell large, obconic, elongate, with slender anterior end. Features of spire, shoulder, suture, or surface ornamentation not preserved. Dimensions: Alt. 100 mm., diam. 45 mm.

The specimen is poorly preserved with little shell material remaining, and that present is coarsely recrystallized. Although a detailed comparison can not be made with other species, its large size makes it probable that this specimen is related to the other giant conids that have been recorded from the west North American coast. Arnold (1910), p. 62, described C. hayesi from middle Miocene sediments of Kern, Kings and Orange Counties. Carson (1926), p. 49, described C. beali from lower Pliocene sediments of Los Angeles County. Grant and Gale (1931), p. 476, consider beali to be synonymous with C. regularis Sowerby, which has been reported from Pliocene sediments in the Gulf of California, Pleistocene sediments in the Gulf of California and Oaxaca, and at Recent localities from Magdalena Bay and the Gulf of California south to Panama. C. Hayesi is similar to C. fergusoni, which is found living from the Gulf of California to Ecuador and at several localities on the west Coast of Baja California as far north as Turtle Bay. It has been found in Pleistocene sediments at Oaxaca, and in the Pliocene Imperial formation of the Colorado Desert. The Castaic formation specimen can not be related to any of these species, and in fact, the relationship of the other coastal californian large conids is not clear--except that all three--C. hayesi, C. beali, and the Castaic formation specimen should probably all be related to species that are at present strictly Panamic in distribution.

Only a single specimen was found, at locality 2085, in the northern part of the outcrop area of the formation. It was in a bed of well-cemented medium-grained sandstone containing otherwise only scattered lenses of fossiliferous material consisting largely of *Lyropecten* and *Astrodapsis* fragments. The bed is one of several intertongueing towards the nearby basal contact with pebble and cobble conglomerates, which, in turn, intertongue with unsorted rubble of Martinez sediment fragments in a reddish matrix. Dr. G. P. Kanakoff, personal communication, 29 June, 1959, states that he found, but subsequently lost, a *Conus* of similar size from locality 1849.

C. fergusoni and *C. regularis* are found living intertidally, but are more common offshore. *C. fergusoni* has been collected from water as deep as 90 fms.; *C. regularis*, from water as deep as 55 fms.

Turricula? sp.

Plate 28, Figures 5a, b.

Shell large, fusiforn; spire very high; shoulder obsolete, whorl broadly convex in profile. Sculpture spiral, very poorly preserved. Aperture narrow, extending into a long straight canal only slightly differentiated from aperture; columella straight, smooth; posterior notch narrow, rounded, close below suture. Suture appressed. Altitude about 65 mm., diameter 15 mm.

A single specimen of this form has been found in the Castaic formation, at locality 1849. It is placed tentatively in the genus Turricula, although it differs from typical species of this genus in having a reduced, obsolete shoulder.

No west North American species with such shape and sculpture has been described.

Turricula is at present confined to tropical oceans. Specimens from the Panamic province are found in the sublittoral zone.

Surculites (Megasurcula) remondii (Gabb)

Plate 29, Figures 1a, b.

?Metula remondii Gabb, 1866, Geol. Survey Calif. Paleontology, v. 2, p. 3, pl. 1, fig. 5.

Megasurcula remondii (Gabb), Weaver, 1942, Univ. Wash. Publ. Geol., v. 5, p. 528, pl. 98, fig. 6.

Shell medium size, biconic; spire moderately high; body whorl three-fourths of shell length. Aperture a little more than one-half shell length, narrow, elongate, with short canal; columella smooth, with light callus; body whorl with obtusely angulated shoulder, profile of whorl above shoulder concave, whorl laps high onto preceding whorl, covering it nearly to the preceding shoulder. Sculpture of spiral alternating first and second order ribs, with a tertiary rib on either side of a second order rib in some places, ribbing less regular and distinct above the shoulder. Growth lines sinuous. Posterior notch broad and shallow, above shoulder. Dimensions in mm.:

Locality	1849			2069
Alt.	45	27	25	ca. 35
Diam.	20	12	10	15

This is a variable species, particularly in respect to the angularity of the shoulder and the prominence of the sculpture. The specimens from the Castaic formation are very like the specimens figured by Grant and Gale (1931), pl. 25, figs. 5, 6, from the lower Pliocene sediments of the Fernando Pass area, Los Angeles County. The lectotype figured by Stewart (1926), pl. 31, fig. 5, has more subdued, rounded shoulders. The two smaller specimens from locality 1849 are weathered so that no spiral sculpture is preserved.

S. remondii has been found in the Castaic formation at localities 1849, in medium-grained sandstone, and at locality 2069, in pebbly sandstone.

The range of *S. remondii* is late Miocene to Recent. Its reported late Miocene distribution is Oregon and Washington. Thus, its presence in the Castaic formation represents a large southward extension of the distribution. It is found in lower Pliocene sediments of southern California. The species is found at present from Monterey, California to Todos Santos Bay, Baja California.

Living specimens of the species are found on gravel substrate along the open coast at depths of 20 to 40 fms.

Lora cf. L. oldroydi (Arnold)

Plate 29, Figures 8, 9.

Mangilia oldroydi Arnold, 1903, Calif. Acad. Sci. Mem., v. 3, p. 213, pl. 6, fig. 16.

Lora declivis (Loven) var. ecarinata (Sars), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 530, pl. 25, fig. 20.

Shell small to medium size, elongate, fusiform, spire elevated; aperture a little less than one-half of shell height. Shoulder near suture, reduced. Sculpture of coarse rounded axial ribs (17 on body whorl) and finer overriding spiral ribs (about 15 on body whorl below shoulder--about 5 of these exposed on preceding whorls); sculpture less distinct above shoulder where there are several additional faint spiral ribs. Whorl profile concave above shoulder, broadly convex below. Aperture narrow, oval, constricting into a moderately long canal; columellar lip smooth, nearly straight; outer lip simple. Posterior notch narrow, above the shoulder adjacent to suture. Alt. 18 mm., diam. 7 mm.

About 10 specimens of this form have been found at locality 1849. Preservation is in general poor so that the description is composite.

The specimens agree very closely with the illustrations of the species by Arnold (1903) and by Grant and Gale (1931). The only noticeable difference is that perhaps the whorls of L. oldroydi are more inflated, expressed by a more inflated posterior margin of the aperture.

L. oldroydi has been reported from lower Pleistocene sediments of San Pedro, and upper Pliocene sediments of Los Angeles.

Clavus (*Clathrodrillia*) *elsmerensis* (English)
Plate 29, Figure 6.

Turris elsmerensis English, 1914, Univ. Calif. Publ. Geol. Sci., v. 8, p. 216, pl. 23, figs. 4a, 4b.

Shell medium size, turreted, spire moderately high, whorl profile convex, shoulder obscure or else not preserved. Suture impressed. Sculpture of prominent axil ribs (15 to 17 on body whorl) which extend undiminished to posterior edge of whorl, numerous finer spiral ribs override the axial sculpture. Aperture narrow, oval, anterior canal short, little differentiated from aperture; columella smooth. Dimensions in mm.:

Alt.	22	27	32
Diam.	7	7	10

Eleven poorly preserved specimens have been found imbedded in coarse-grained sandstone at locality 1670.

Grant and Gale (1931), p. 580, consider *C. elsmerensis* (English) to be synonymous with *C. coalingensis* (Arnold). It is true that *C. elsmerensis* was distinguished on sculptural features alone. Although the two species are similar, the specimens from the Castaic formation resemble the holotype of *elsmerensis* much more than they do that of *coalingensis*. Compared to Arnold's original illustration of *coalingensis*, the sculpture of the Castaic formation specimens contains more, finer, spiral ribs which overlie the axial ribs without appreciably breaking them into nodes.

C. coalingensis, excluding *elsmerensis*, has been found only in lower and middle Pliocene sediments of the Coalinga-Kettleman Hills area. *C. elsmerensis* has been reported only from the lower Pliocene sediments of Elsmere Canyon. This occurrence in the Castaic formation thus represents an extension of the range of *elsmerensis* into upper Miocene sediments in the same region.

Recent specimens of *Clathrodrillia* on the west North

American coast are found offshore in the inner sublittoral zone.

Clavus cf. C. (Cymatosyrinx) hemphilli (Stearns)

Plate 29, Figure 7.

Pleurotoma (Drillia) hemphilli Stearns, 1873, Calif. Acad. Sci. Proc., v. 5, p. 80, pl. 1, fig. 3.

Clavus (Cymatosyrinx) hemphilli (Stearns), Grant and Gale, 1931, San Diego Soc. Nat. Hist. Mem., v. 1, p. 577, pl. 26, fig. 8.

Shell medium size, turreted, spire high; aperture about one-third shell length; whorls about 7; whorl profile broadly convex, shoulder reduced, profile concave above shoulder; sculpture of 13 prominent rounded slightly protractive axial ribs, ribs reduced above shoulder. No spiral sculpture. Aperture narrow, oval, canal short, columella smooth, outer lip not preserved. Altitude of incomplete shell 18 mm., about 3 mm. of spire is broken off, diameter 7 mm.

The specimen closely resembles the description and illustration of hemphilli by Grant and Gale (1931). This description is more general than that by Arnold (1903), p. 204, which also compares well with the specimen. C. hemphilli differs in having a small amount of spiral sculpture and in being only about one-half the size of the Castaic formation specimen. The specimen is similar to C. johnsoni Arnold (1903), p. 206, pl. 8, fig. 17, but is smaller and lacks the more sculptured sutural band.

A single specimen has been found at locality 1670.

C. hemphilli has been reported previously from Pleistocene sediments between Ventura, California and San Quintin Bay, Baja California. Its present distribution is from southern California south to at least Todos Santos Bay, Baja California.

Living representatives of C. (Cymatosyrinx) are most commonly found in the inner sub-littoral zone.

Mangelia sp.

Plate 29, Figure 5.

Shell small, elongate-ovate; spire moderately high; whorl profile flat to slightly convex, suture tangential; sculpture of rounded spiral cords with narrow interspaces; and low rounded axial ribs, sculpture best formed and preserved on the spire. Aperture elongate-oval; anterior canal short, little differentiated from aperture. Posterior canal poorly preserved, marked by moderate indentation of growth line and reduction of the axial sculpture just below suture. Columella straight, smooth, lightly callused. Outer lip neither thickened nor denticulate. Aperture about two-fifths shell length. Approximate dimensions in mm. of specimens from locality 1849:

Alt.	17	14	15
Diam.	6	6	6

This species is very much the shape of a Mitrella, but is distinguished from that genus by the poorly preserved axial ribbing, the faint embayment in the growth line at the posterior edge of the whorl, and by the lack of denticles on the interior of the outer lip. The specimens are too poorly preserved to be identified specifically.

Five specimens have been found at locality 1849. A single minute specimen from locality 1624 is probably the same species, but is broken and incomplete.

Living Mangelia are found along the Pacific coast of North America in the littoral and the upper part of the inner sublittoral zones.

Bulla? sp.

Plate 29, Figure 2.

Shell small, cylindrical; spire sunken, narrowly umbilicate. Aperture the length of the shell, extending slightly above the previous whorls; posterior half of aperture narrow, anterior part is wider as body whorl narrows; anterior end of aperture broadly rounded. Columellar and labral margins of aperture not preserved. Shell surface smooth. Dimensions in mm. of two specimens:

Locality	1849	2098
Alt.	13	15
Diam.	6	8

On the basis of shape, the specimens most closely resemble Bulla. However, considering the poor preservation, particularly that of the columella and any folds that might have been present, several other opisthobranch and marginellid genera can not be completely ruled out--for example, Atys, or Cylichrella.

Specimens have been found in the Castaic formation at localities 1849, 232, 2097, and 2098. At locality 1849 the specimen is moderately well preserved, imbedded in the well-cemented, fine-grained sandstone. At the localities in Castaic and Haskell Canyons, the material is poorly preserved, the shell being more or less dissolved as a result of surface weathering. The sediment is pebbly sandstone.

Scaphander? sp.

Shell small, cylindrical-conical. Spire deeply umbilicate, probably concealed. Body whorl narrow, cylindrical. Aperture the length of the shell; the posterior part spiraling sharply upwards; the anterior part broadly rounded. The outline of the outer aperture margin imparts a conical shape to the shell, being close to the body whorl posteriorly but being far from it anteriorly. Alt. 9 mm., Diam. 4 mm.

This fossil is an internal mold. In shape it most closely resembles Scaphander. The preservation being poor, however, this comparison is only very general. The specimen was found at locality 232.

Acteon cf. *A. boulderana* Etherington

Plate 29, Figure 3.

Acteon boulderana Etherington, 1931, Univ. Calif. Publ. Geol. Sci., v. 20, p. 113, pl. 14, fig. 9.

Aceton boulderana Etherington, Keen, 1943, San Diego Soc. Nat. Hist. Trans., v. 10, p. 42, pl. 4, fig. 22.

One specimen has been found in the Castaic formation. It is well preserved except that the spire has been crushed downward into the body whorl and distorted, and the margin of the outer lip is missing. Shell medium size, body whorl large; sculpture of about 30 spiral ribs, ribs flattened, rounded, with narrow interspaces. Anterior ribs become narrower, interspaces wider, they are of equal width at the anterior end of the body whorl. Fine radial ribs in the interspaces create a punctate or cancellate appearance. Spiral ribs are not of uniform thickness but there is no evidence that the wider ones bifurcate. Aperture oval, rounded below, a single simple spiral columellar fold present. Posterior and anterior margins of aperture not preserved. Original altitude about 20 mm., diameter about 9 mm.

Positive specific identification of the specimen is not possible because of its crushed spire. It most closely resembles *A. boulderana* from the middle Miocene Round Mountain silt of Kern County, as illustrated by Keen (1943), pl. 4, fig. 22. It is similar to *A. boulderana* in size, sculpture, and perhaps shape. It differs in having a slightly more strongly developed columellar fold.

Acteon has been found in the Castaic formation only at locality 2093, in Castaic Canyon. There it occurs in pebbly sandstone deposited very near the basal contact.

Acteon is, and was in the late Tertiary period, a small but widely distributed genus. Recent species occur on the east Pacific coast from the tropics to Alaska. *A.*

boulderana has been reported from middle Miocene sediments of southwest Washington and Kern County, California.

The genus has a wide bathymetric as well as a wide geographic distribution. Some species are found from low tide to 60 or 80 fms. Others are confined to a narrower range within the same limits. Thus, a specimen of *Acteon* is not significant as an indication of water depth. Species are most commonly found living on a mud or fine sand substrate in bays and along protected outer coasts. They are not found in bays containing marine water of reduced salinity.

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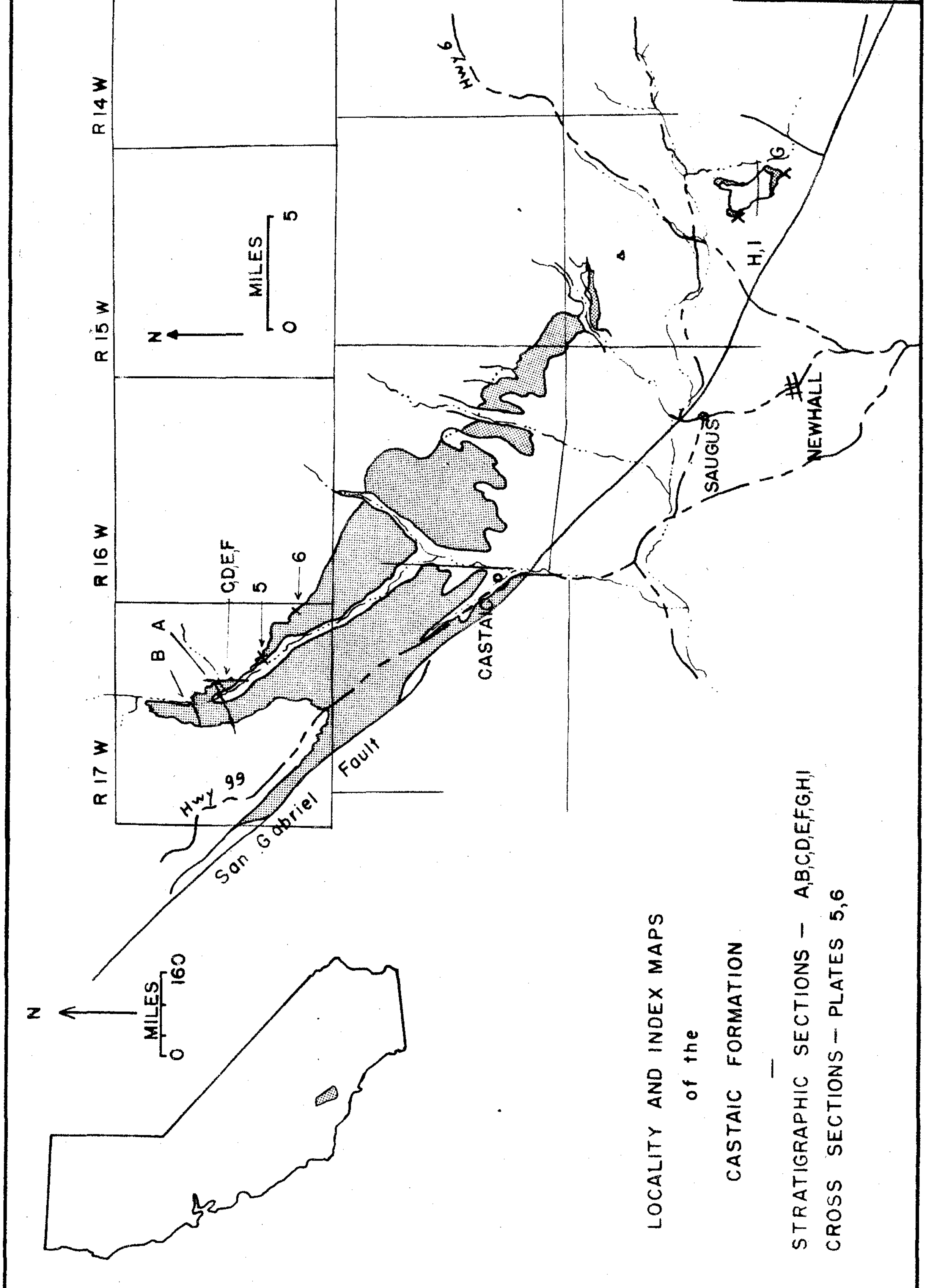
X. List of fossil localities

Locality	Sec.	T (N)	R (W)	Plate	Remarks
230	36	5	16	39	Peb. Cgl.
231	36	5	16	"	" "
232	36	5	16	"	" "
233	36	5	16	"	" "
234	31	5	15	"	Crse.-grained ss.
277	18	5	16	40	Mudstone
279	7	5	16	"	Peb. ss.
1623	6	4	15	39	Mudstone
1624	36	5	16	"	Crse.-grained ss.
1625	35	4	15	"	Fine-grained ss.
1626	2	3	15	"	Diatomaceous mudstone
1627	27	4	15	"	Peb. ss.
1663	27	4	15	"	" "
1670	26	5	16	"	" "
1671	26	5	16	"	Fine-grained ss.
1849	35	4	15	"	Medium-grained ss.
2069	27	4	15	39	Peb. cgl.
2070	25	6	17	40 inset	Peb. cgl. Basal member
2071	25	6	17	"	" " " "
2072	25	6	17	"	Fine-grnd. ss " "
2073	up. Castaic Cnyn			"	Crse.-grnd.ss " "
2074		"		40	Peb. cgl. " "
2075	31	6	16	38	" " " "
2077	31	6	16	40 inset	Peb. ss. " "
2081	31	6	16	"	" " " "
2082	Triangle Ridge				Peb. cgl. " "
2083		"		"	Cobble cgl. " "
2084		"		"	Peb. ss. " "
2085		"		"	Med.-grnd.ss. " "
2086		"		"	Peb. ss. " "
2087		"		"	Med.-grnd.ss " "
2088		"		"	Peb. ss. " "
2089		"		"	" " " "
2090	31	6	16	"	" " " "
2091	31	6	16	"	" " " "
2092	26	6	17	"	" " " "
2093	25	6	17	"	" " " "
2094	Cordova Cnyn.			"	Mudstone
2095	Fish Cnyn.			"	Peb. ss. Basal member
2096	36	6	17	"	Granule ss. " "
2097	1	5	17	40	Crse.-grnd.ss. " "
2098	12	5	17	"	" " " "
2099	Elderberry Cnyn,			38	Peb. ss. " "
2100		"		"	Peb. cgl. " "

Locality	Sec.	T. (N)	R (W)	Plate		Remarks	
2101	up. Castaic Cnyn			40	inset	Med.-grnd. ss.	Basal member
2102	Triangle Ridge			"		Peb. ss.	"
2103	"			"		" "	"
2104	Fish Cnyn.			"	inset	Peb. cgl.	"
2105	" "				"	Peb. ss.	"
2106	Elderberry Cnyn.			38		Crse.-grnd 22.	"
2107	31	6	16	40	inset	Peb. cgl.	"
2108	26	6	17		"	Peb. ss.	"
Plum Cnyn	9	4	15	39		Peb. cgl.	
Haskell Cnyn.	36	5	16	"		Locs. 230-233, 1624, 1672, 1674-1678	
7-6-8	up. Castaic Cnyn.			40	inset	Mudstone	
7-6-9	12	5	17	40		"	
7-7-12	31	6	16	40	inset	"	
7-7-21	Triangle Ridge				"	Cobble cgl. -Basal mbr.	
7-11-3	31	6	16		"	Crse.-grnd.ss.	" "
7-11-19	6	4	15	39		Mudstone	
7-11-24	25	6	17	40		"	
7-11-27	26	5	16	39		Crse.-grnd.ss.	
7-11-33	26	5	16	39		Mudstone	
7-12-18	31	6	16	40	inset	Peb.ss.	Basal mbr.
9-4-4-	4	5	16	40		Mudstone	
9-8-1	9	5	16	"		Granule ss.	
B-4	25	6	17	40	inset	Mudstone	
E	up. Castaic Cnyn.			40		Cobble cgl.	Basal mbr.
E-1	"			"		Peb. cgl.	" "
F-4	"					Crse.-grnd.ss.	
H-5	W. side, Castaic Cnyn.			"		Mudstone	
H-13	"					"	

PLATE I



LOCALITY AND INDEX MAPS
of the
CASTAIC FORMATION
—
STRATIGRAPHIC SECTIONS — A,B,C,D,E,F,G,H,I
CROSS SECTIONS — PLATES 5,6

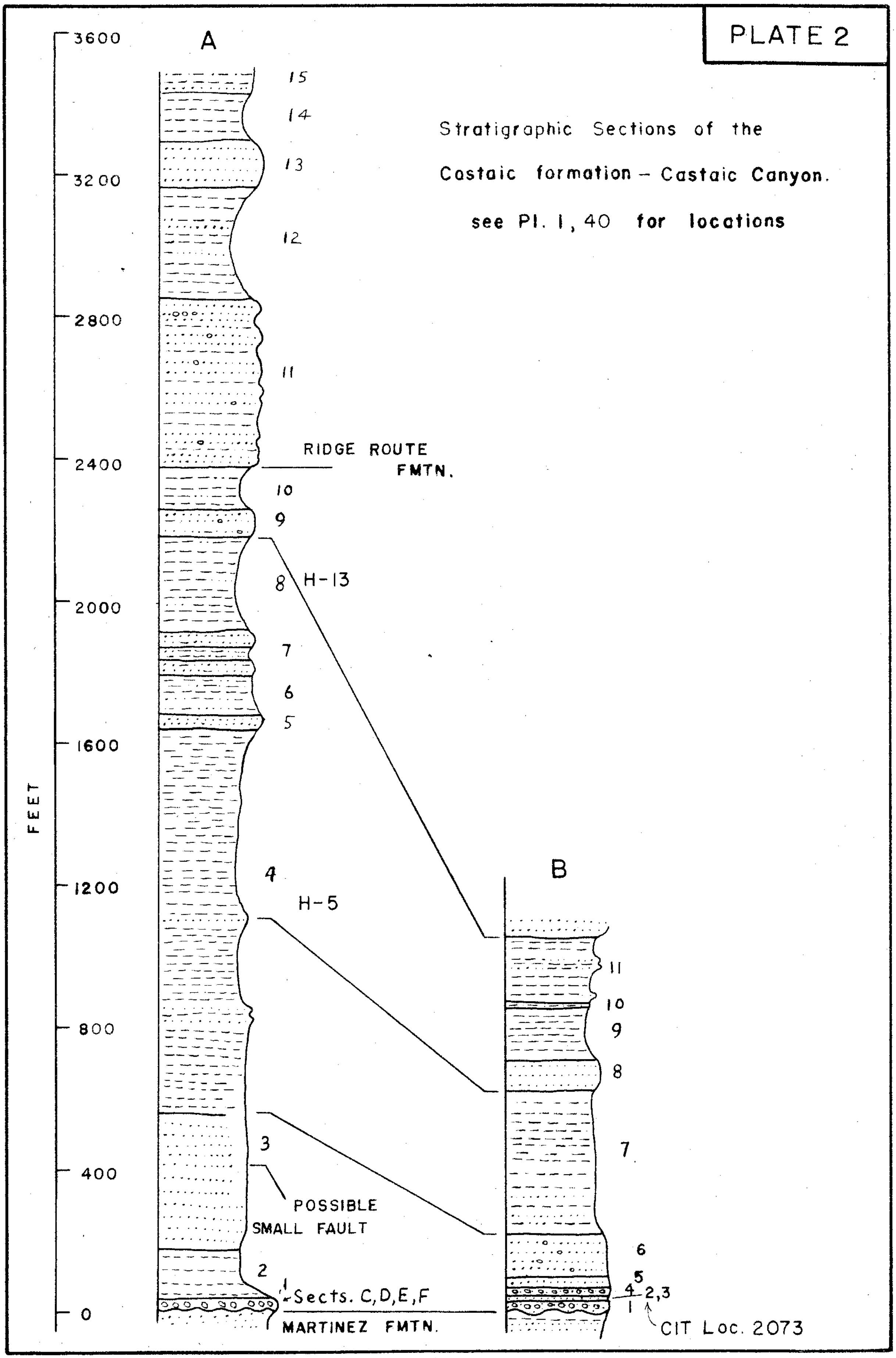
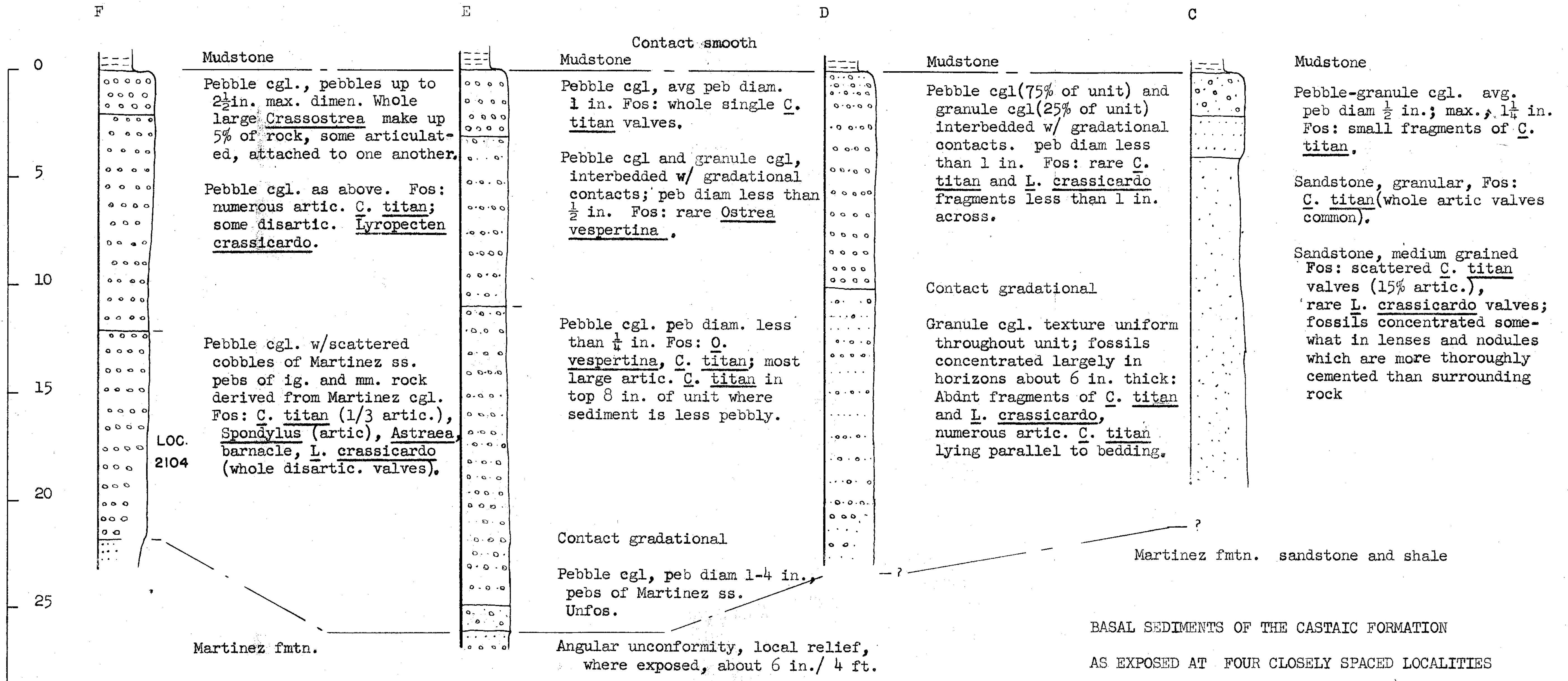


PLATE 2

Stratigraphic Sections of the Castaic formation – Castaic Canyon.

see Pl. 1, 40 for locations

PLATE 3



F

Mudstone

Pebble cgl., pebbles up to $2\frac{1}{2}$ in. max. dimen. Whole large *Crassostrea* make up 5% of rock, some articulated, attached to one another.

Pebble cgl. as above. Fos: numerous artic. *C. titan*; some disartic. *Lyropecten crassicardo*.

Pebble cgl. w/scattered cobbles of Martinez ss. pebs of lg. and mm. rock derived from Martinez cgl. Fos: *C. titan* (1/3 artic.), *Spondylus* (artic), *Astraea*, barnacle, *L. crassicardo* (whole disartic. valves).

Martinez fmtn.

E

Contact smooth

Mudstone

Pebble cgl, avg peb diam. 1 in. Fos: whole single *C. titan* valves.

Pebble cgl and granule cgl, interbedded w/ gradational contacts; peb diam less than $\frac{1}{2}$ in. Fos: rare *Ostrea vespertina*.

Pebble cgl. peb diam. less than $\frac{1}{4}$ in. Fos: *O. vespertina*, *C. titan*; most large artic. *C. titan* in top 8 in. of unit where sediment is less pebbly.

Contact gradational

Pebble cgl, peb diam 1-4 in., pebs of Martinez ss. Unfos.

Angular unconformity, local relief, where exposed, about 6 in./ 4 ft.

D

Mudstone

Pebble cgl(75% of unit) and granule cgl(25% of unit) interbedded w/ gradational contacts. peb diam less than 1 in. Fos: rare *C. titan* and *L. crassicardo* fragments less than 1 in. across.

Contact gradational

Granule cgl. texture uniform throughout unit; fossils concentrated largely in horizons about 6 in. thick: Abdnt fragments of *C. titan* and *L. crassicardo*, numerous artic. *C. titan* lying parallel to bedding.

C

Mudstone

Pebble-granule cgl. avg. peb diam $\frac{1}{2}$ in.; max. $1\frac{1}{4}$ in. Fos: small fragments of *C. titan*.

Sandstone, granular, Fos: *C. titan*(whole artic valves common).

Sandstone, medium grained Fos: scattered *C. titan* valves (15% artic.), rare *L. crassicardo* valves; fossils concentrated somewhat in lenses and nodules which are more thoroughly cemented than surrounding rock

Martinez fmtn. sandstone and shale

BASAL SEDIMENTS OF THE CASTAIC FORMATION

AS EXPOSED AT FOUR CLOSELY SPACED LOCALITIES

ON THE SOUTH SIDE OF FISH CANYON

Vertical scale 1 inch = 5 feet
No horizontal scale Distance from F to C is about 400 feet.

Upper contact of basal sediments smooth, sharp; lower contact irregular with several feet of relief between section localities

PLATE 4

STRATIGRAPHIC SECTIONS

OF THE CASTAIC FORMATION SOUTH OF
SOLEDAD CANYON - SEE LOCALITY DESCRIPTIONS,
CHAPT. IV, FOR DETAILS

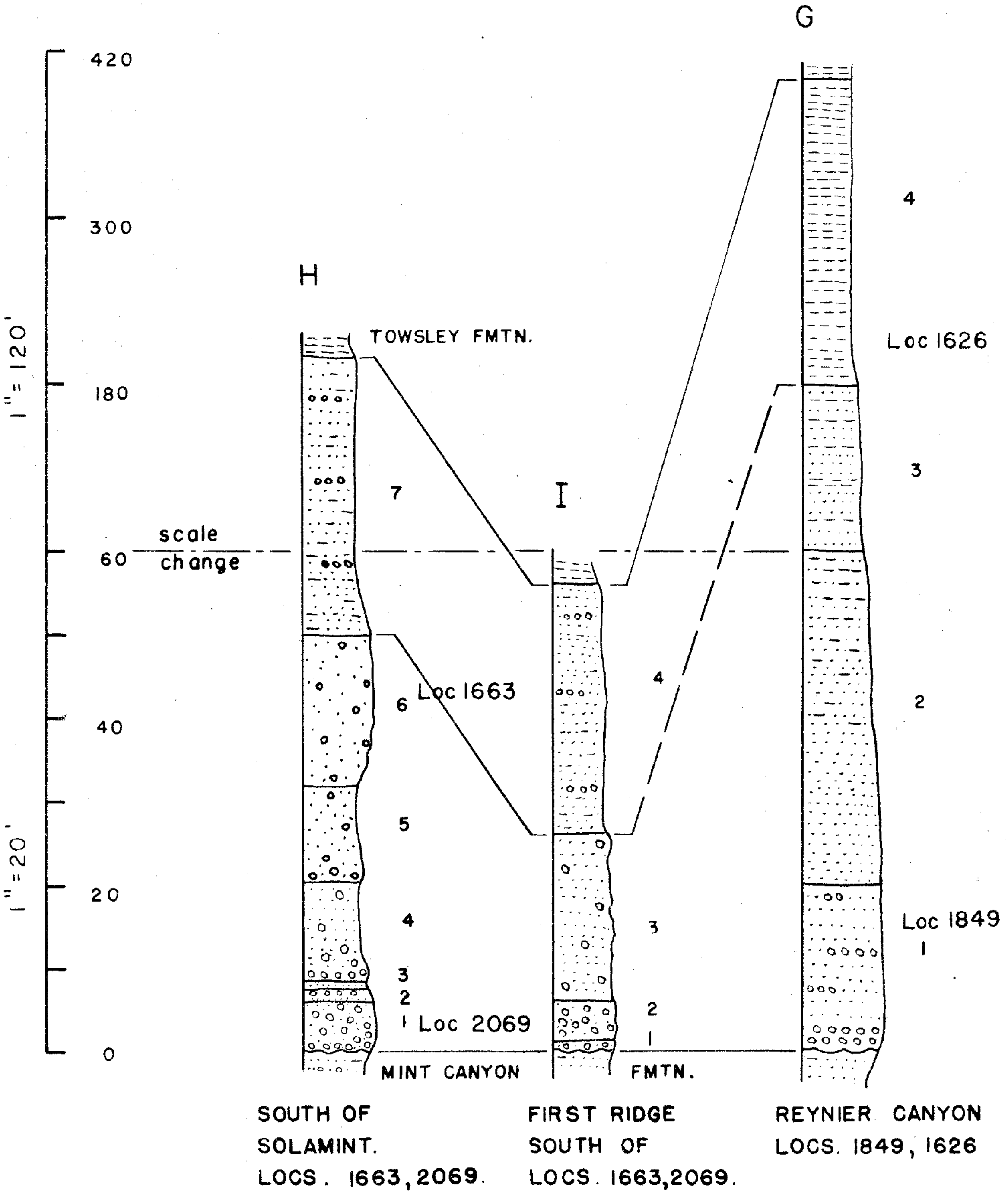


PLATE 5

CROSS SECTION -- BASAL SEDIMENTS OF THE CASTAIC FORMATION
AS EXPOSED ON THE NORTH SIDE OF
TRIANGLE RIDGE, CASTAIC CANYON.
compare with Pl. 37. one inch = 100 feet

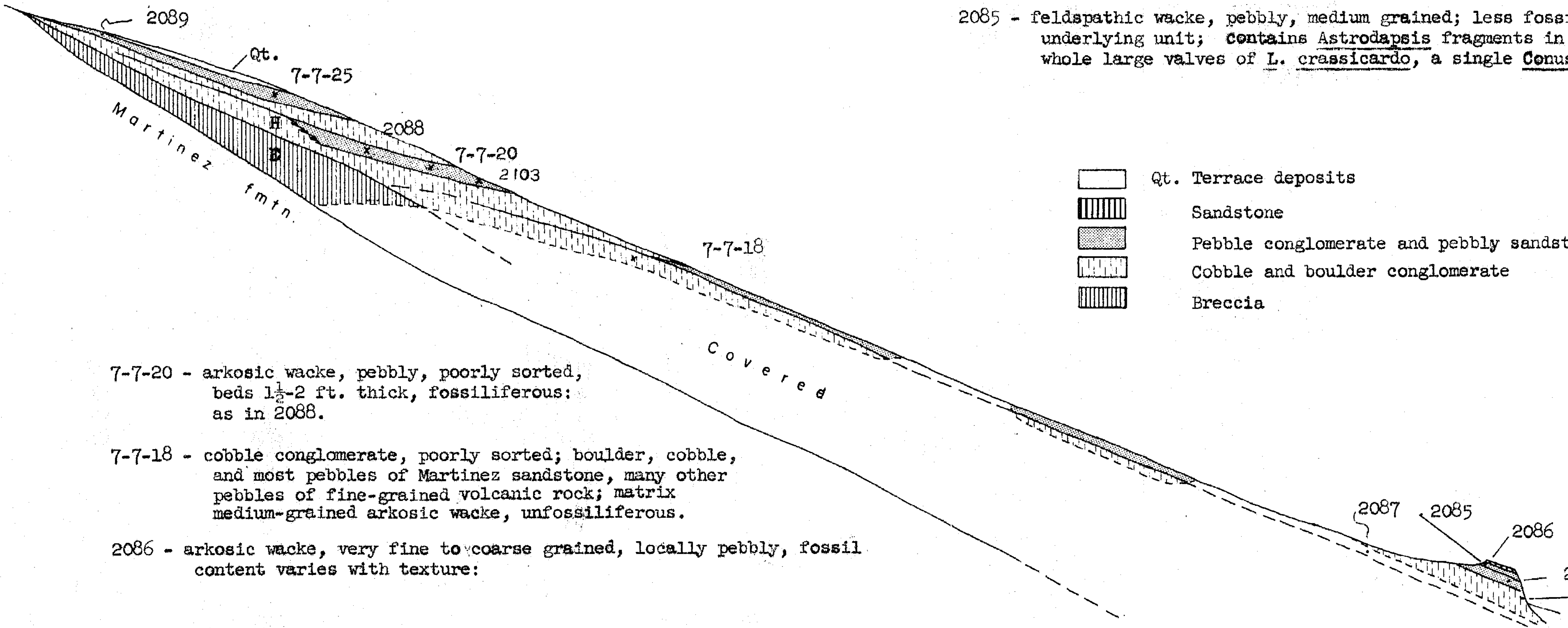
2089 - arkosic arenite, coarse grained, pebbly, beds 2-3 ft. thick, very fossiliferous: fragments and whole valves of *Lyropecten crassicardo* & *Crassostrea titan*. Fragments of indeterminate gastropods, pelecypods, and bone.

7-7-25 - pebble conglomerate, poorly bedded; pebbles primarily light colored fine-grained volcanic rocks, fossiliferous: fragments and whole valves of *L. crassicardo* & *C. titan*, no gastropods.

H - cobble-boulder conglomerate, poorly sorted, unfossiliferous.

2088 - arkosic wacke, medium grained, pebbly, poorly sorted, poorly bedded, pebbles = 10-15% of unit, fossiliferous: articulated *L. crassicardo*, fragments of *C. titan*; gastropods and bryozoan in pebble-free sand strata in addition.

E - breccia, unsorted, bedding vague to absent, matrix reddish, blocks composed of Martinez sandstone, unfossiliferous.



□ Qt. Terrace deposits
▥ Sandstone
▒ Pebble conglomerate and pebbly sandstone
▤ Cobble and boulder conglomerate
▥ Breccia

7-7-20 - arkosic wacke, pebbly, poorly sorted, beds 1½-2 ft. thick, fossiliferous: as in 2088.

7-7-18 - cobble conglomerate, poorly sorted; boulder, cobble, and most pebbles of Martinez sandstone, many other pebbles of fine-grained volcanic rock; matrix medium-grained arkosic wacke, unfossiliferous.

2086 - arkosic wacke, very fine to coarse grained, locally pebbly, fossil content varies with texture:

2083 - cobble conglomerate, scattered boulders as large as 2 ft. in diam. clasts largely of Martinez sandstone, fossiliferous, all forms largely fragmental, *L. crassicardo* & *C. titan* predominant

2084 - arkosic wacke, pebbly, medium to fine grained; pebble content decreases upwards; articulated *L. crassicardo* common in sandstone beds, *Astrodapsis* fragments in pebbly beds

2085 - feldspathic wacke, pebbly, medium grained; less fossiliferous than underlying unit; contains *Astrodapsis* fragments in lenses, whole large valves of *L. crassicardo*, a single *Conus* sp.

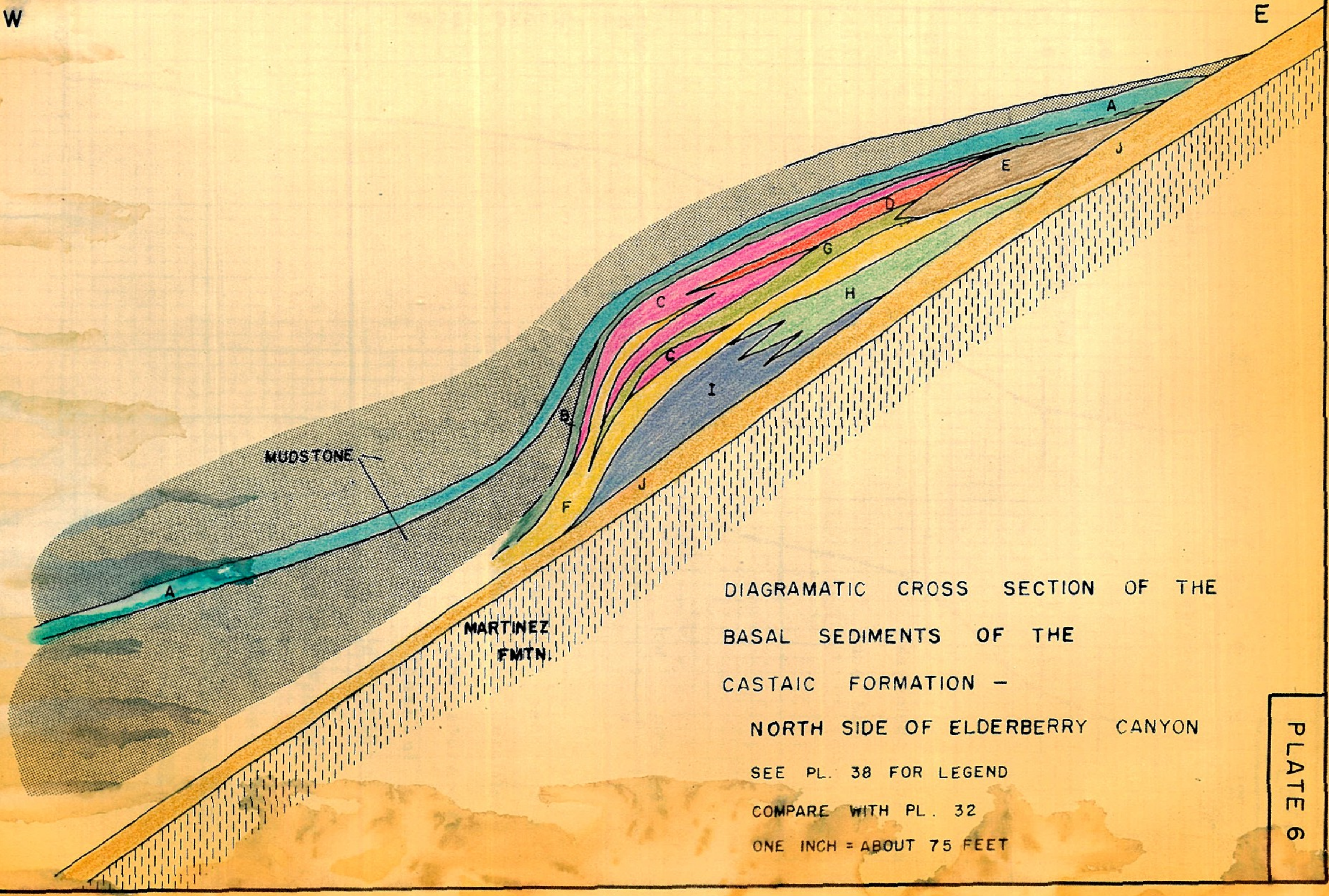


PLATE 6

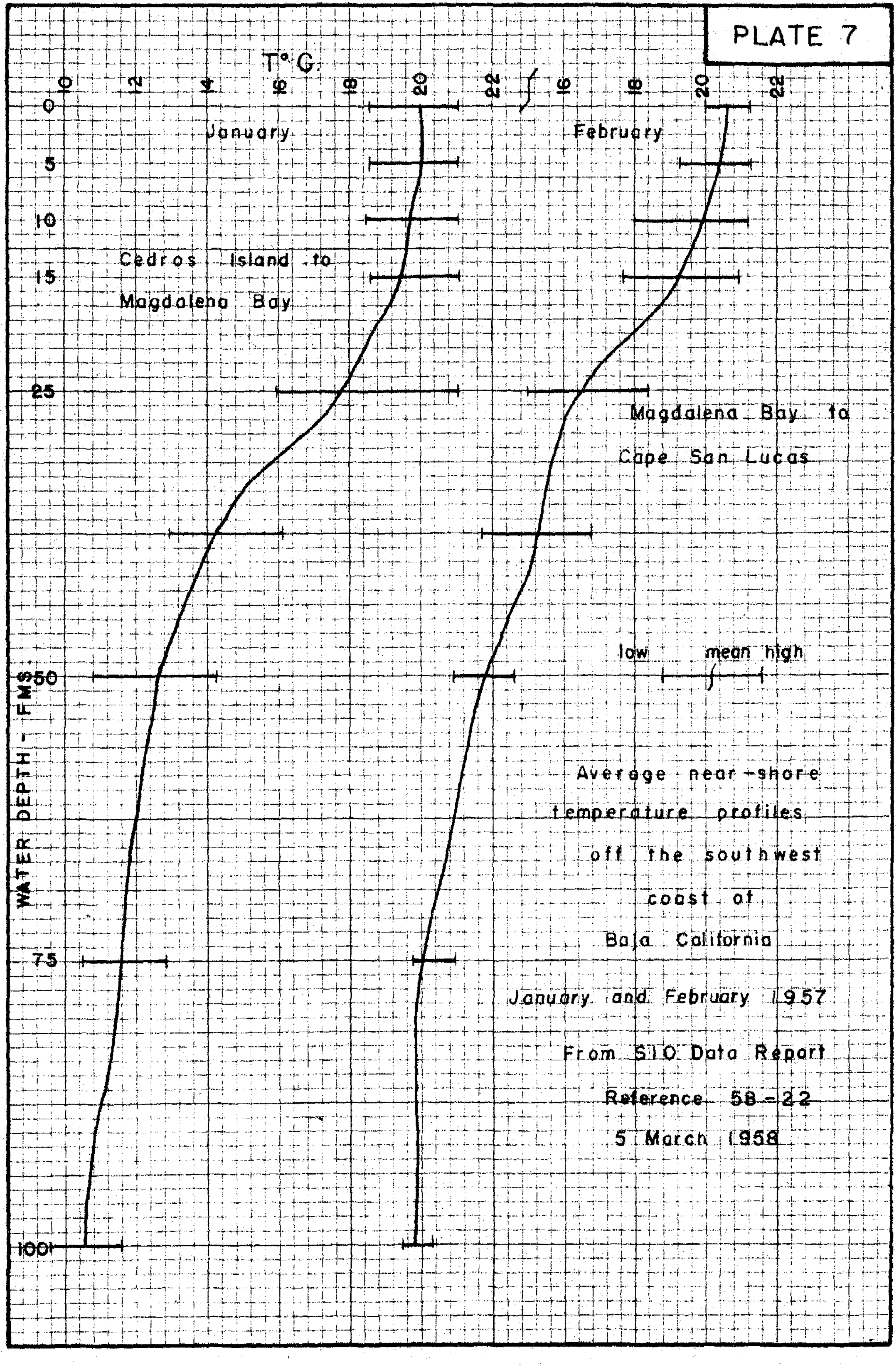
DIAGRAMATIC CROSS SECTION OF THE
BASAL SEDIMENTS OF THE
CASTAIC FORMATION –
NORTH SIDE OF ELDERBERRY CANYON

SEE PL. 38 FOR LEGEND

COMPARE WITH PL. 32

ONE INCH = ABOUT 75 FEET

PLATE 7

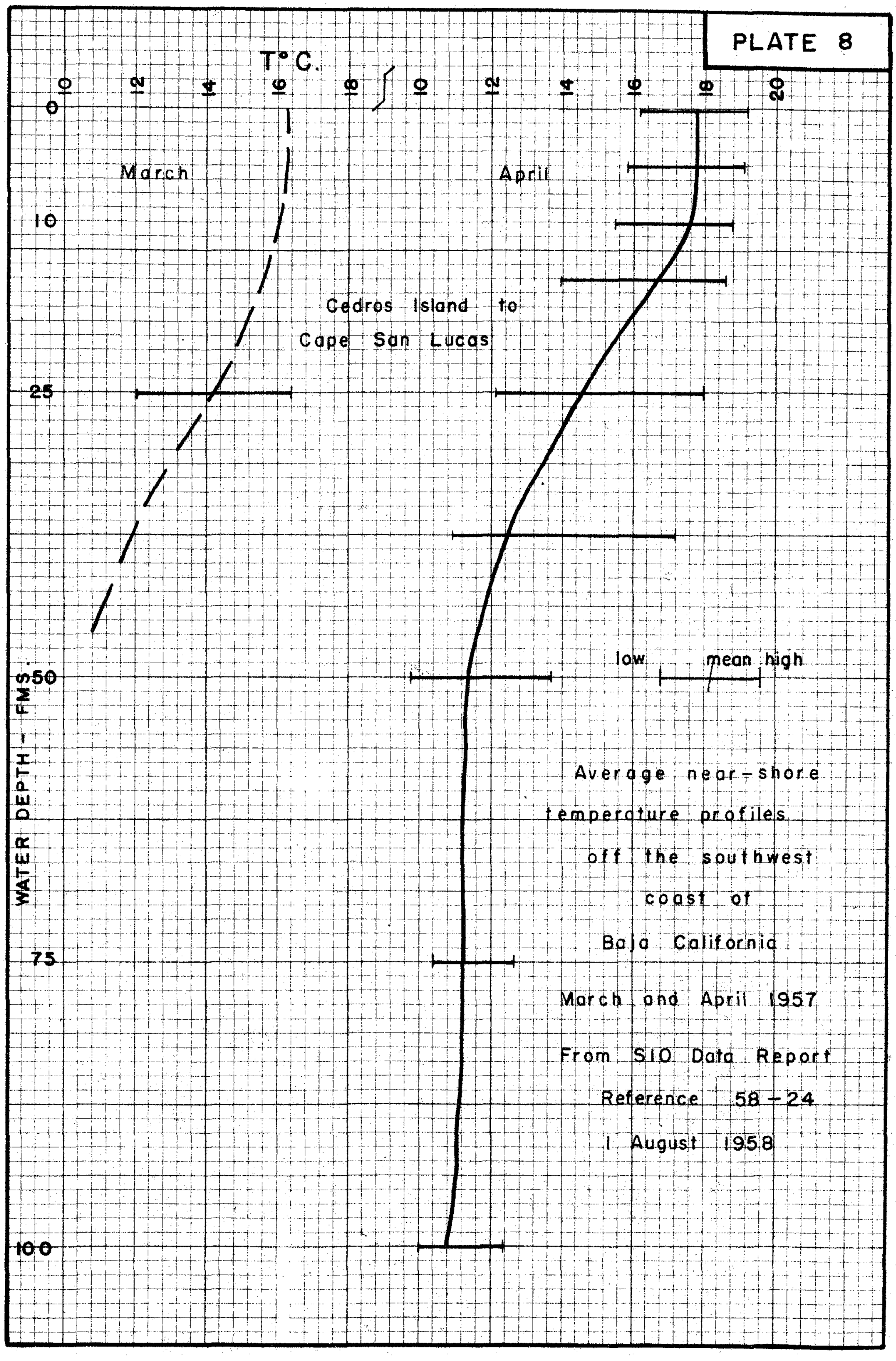


Average near-shore
temperature profiles
off the southwest
coast of
Baja California

January and February 1957

From SIO Data Report
Reference 58-22
5 March 1958

PLATE 8



Average near-shore temperature profiles off the southwest coast of Baja California

March and April 1957

From SIO Data Report
Reference 58 – 24
1 August 1958

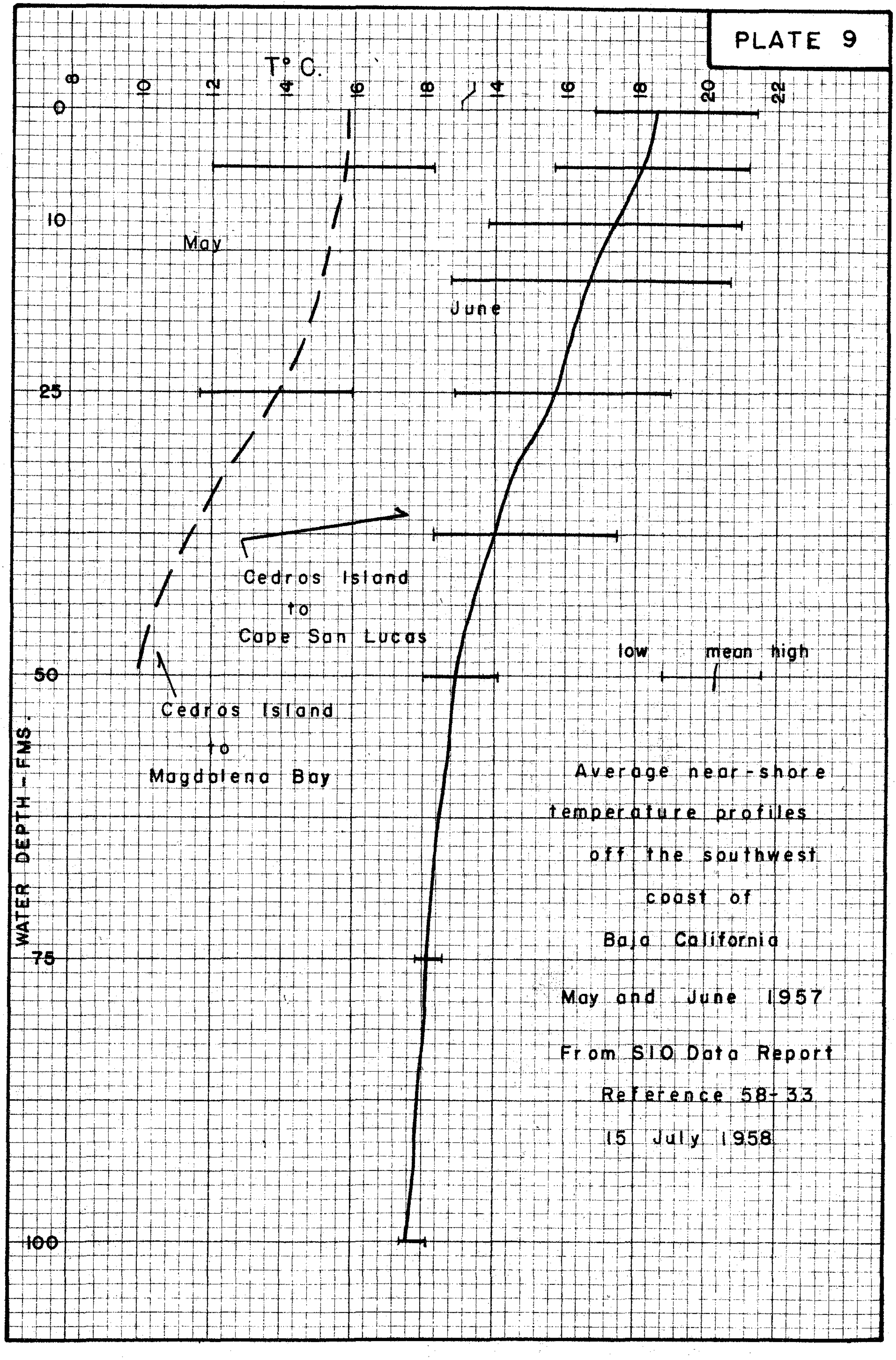


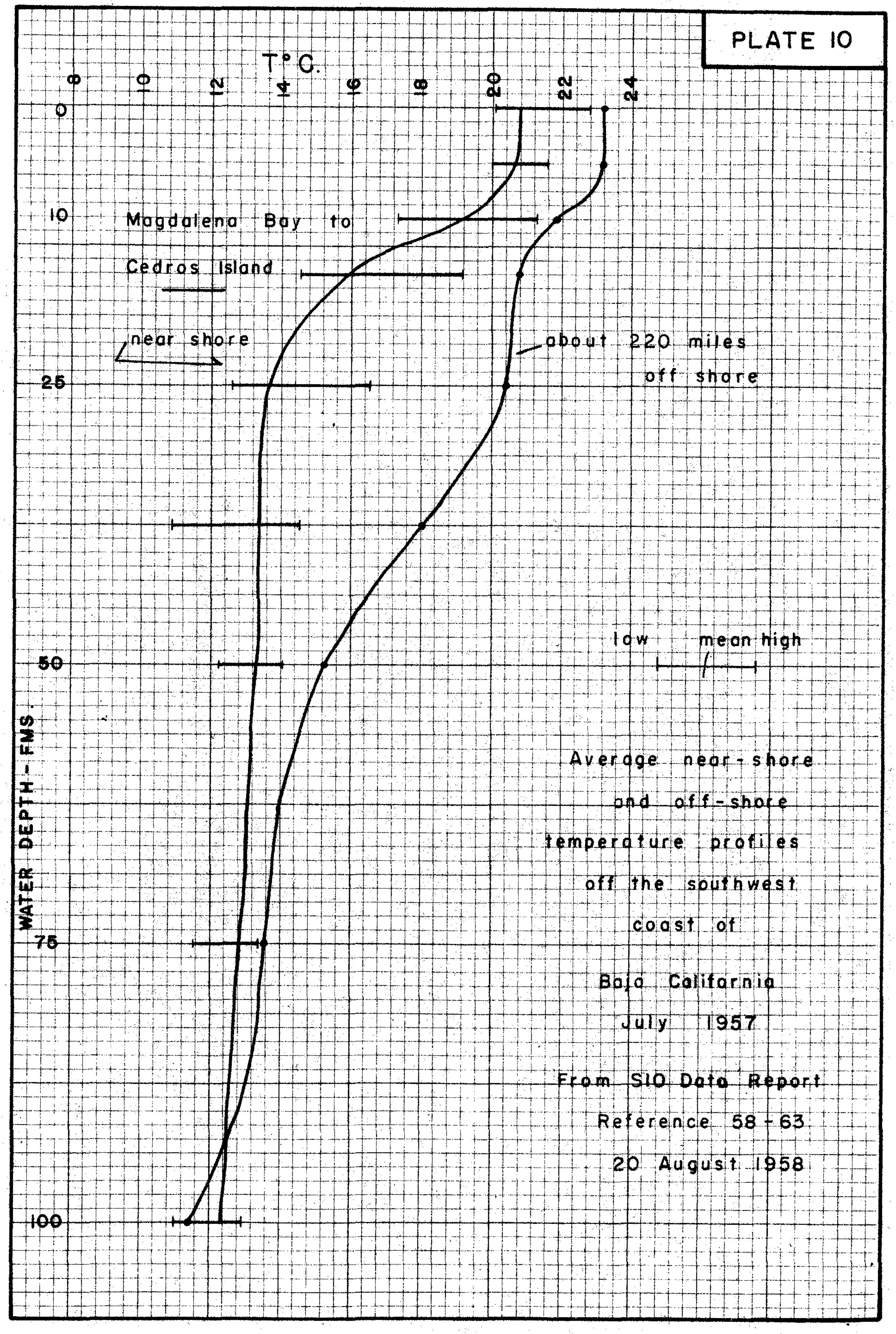
PLATE 9

Average near-shore temperature profiles off the southwest coast of Baja California

May and June 1957

From SIO Data Report Reference 58-33 15 July 1958

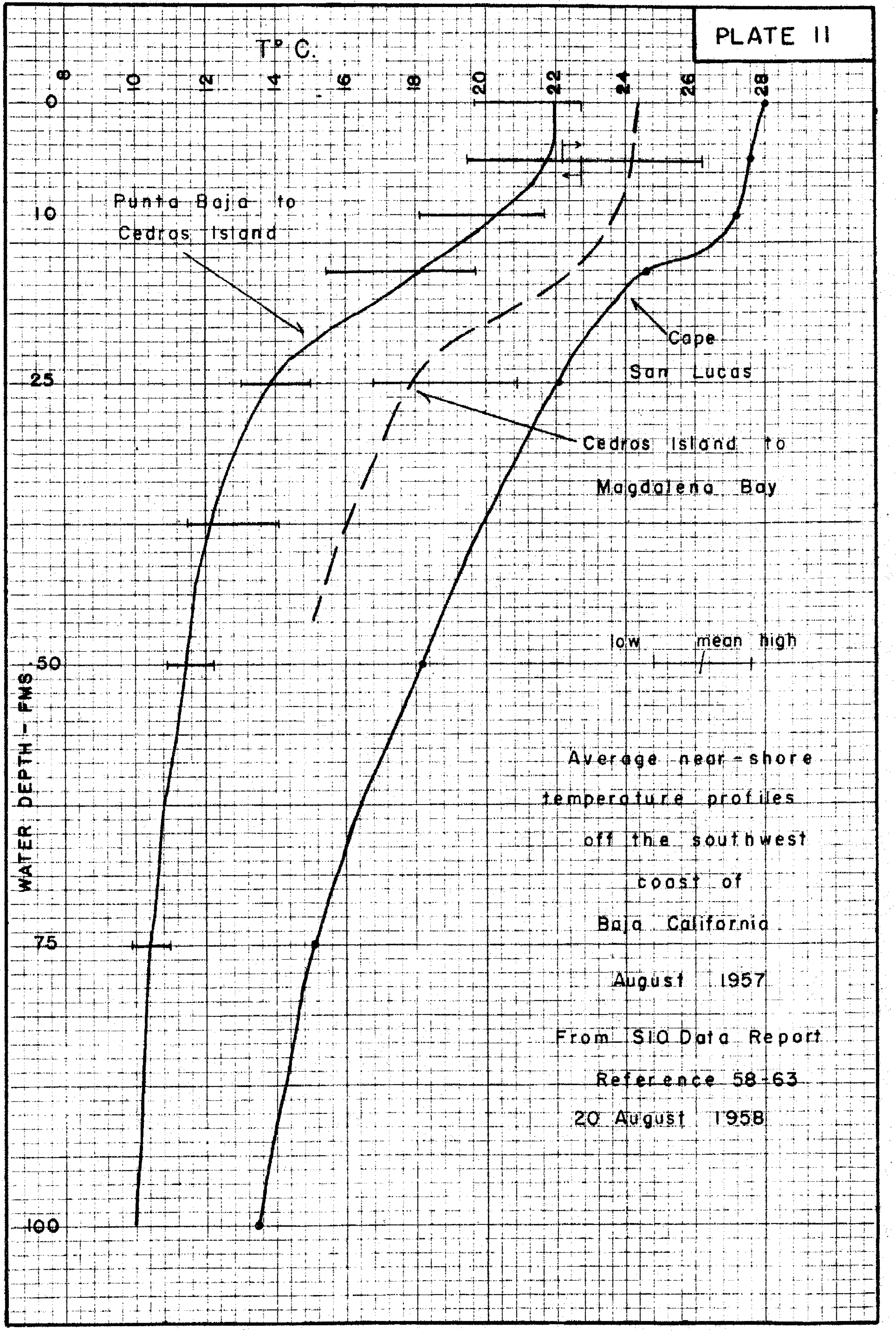
PLATE 10



Average near-shore and off-shore temperature profiles off the southwest coast of Baja California July 1957

From SIO Data Report Reference 58-63 20 August 1958

PLATE II



Average near-shore temperature profiles off the southwest coast of Baja California

August 1957

From SIO Data Report Reference 58-63 20 August 1958

PLATE 12

10 METER TEMPERATURE °C.

FEBRUARY 1957

From SIO Reference 58-22
5 March 1958

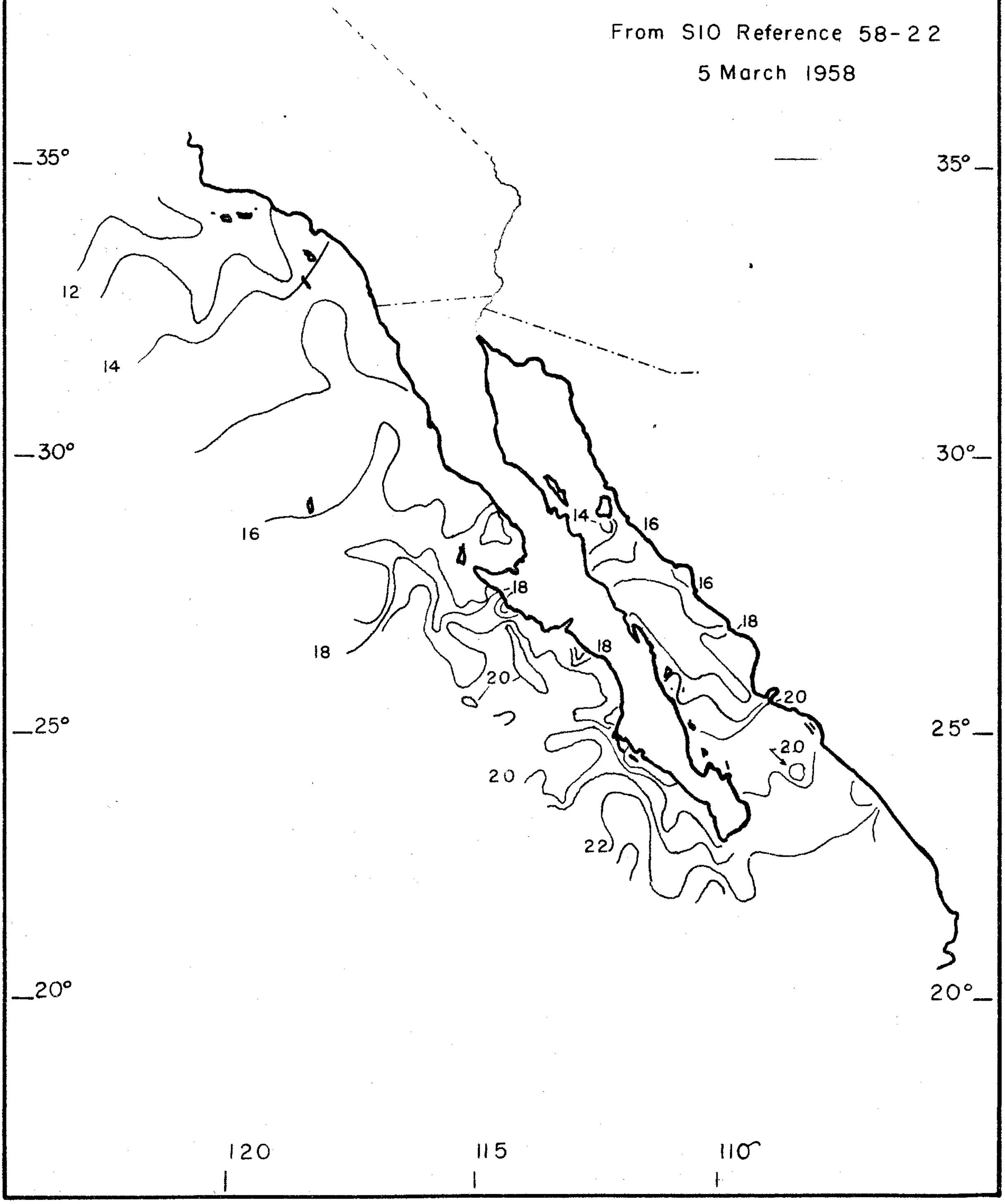
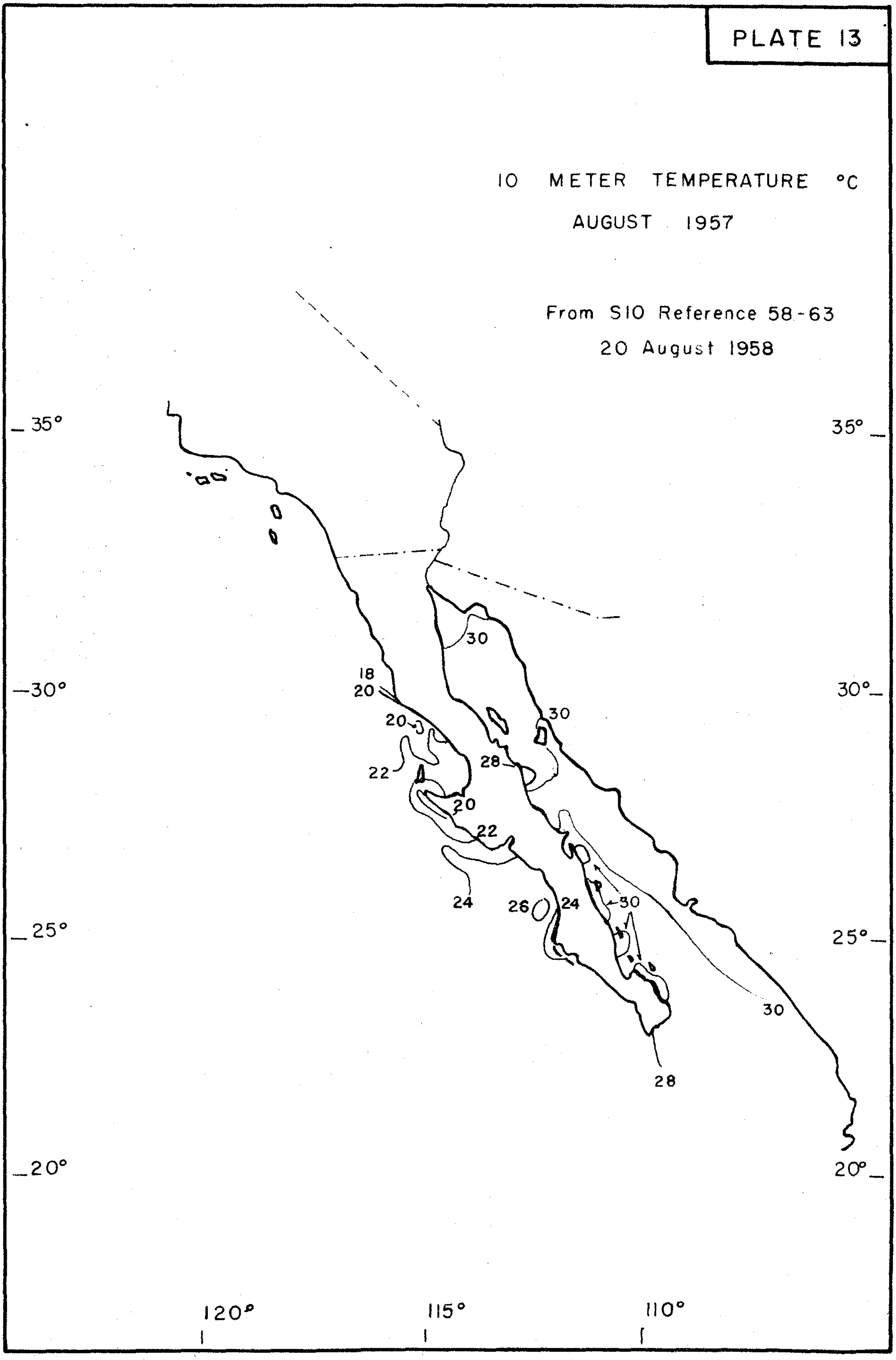


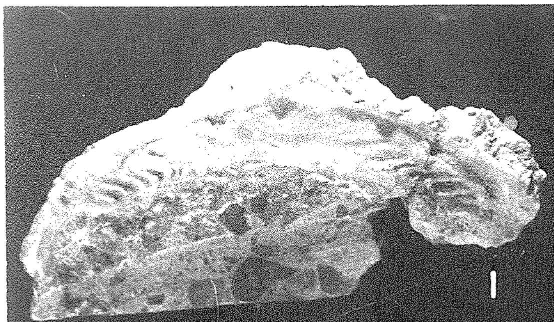
PLATE 13



10 METER TEMPERATURE °C
AUGUST 1957

From SIO Reference 58-63
20 August 1958

PLATE 14



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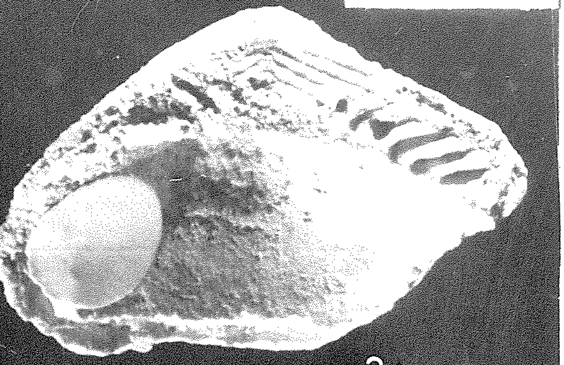
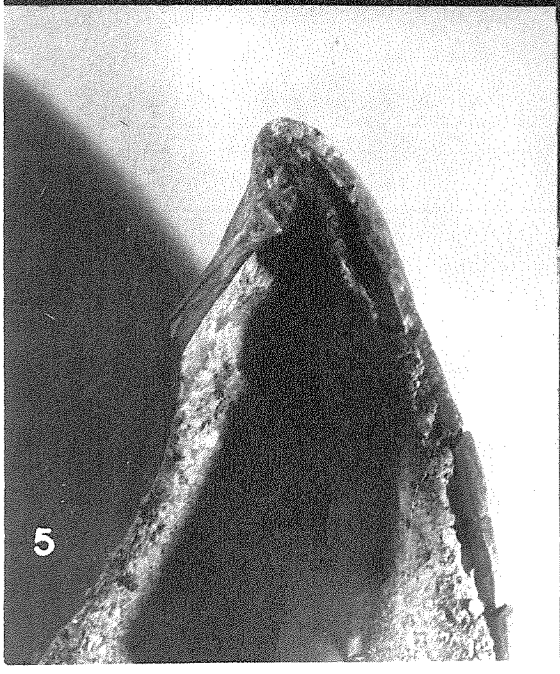


2A

3

4



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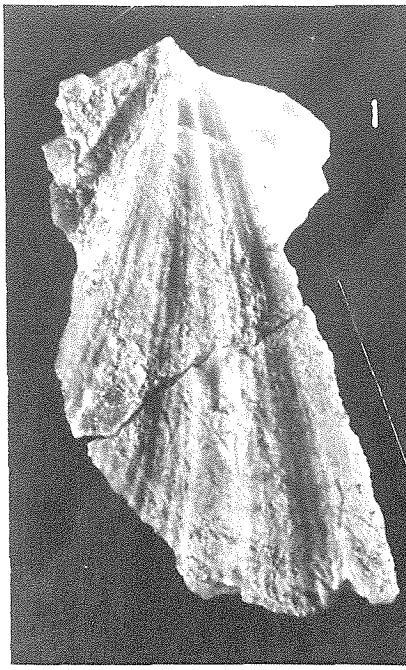
2B

PLATE 15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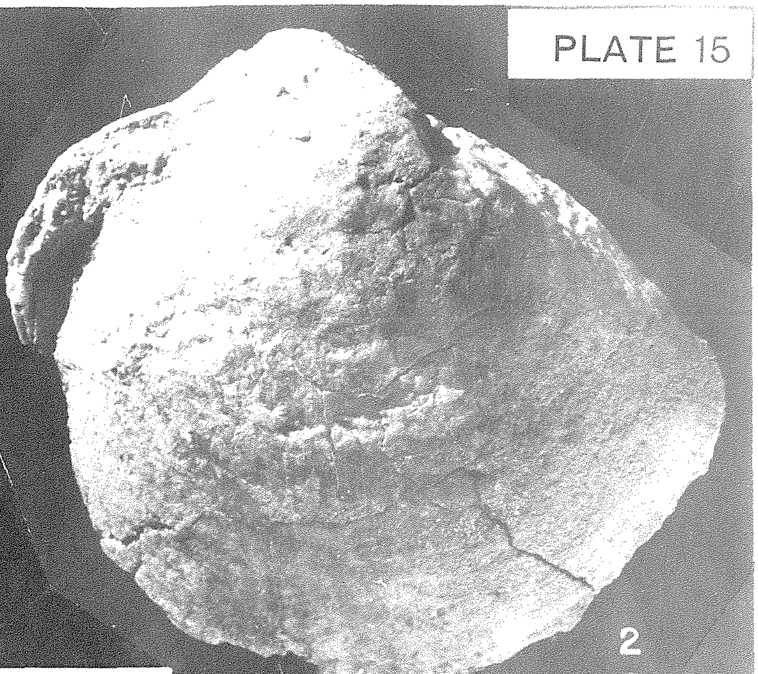
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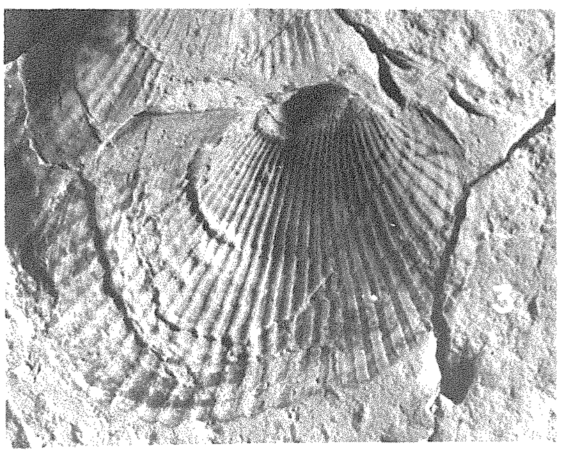
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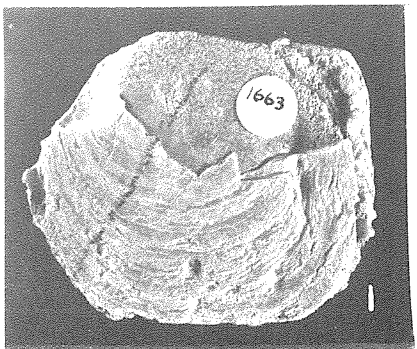
4


5


6

PLATE 16



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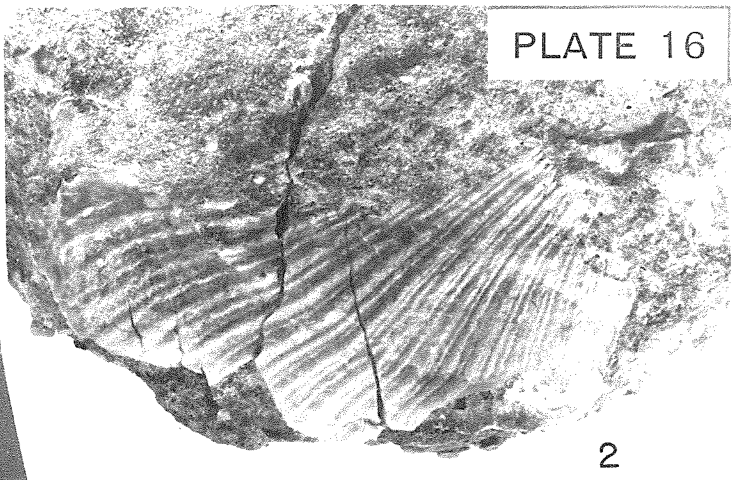
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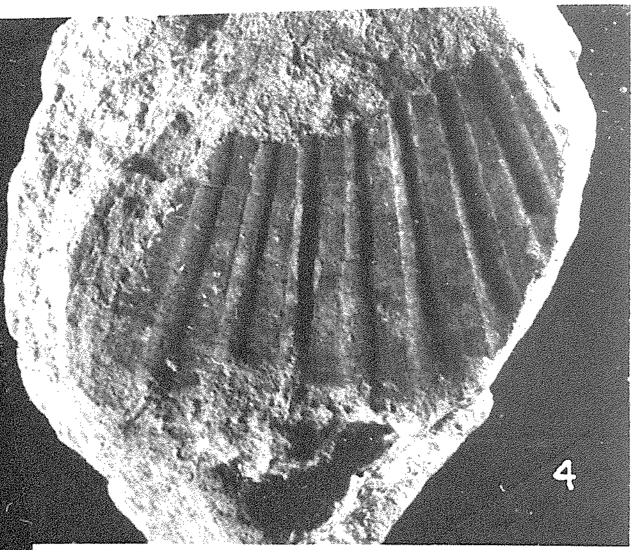
3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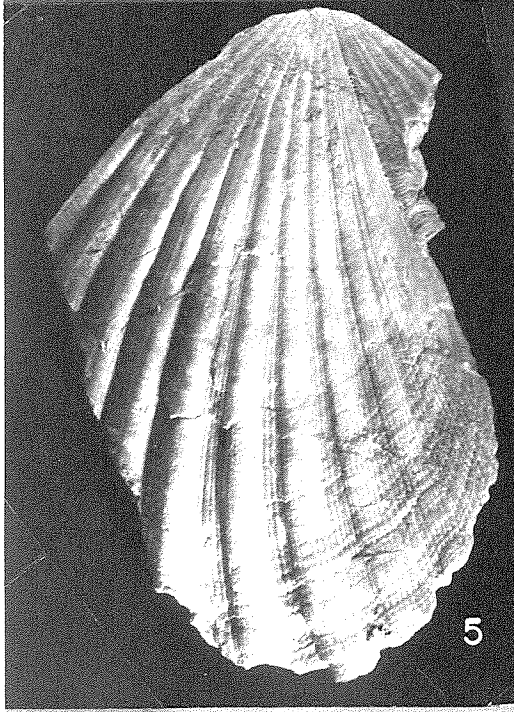
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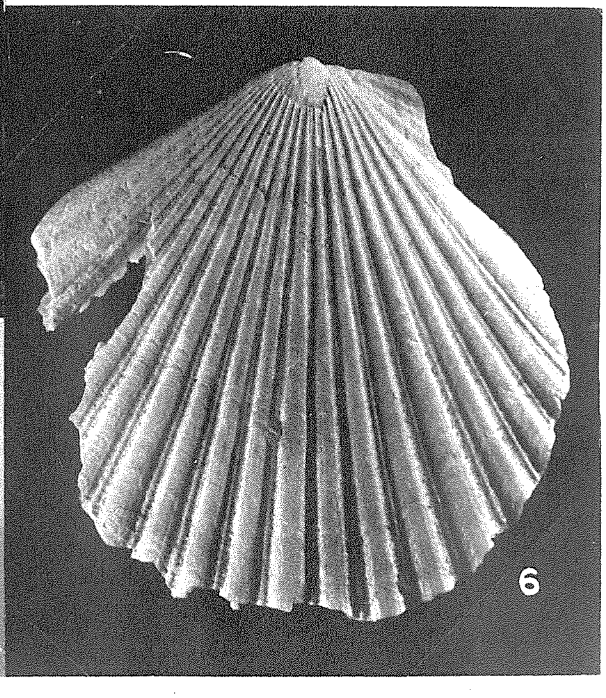
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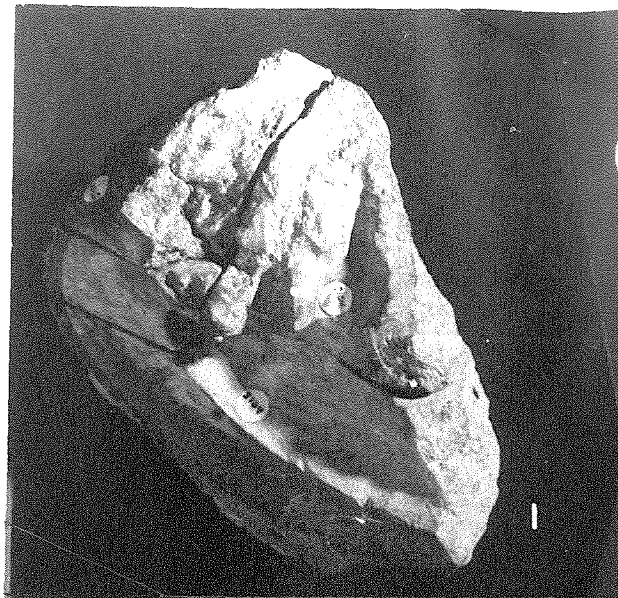
7

PLATE 17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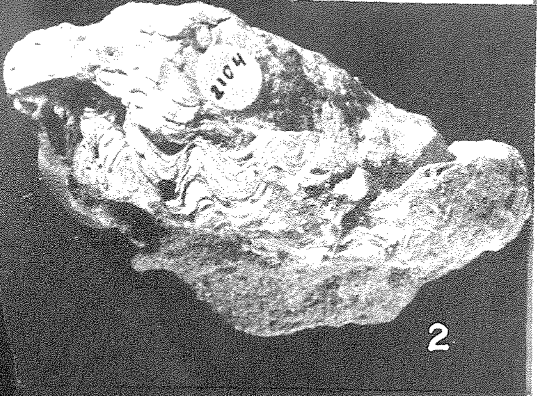

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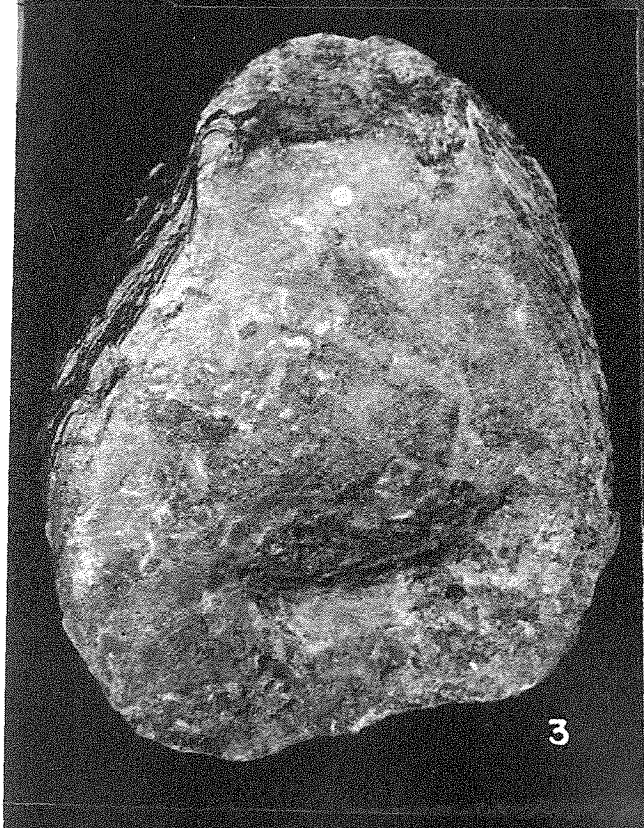
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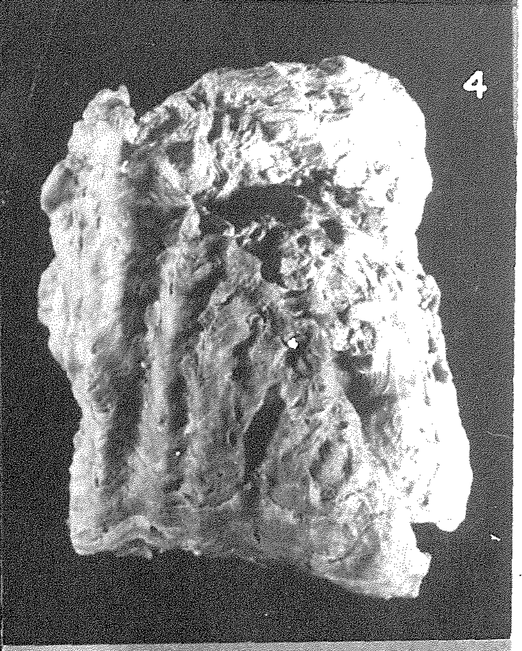
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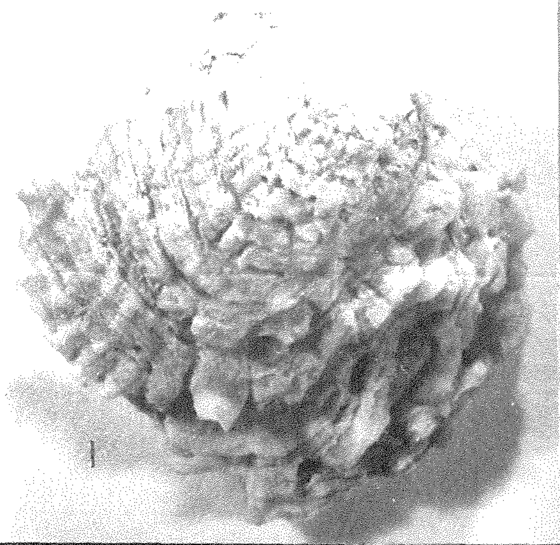
5


6


7

PLATE 18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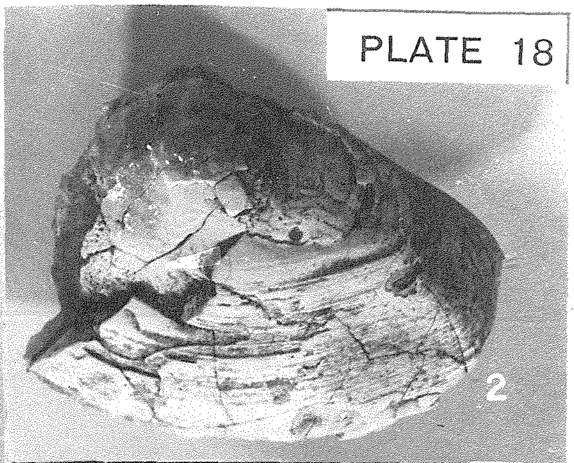
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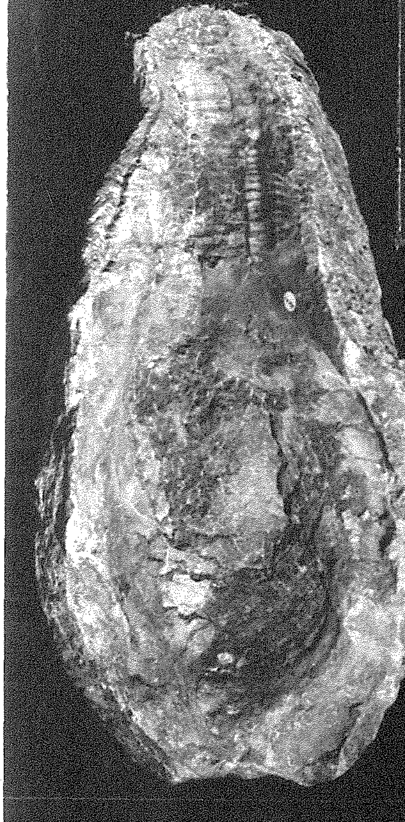
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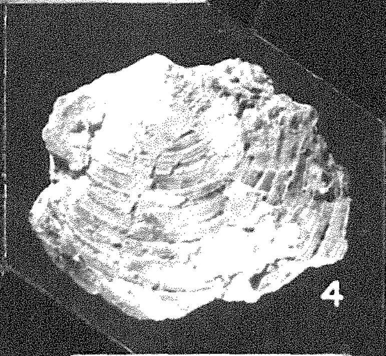
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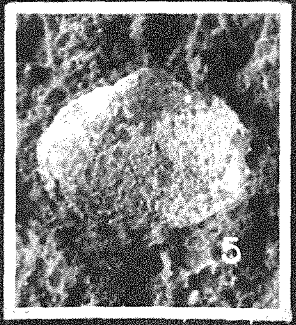
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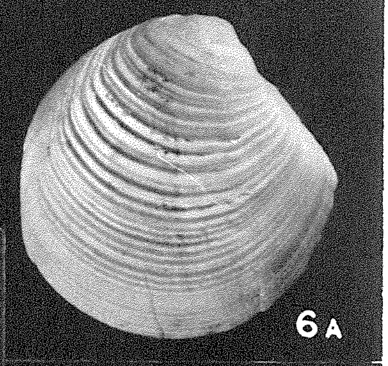
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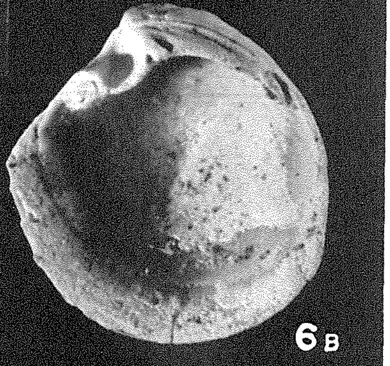
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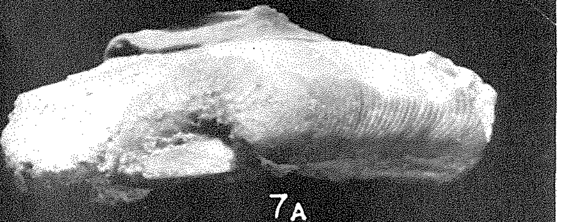
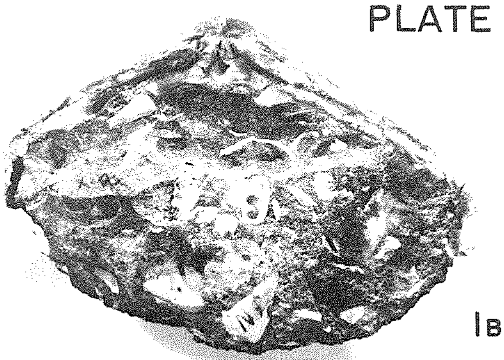

7A

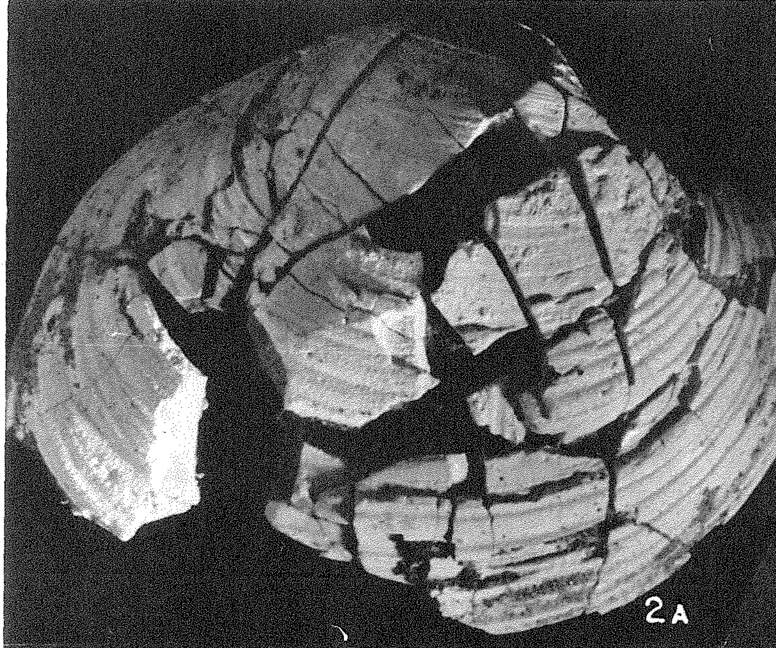

8


7B

PLATE 19


1A


1B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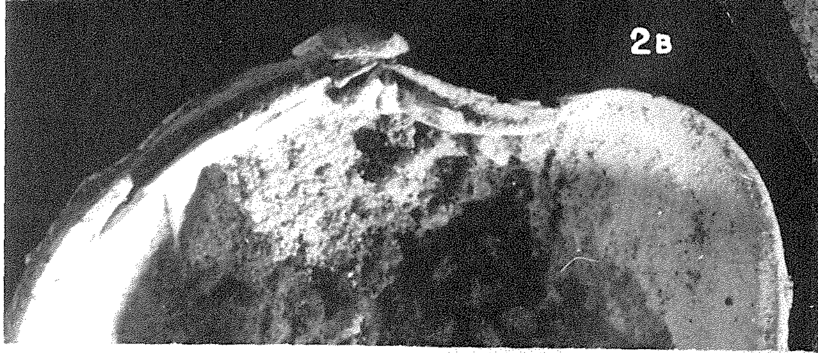
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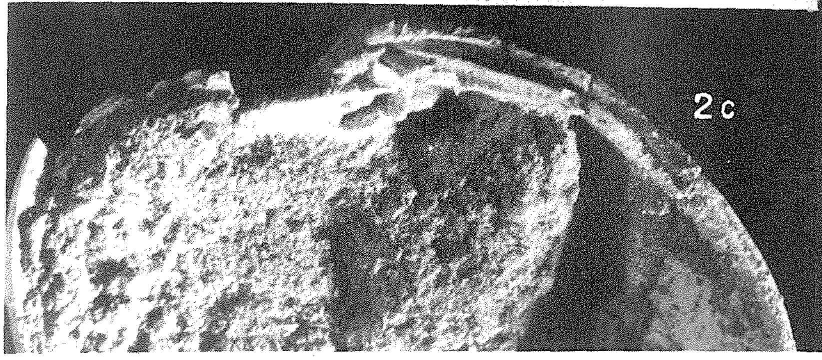
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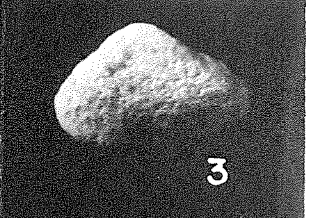
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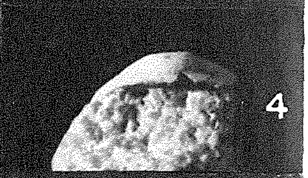
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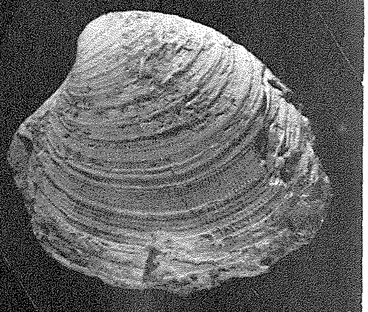
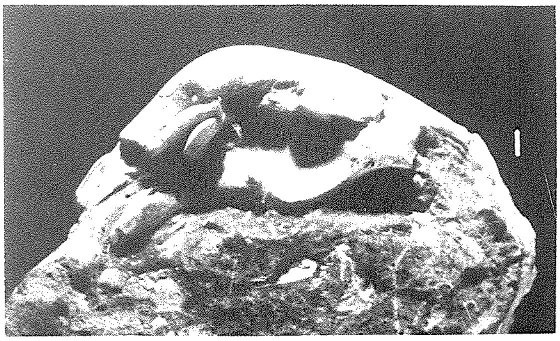

5A


5B

PLATE 20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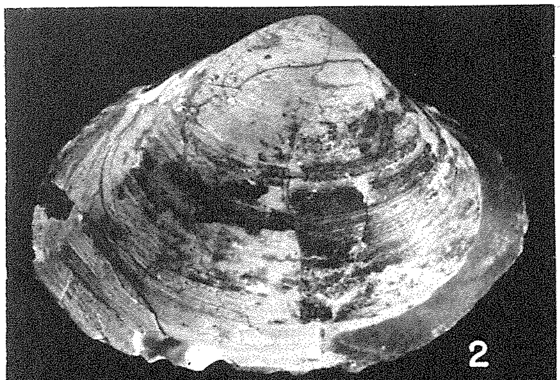
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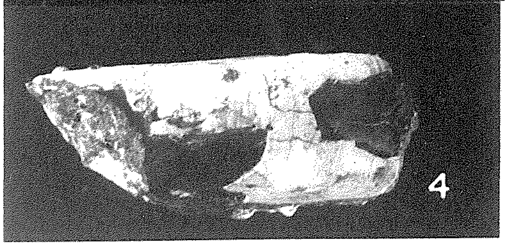
3A


3B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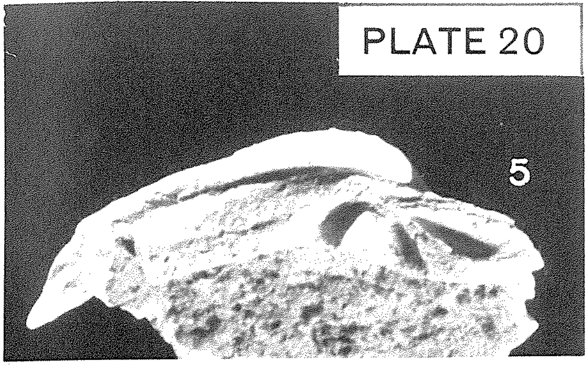
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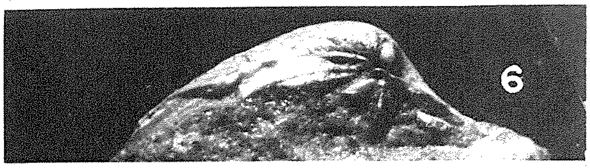
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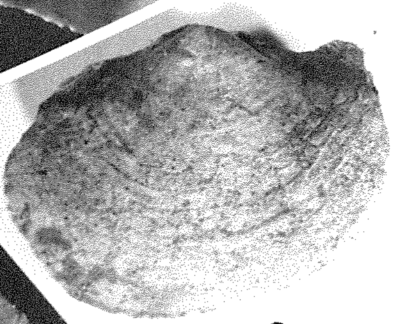
7


8A


8B

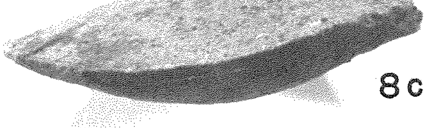

8C

PLATE 21

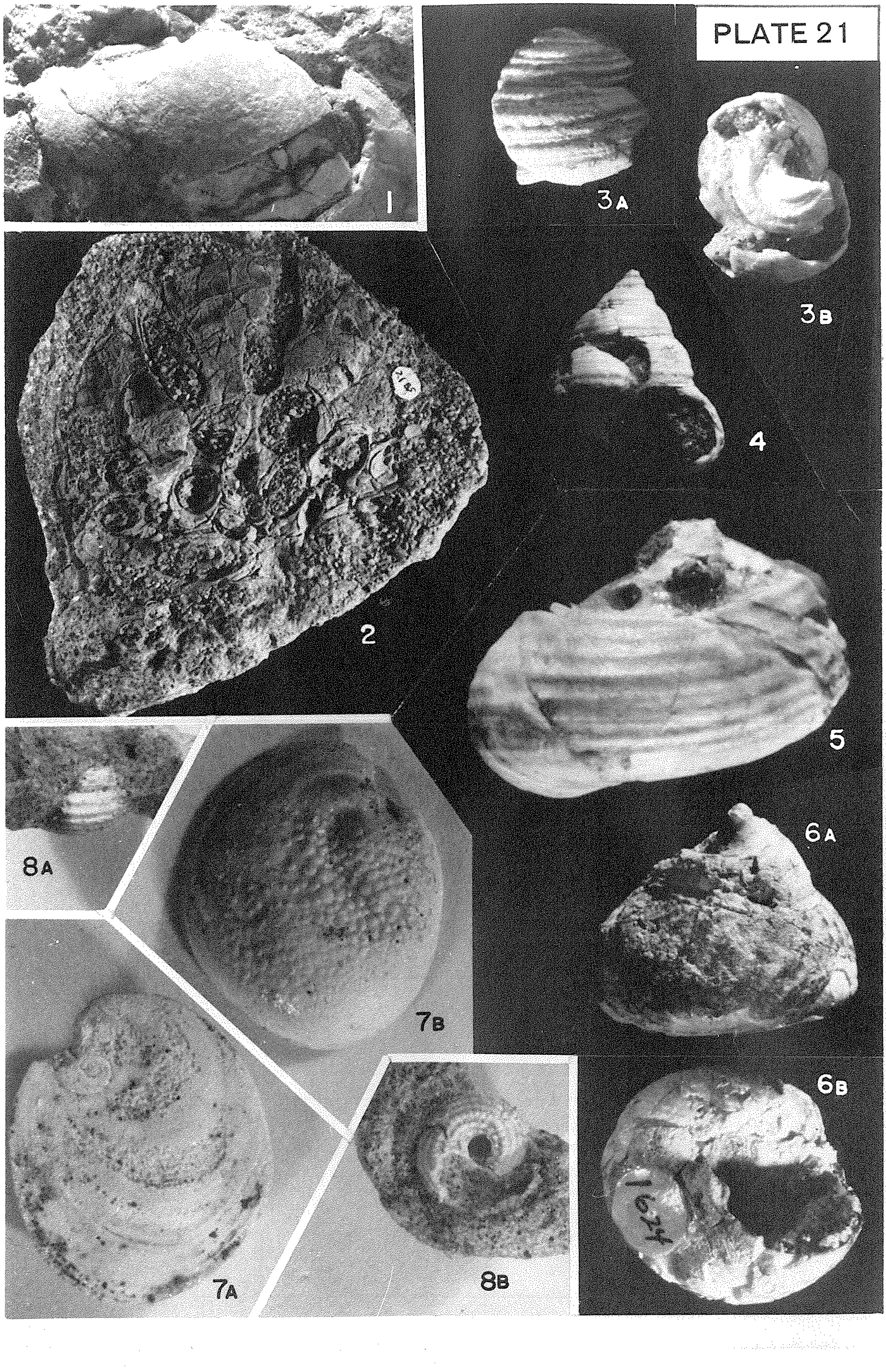
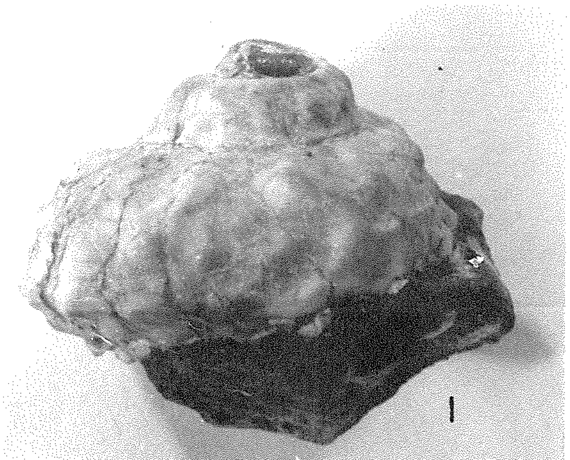


PLATE 22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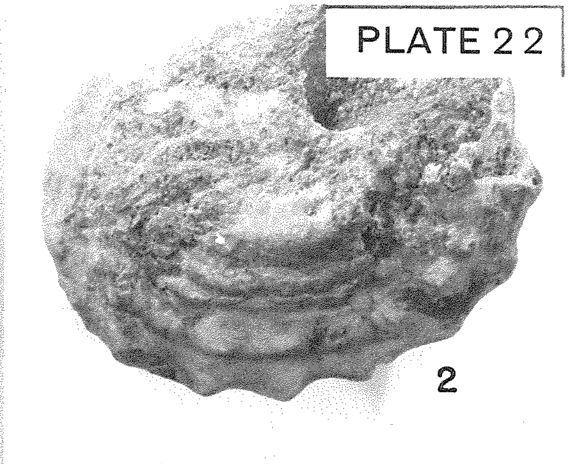
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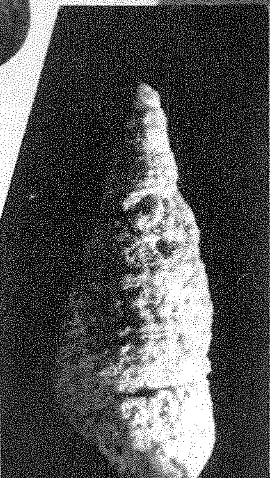
4


3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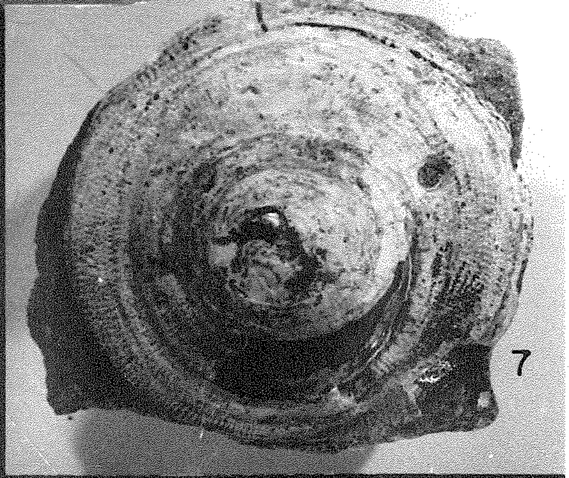
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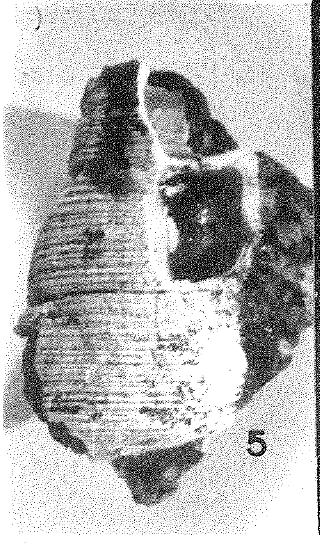
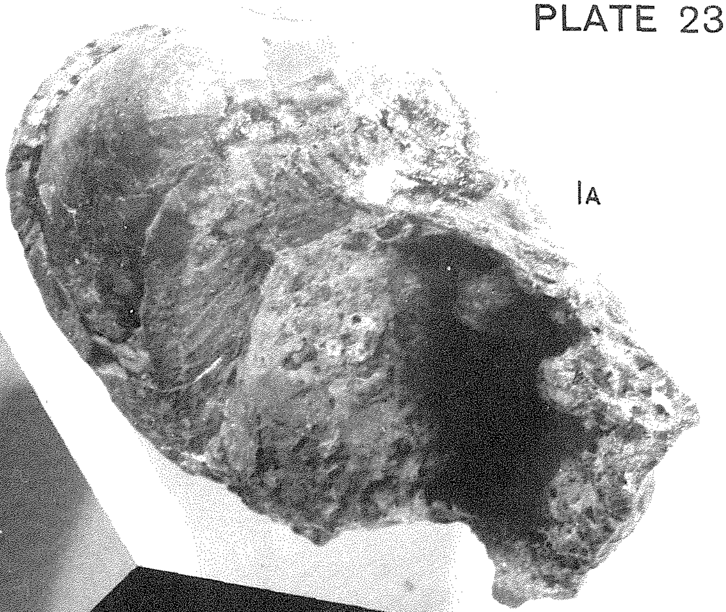

5


8

PLATE 23



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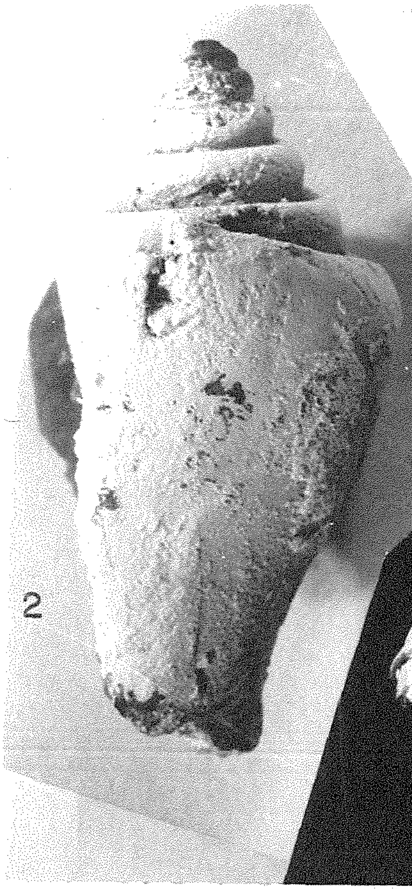

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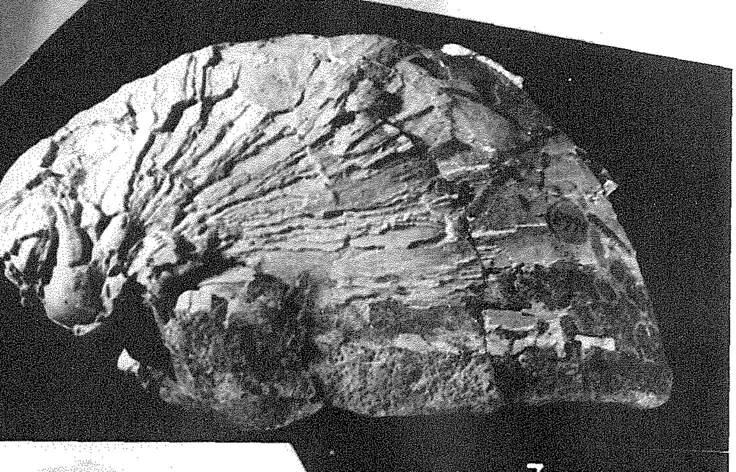

3

1B

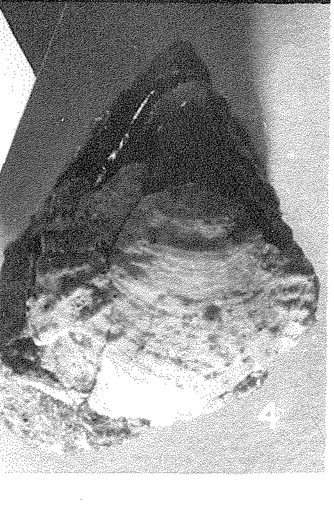

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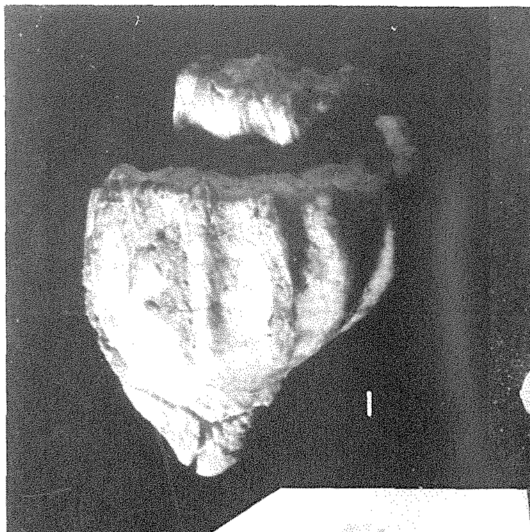
PLATE 24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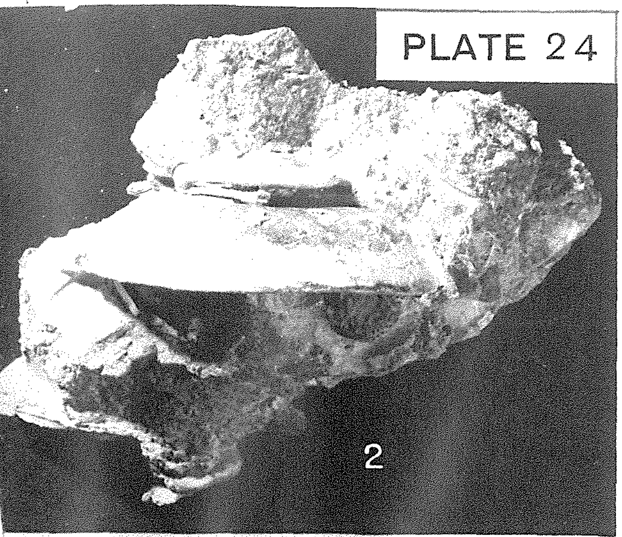
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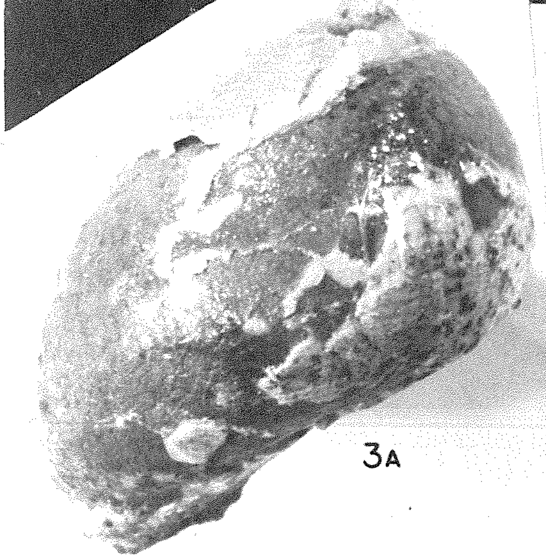
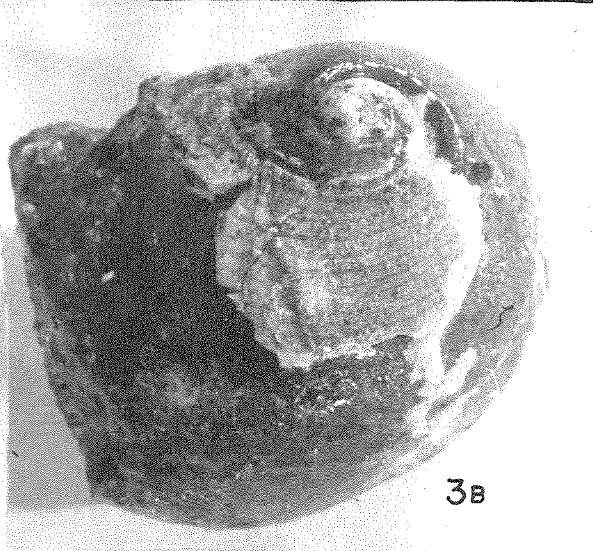
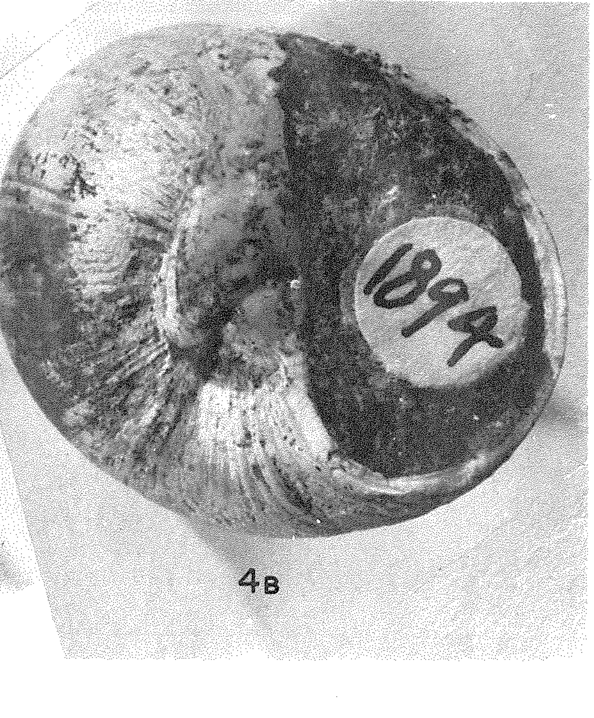

3A


3B

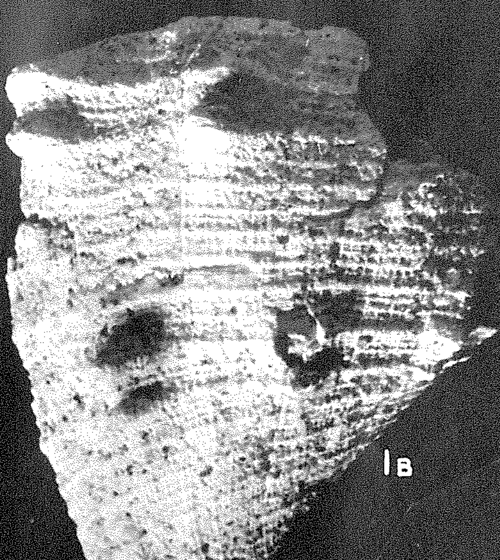
4A



4B

PLATE 25

1A

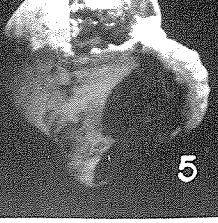


1B

3

1C

4



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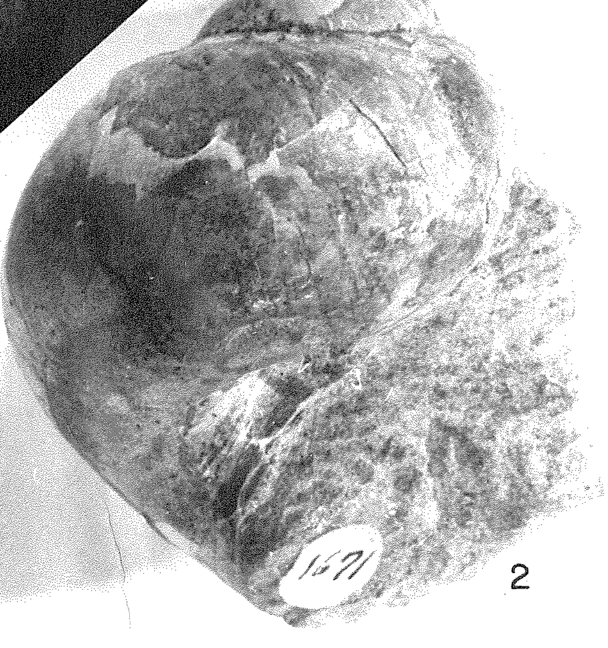

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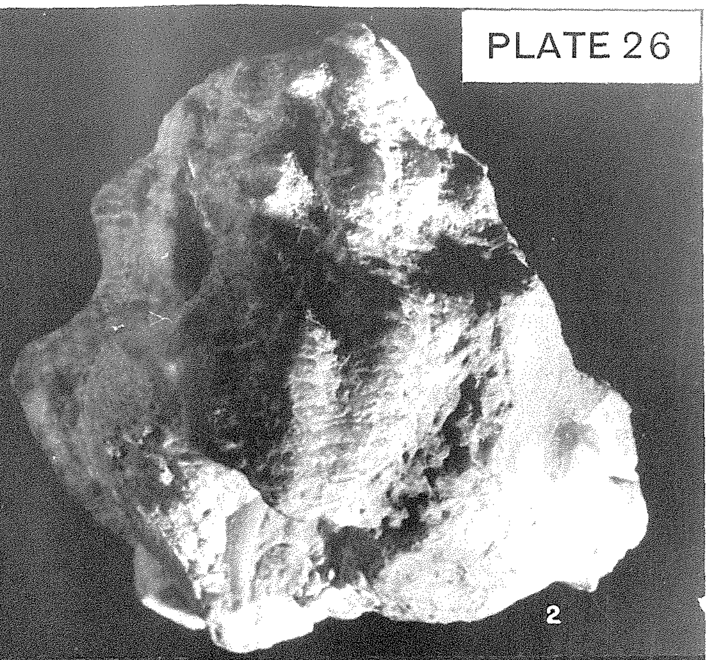
PLATE 26

1



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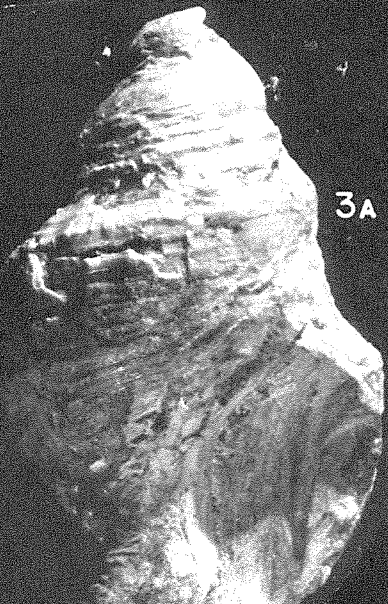

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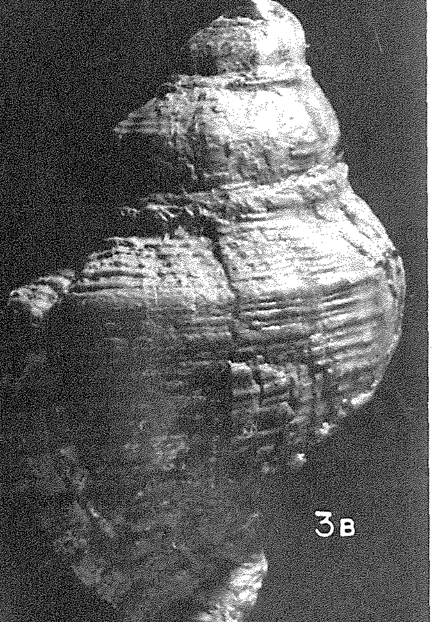

3B

4

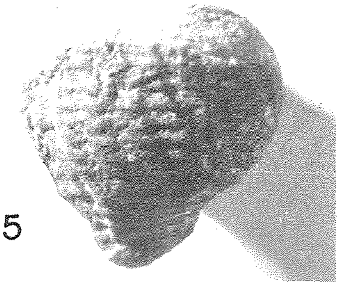

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PLATE 27

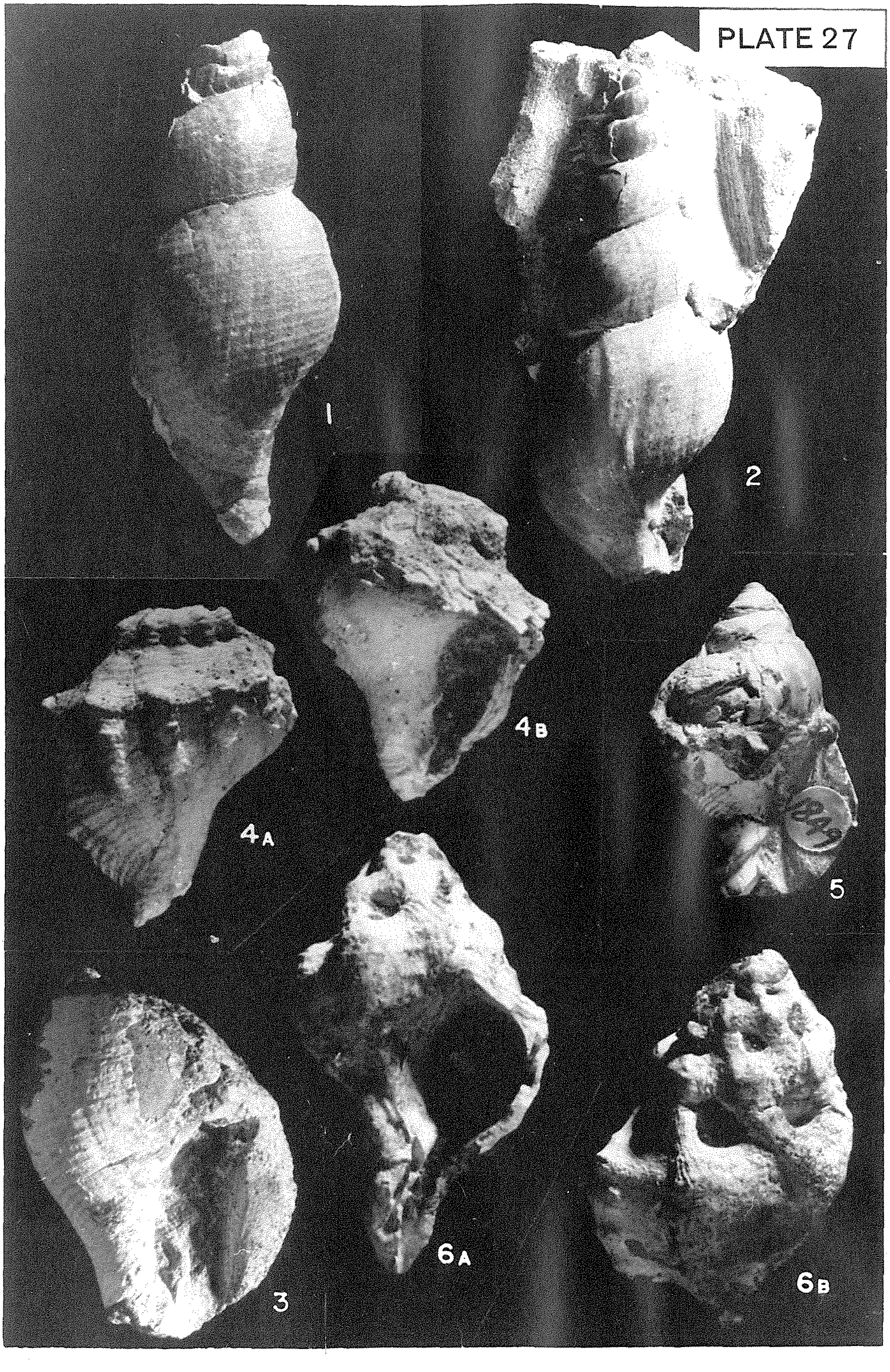
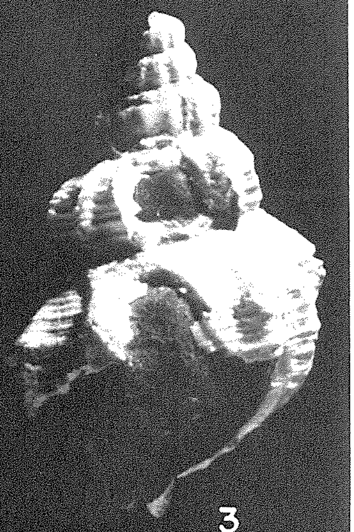


PLATE 28


1


2


3

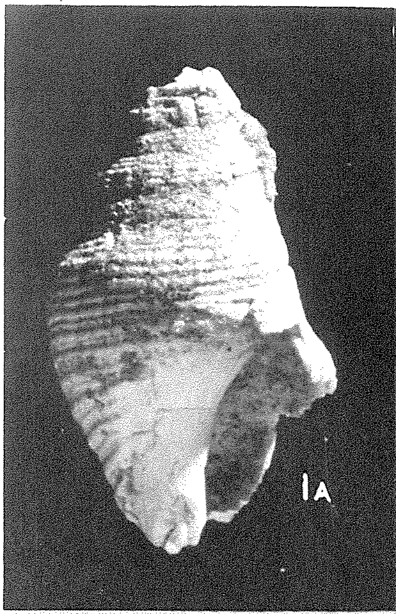

4A


5A

4B


5B

PLATE 29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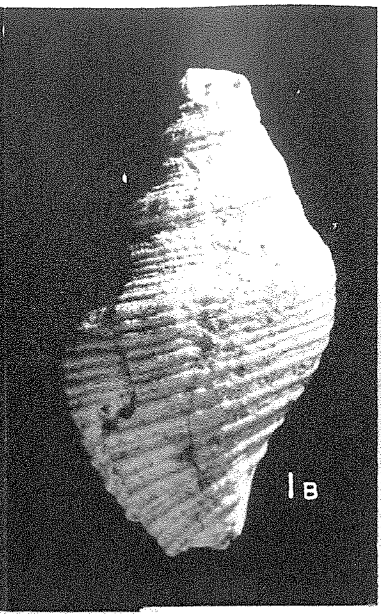
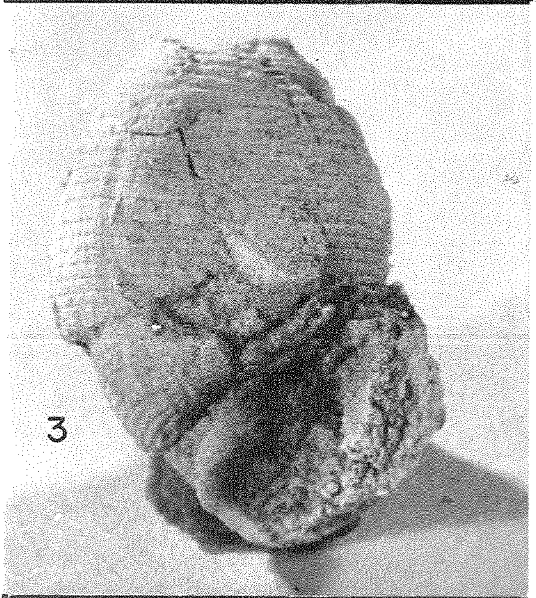

1B


2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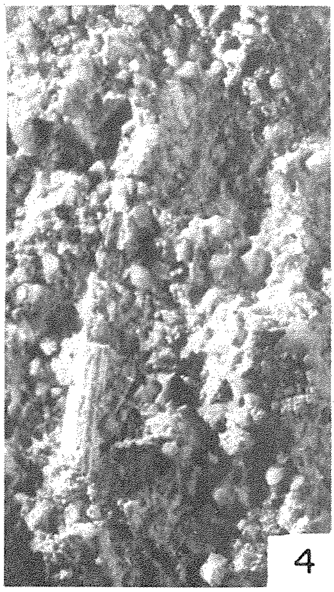
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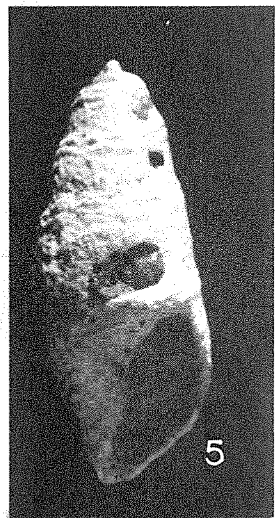
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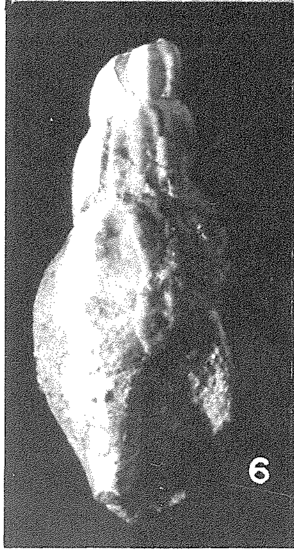
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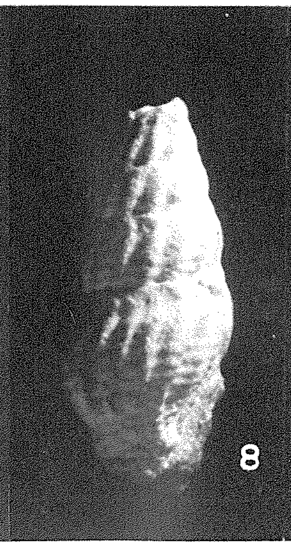
7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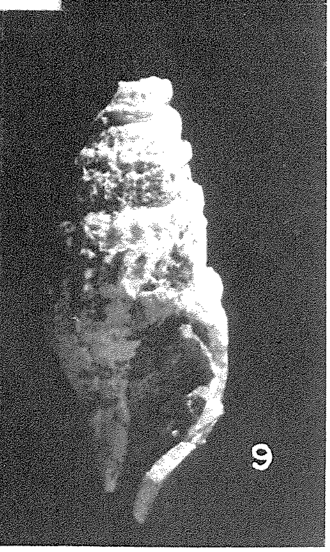
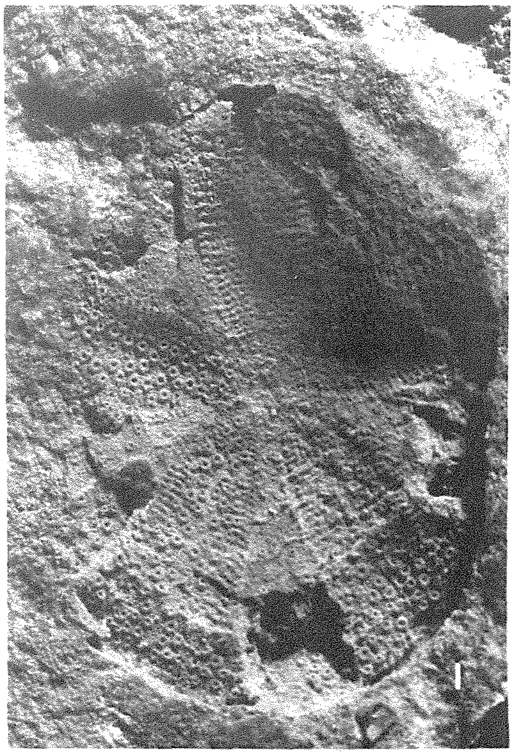

9

PLATE 30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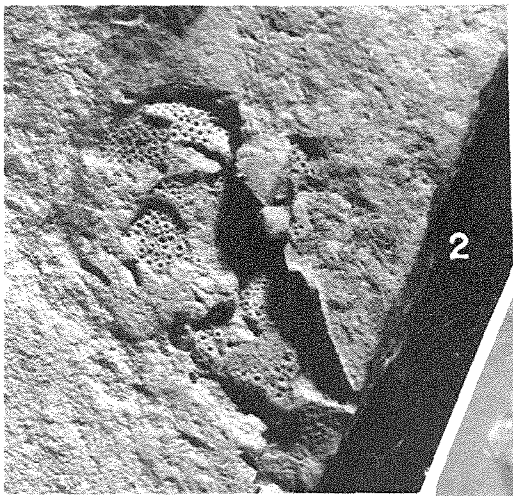
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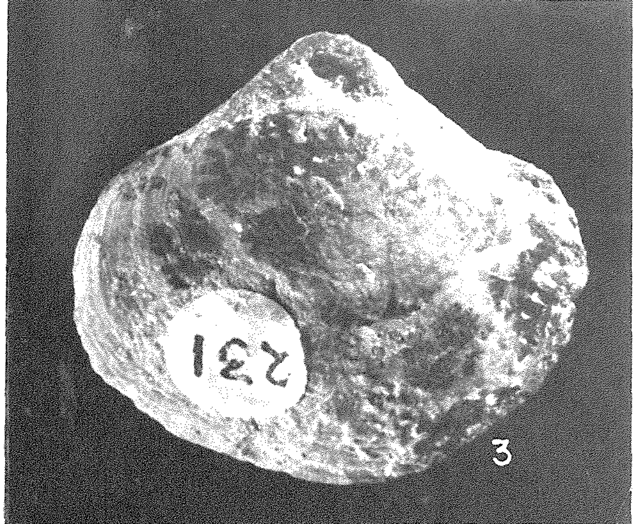

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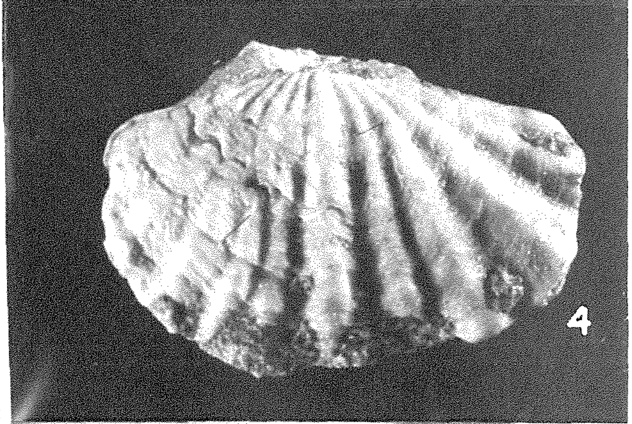
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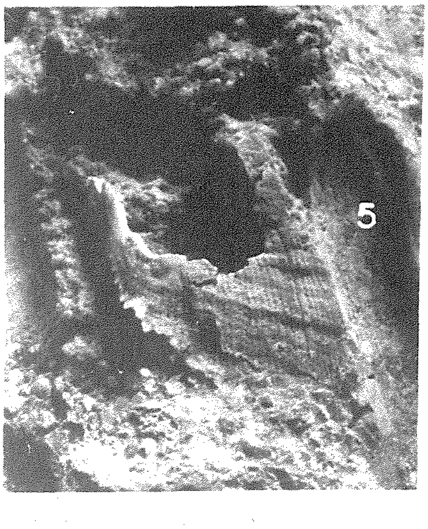
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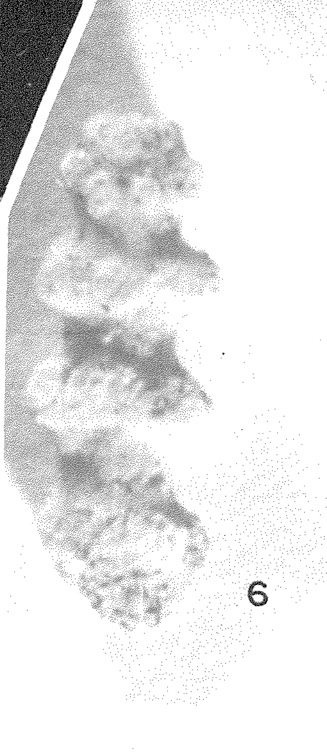
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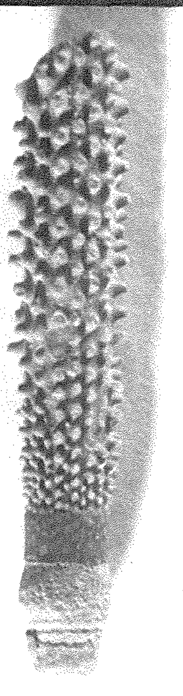
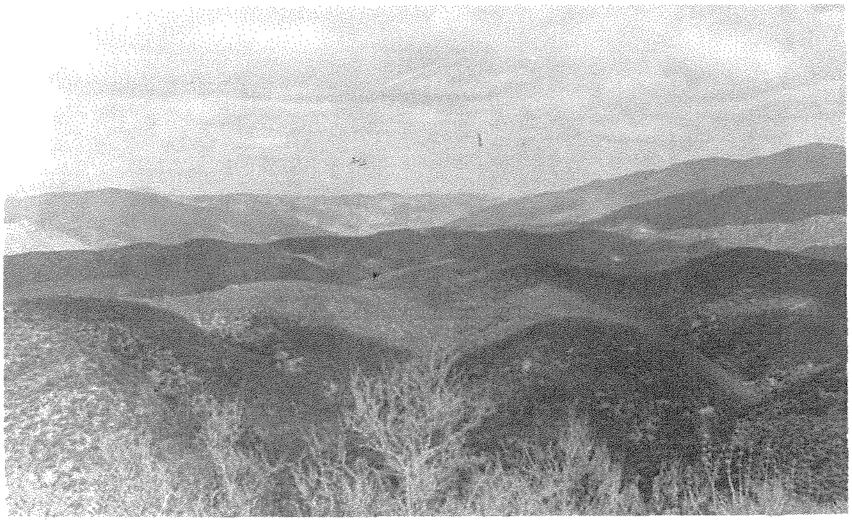

7

PLATE 31

1



2

3

PLATE 32

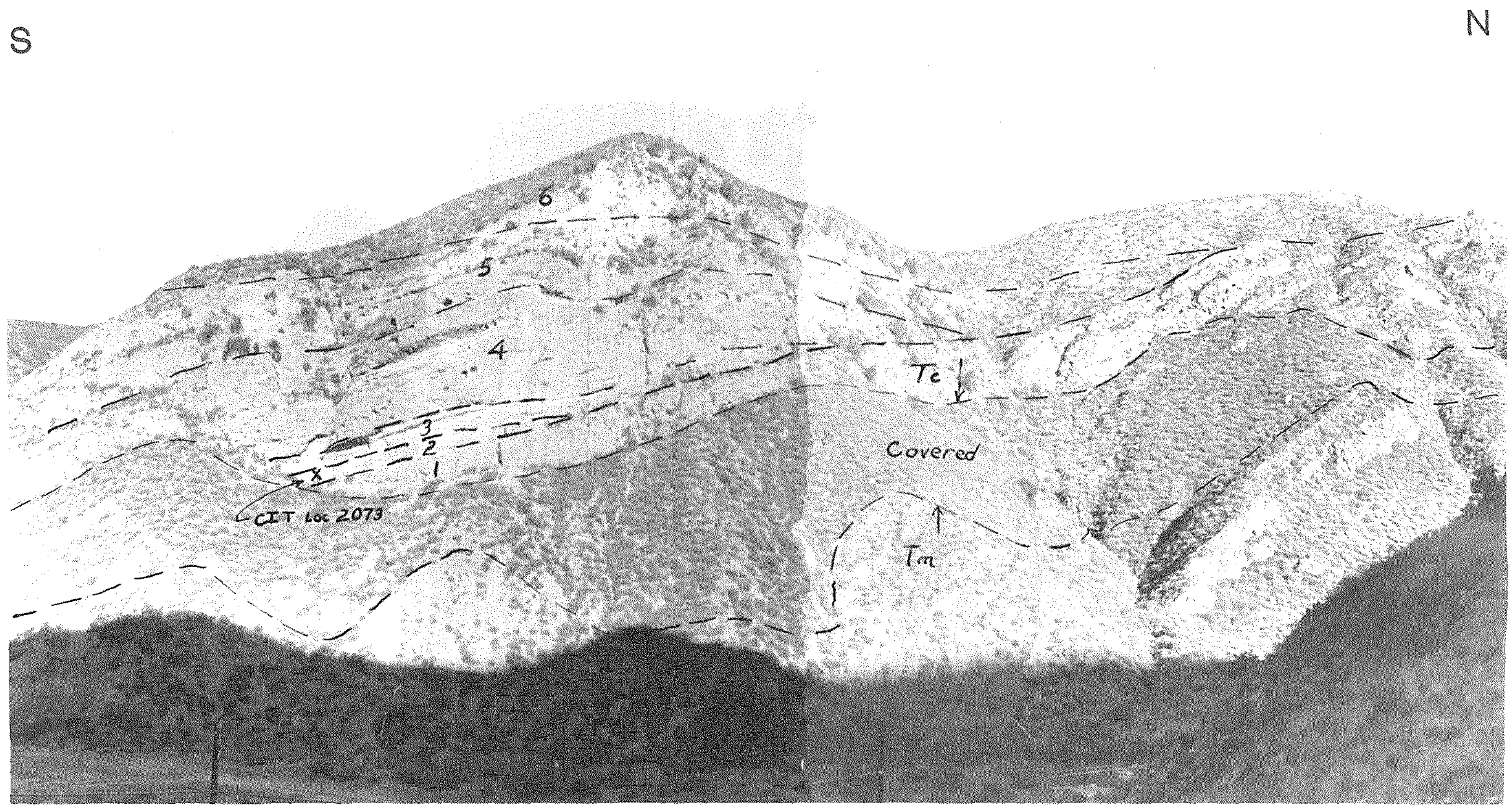
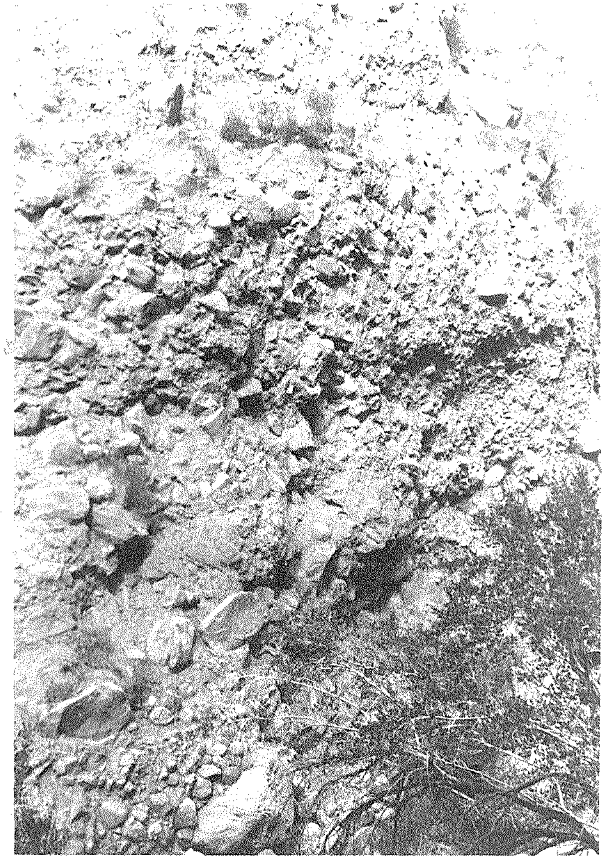


PLATE 33

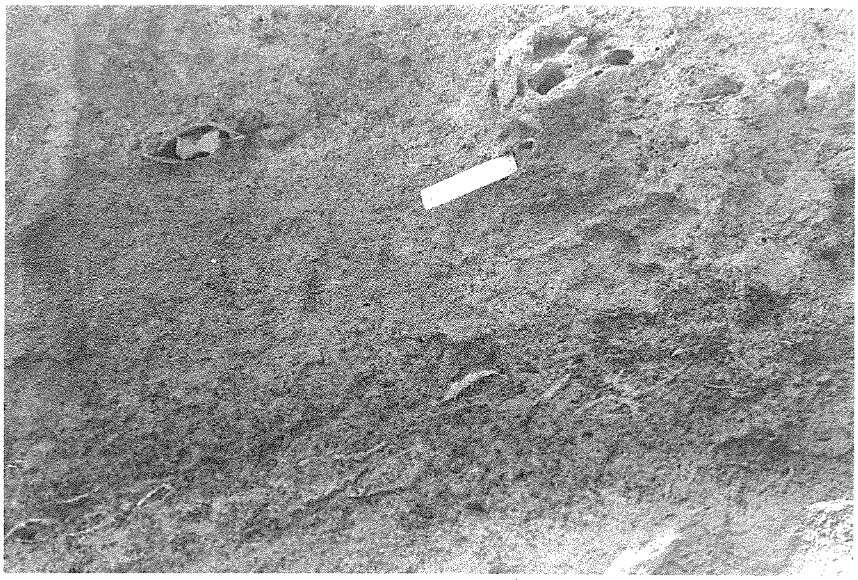
PLATE 34



1

2

PLATE 35



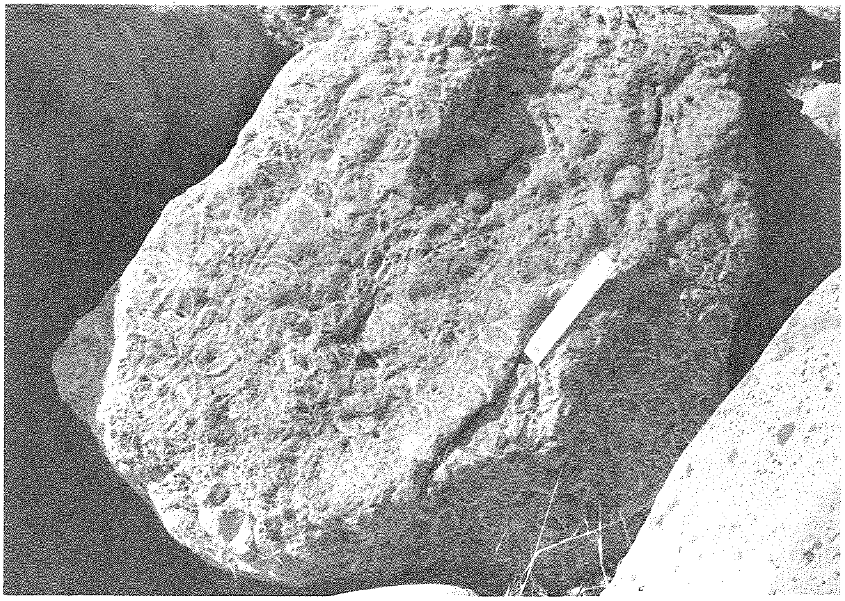
1

2

3

PLATE 36

1



2

PLATE 37