FOSSIL MOLLUSKS
OF SAN DIEGO COUNTY

ELLEN J. MOORE

SAN DIEGO
SOCIETY OF NATURAL HISTORY

OCCASIONAL PAPER 15

FOSSIL MOLLUSKS OF SAN DIEGO COUNTY

ELLEN J. MOORE
Associate Curator of Paleontology
San Diego Natural History Museum

San Diego Society of Natural History
Balboa Park, San Diego, California
Occasional Paper 15
1968

CONTENTS

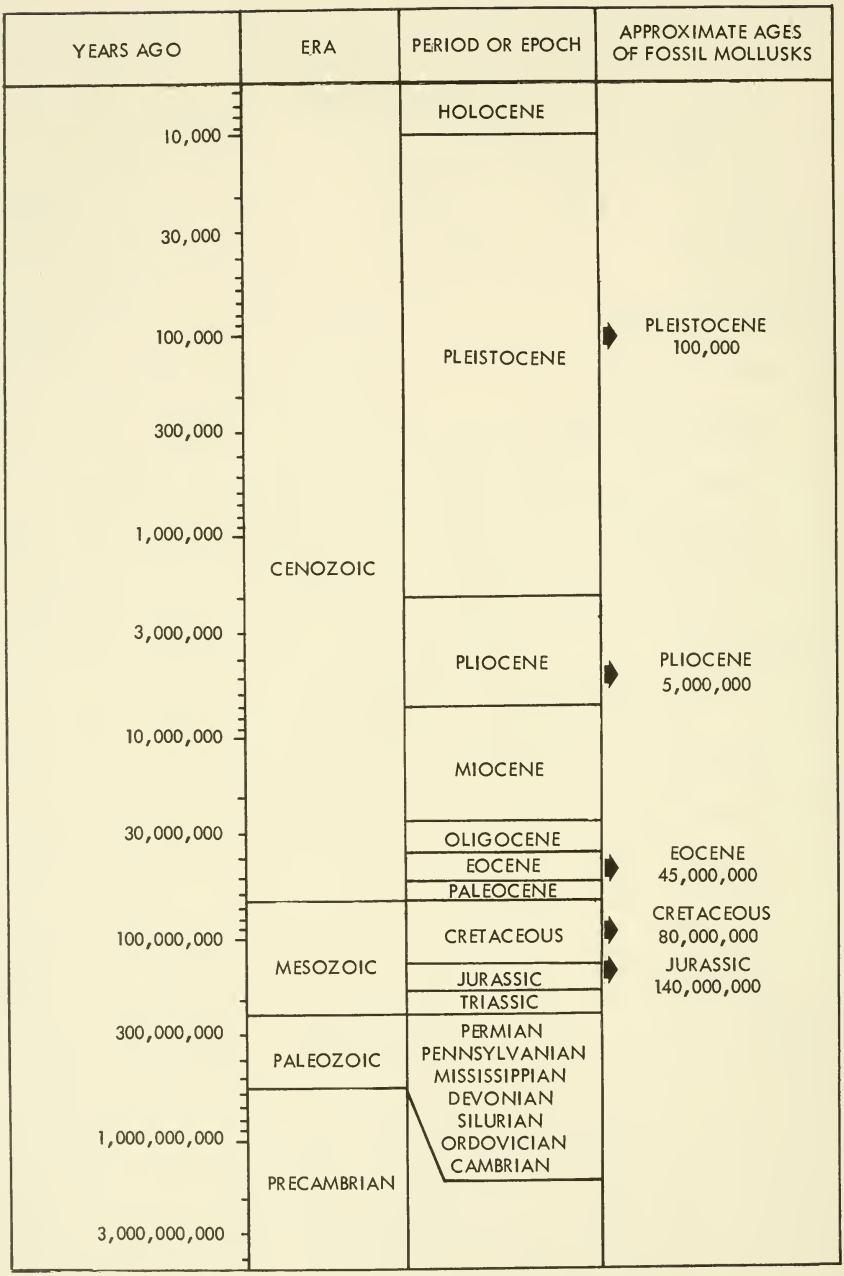


Table 1. Geologic time scale and the ages of fossil mollusks in San Diego. Time-scale boundaries from Harland and others (1964).

INTRODUCTION

Many times in the geologic past, the area that is now San Diego has been partly or wholly beneath the sea. The most recent time in which that occurred was about 100,000 years ago, toward the end of the Pleistocene Epoch, and the oldest for which we have a fossil record was in the Jurassic Period, about 140 million years ago (Table 1). These submergences are recorded by sedimentary rocks containing marine fossils. Such fossils may be collected in and near San Diego from rocks of those ages and of Cretaceous, Eocene, and Pliocene age, about 80,000,000, 45,000,000, and 5,000,000 years old respectively.

A fossil is a trace or a remnant of an animal or plant preserved from a past geologic epoch. Remnants of animals that lived in the present, or Holocene Epoch, are not technically fossils, even if they represent extinct species. For example, the last passenger pigeon is not a fossil. The youngest fossils are those of organisms that lived in the Pleistocene Epoch, which ended approximately 10,000 years ago.

The age of a fossil may be determined by its position in a rock sequence. The fossils in a given rock layer or bed are generally younger than those in underlying beds. Geologic age can also be determined by radioisotope dating — by ascertaining the extent to which radioactive isotopes, such as carbon-14 and potassium-40, of known decay rate and original concentration, have decayed in the enclosing rocks.

Shell middens, disposal piles accumulated by Indians, are very common in the San Diego area. Most of the shells in these middens are not fossils, but unfortunately, some can be mistaken for fossils, especially when they roll down cliffs and come to rest on rocks containing true fossils. Since Pleistocene rocks may contain fossil shells of species that are not yet extinct, this can cause confusion.

One of the first fossils from California to be described was a Pliocene oyster, *Ostrea vespertina,* which was named in 1854 by Timothy A. Conrad, a famous paleontologist at the Academy of Natural Sciences of Philadelphia. This oyster occurs in Pliocene rocks in San Diego and also in the Imperial Valley.

Among the publications on fossil mollusks of the San Diego area are those of Marcus A. Hanna on the Eocene fauna of the La Jolla area, those of Leo G. Hertlein and U. S. Grant IV on the Pliocene fauna of San Diego; the Pleistocene fauna is treated in papers by W. K. Emerson, E. P. Chace, W. O. Addicott, Frank Stephens, and J. W. Valentine.

Not all of the fossil mollusks found in the San Diego area can be described and illustrated in this guide. Those species chosen for inclusion are common in the area, highly distinctive, or were first collected in or near San Diego.

In this guide the dimensions of fossil shells are given in centimeters, which can be converted to inches by means of a conversion scale on the outside back cover. The fossils have been photographed at their natural size when possible. For some very small or large shells, however, this was not practical. The small shells are magnified to make them easier to identify, and the large ones are reduced to accommodate a page. If x 2 appears after a fossil name, the shell is twice as large in the photograph as is the actual specimen. If x ½ appears with the name, the image is half the size of the specimen.

A person who intends to collect fossils should bear two things in mind. The first is that a permit is required to collect on government land, and the permission of the owner on private land. The second is that the locality at which each specimen was collected should be recorded. A fossil is of most scientific value if the precise locality from which it came is known. The locality description should be so worded as to enable another collector to find the locality with as little trouble and as much certainty as possible. Just "Pacific Beach" is not much help, whereas "2000 feet north of Crystal Pier, Pacific Beach, San Diego County, California, in cliff 20 feet above tide level at 2:00 p.m., May 15, 1968," is more useful. If it is possible also to describe the locality by latitude and longitude, as it can be measured on a topographic map, such precision is most helpful. A paleontologist also records his name, the date, and the age of the rocks from which the specimen was taken, if the age is known.

The first step in identifying a fossil is to determine what kind of an animal or plant was fossilized. Is it a sand dollar, a clam, a coral, a seed, a leaf, or the tooth of a shark. Usually this is obvious, but sometimes even the experts are stumped. Books of a general nature

are the most useful source for preliminary identifications. Examples of such books are:

Moore, R. C., Lalicker, C. G., and Fischer, A. G., 1952, Invertebrate fossils: New York, McGraw-Hill Book Company, Inc., 766 p., illus.

Moore, R. C., ed., 1953 to date, Treatise on invertebrate paleontology: Geol. Soc. America and Univ. Kansas Press, pts. A through X, illus.

Shimer, H. W., and Shrock, R. R., 1944, Index fossils of North America: New York, John Wiley and Sons, Inc., 837 p., 303 pls.

The next step is to go to a paper on the fossil fauna of the area from which your fossil came, such as Hanna (1927) on the Eocene of La Jolla and this book, or to a monograph on the particular type of organism, such as Hertlein and Grant (1960) on brachiopods, or Keen (1958) on mollusks. By comparison with pictures in the books, the identification of the fossil can usually be narrowed down to one of two or three species. Then the description is checked, and a further refinement to a specific name can be made.

A fossil mollusk collected in the San Diego area can be dated on the basis of the maps in this book that show the distribution of rocks of various geologic ages. When you have determined the age, compare the fossil with illustrations of fossils of the same age in this guide. If a similar one is found, a check against the description, to see if it agrees with your specimen, helps to strengthen the identification. For fossils not illustrated in this book, those of Cretaceous age should be checked in Anderson (1958), of Eocene age in Hanna (1927), of Pliocene age in Hertlein and Grant (1960) and Grant and Gale (1931), and of Pleistocene age in Grant and Gale and in books on modern shells such as Keen (1958) or Abbott (1954). The Treatise on Invertebrate Paleontology is also of particular help in the identification of fossils; parts I, J, K, L, M, and N are devoted to mollusks.

The San Diego Museum of Natural History welcomes gifts of fossils, especially with adequate collecting data. Some are retained in the study collections used by specialists, some are put on exhibit, some are added to teaching collections used by students, and some may be exchanged with other museums and universities.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the assistance of my colleagues at the San Diego Museum of Natural History. Edward C. Wilson, former curator, was particularly helpful and encouraging. The photographs of all but the Cretaceous fossils were taken by Dallas Clites, and the drawings in plates 1, 2, and 3 were made by Anne Acevedo. Arnold Ross, Curator of Invertebrate Paleontology, read the manuscript as technical critic.

Leo G. Hertlein of the California Academy of Sciences kindly provided photographs of Cretaceous fossils, read the manuscript as technical critic, and also assisted me in other ways. The geologic maps were prepared by George W. Moore, U. S. Geological Survey. Edward C. Wilson, Los Angeles County Museum, Edwin C. Allison, San Diego State College, and Warren O. Addicott, U. S. Geological Survey, read the paper as technical critics, and Frank C. Calkins, U. S. Geological Survey, read it as a critic of style. I am indebted to all of these people.

CLASSES OF MOLLUSKS

PELECYPODS (clams). — A clam usually possesses two similar shells or valves that are hinged and that the living animal can open and shut at will (Plate 1). The shells are kept open by the tension of an elastic ligament at the hinge except when they are closed by the contraction of muscles attached to the insides of the shells. The impressions or scars left on the shells where the muscles were attached can usually be seen in fossil clams (Plate 17a). On some, one scar is at the front or anterior end and one at the rear or posterior end of the shell. The outside of the shell may be smooth or may be marked or sculptured with radial ribs, concentric lines, or spines, not all, however, occurring on one specimen as on the composite drawing on Plate 1.

GASTROPODS (snails). — Most snails have a single shell that is spirally coiled (Plate 2). Many have a calcareous or chitinous plate (operculum) that is used to close the aperture of the shell, and occasionally these are also found as fossils. A few snail shells are coiled flat in one plane like watch springs. The shells may be sculptured either with spines, nodes, axial ribs, or spiral cords.

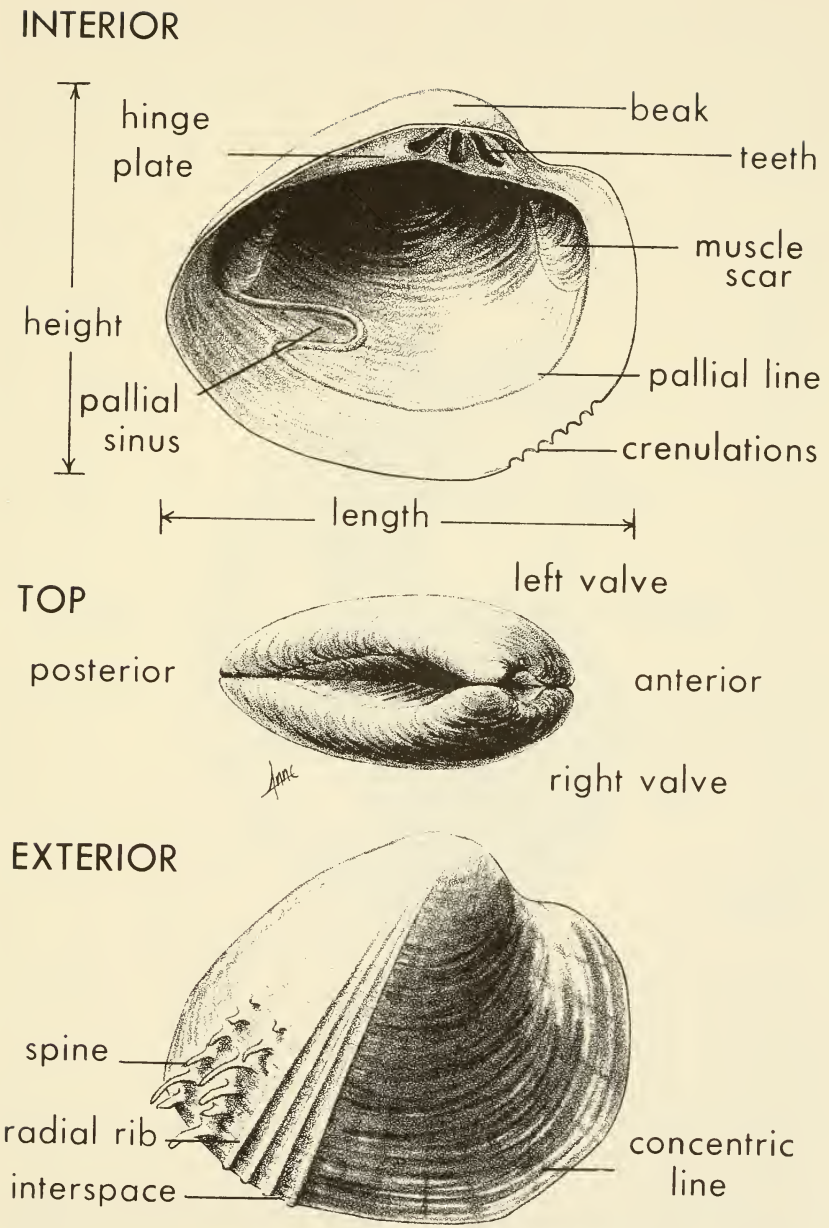


Plate 1. Terminology for clam shells.

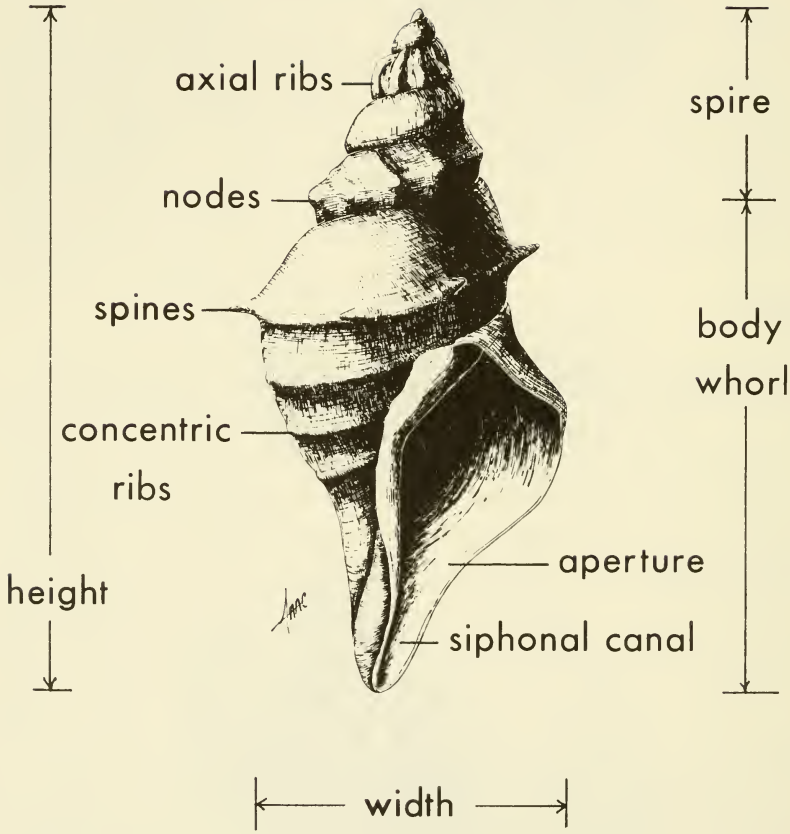


Plate 2. Terminology for snail shells.

Plate 3. Cross-section of *Nautilus* shell, x ½.

CEPHALOPODS. — This group includes the squid and octopus, which have no external shell, and other forms that do have them; among these are the chambered *Nautilus* (Plate 3), which lives today, and ammonites (Plate 6), which became extinct at the end of the Cretaceous.

The cephalopod shell is like a cone, either straight as in some fossil species or coiled in one plane. The animal lives only in the larger end, and builds a wall or partition between that and the rest of the shell. When it has outgrown its chamber it moves forward and builds a new partition behind its body. The shell thus consists of many chambers, or rooms, each one larger than the one formed before it, and all empty but the youngest and largest.

The partition between two rooms, which is called a septum, is attached to the inner surface of the shell along a line called a suture (Plate 4). The outline of this suture is important in the classification and identification of cephalopods. The nautiloids have simple septa and therefore simple sutures; the septa and sutures of ammonites are fluted and convolute near their edges; these convolutions may be extremely intricate. The compartments in any individual are all connected by a slender tube called a siphuncle (Plate 3). The siphuncle and sutures can often be seen in fossil cephalopods, and these features immediately separate them from the gastropods, which have no such structures.

SCAPHOPODS (tusk shells). — The shell of a scaphopod is a slightly curved tapering tube, open at both ends (Plate 4). Most present-day species of the Scaphopoda live in deep water.

TERMINOLOGY

In scientific terminology, fossil and living mollusks bear two Latin names, as do all animals and plants. The first, or generic name is the genus, that of cats and their relatives being *Felis*. The second, or specific name is the species, as *domestica* for house cats. The generic name is capitalized and the specific name lower-cased; both are italicized. A mountain lion is in the genus *Felis*, but differs in species from the domestic cat; its full name is *Felis concolor*. The Latin name is usually followed by the surname of the person who first described the

nautiloid suture

ammonoid suture

tusk shell

Plate 4. Cephalopod suture types and tusk shell.

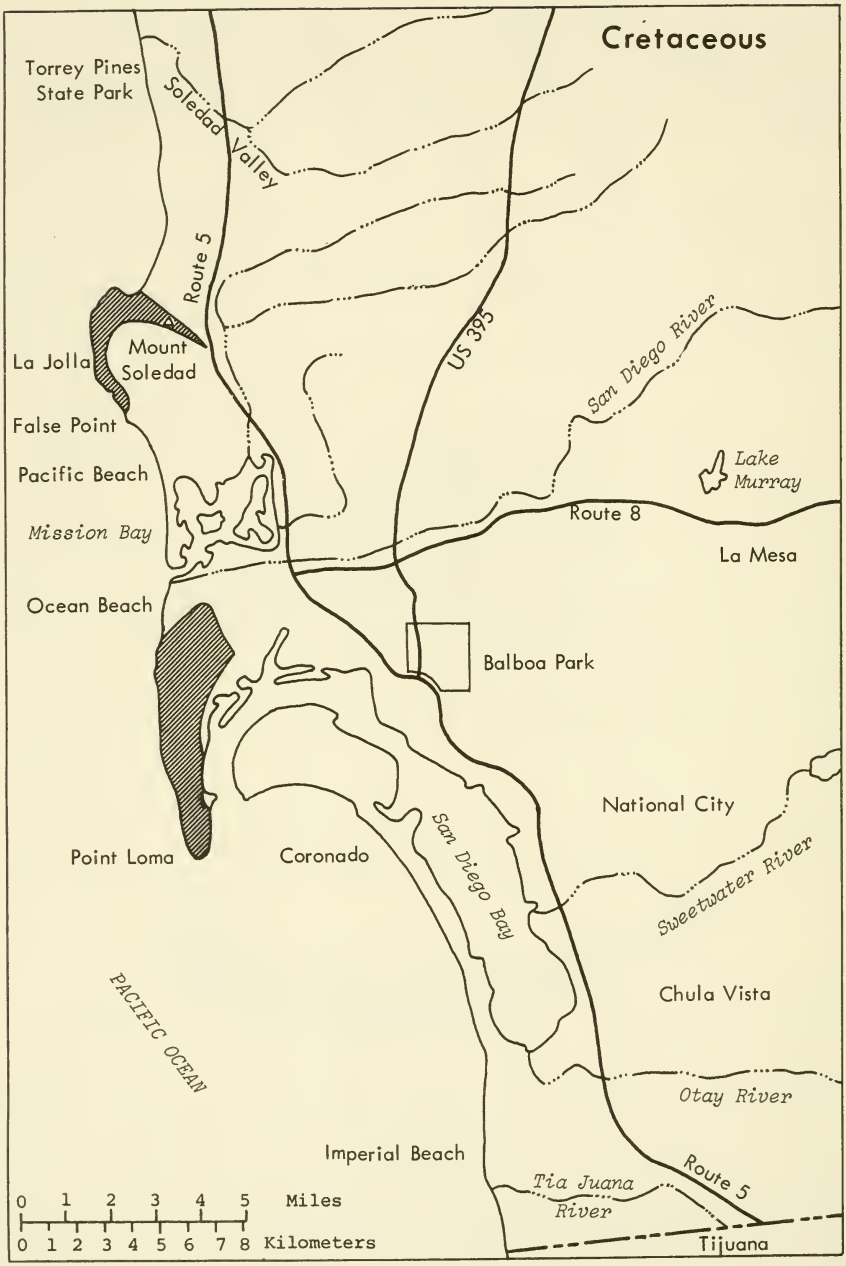


Plate 5. Area at San Diego underlain by Upper Cretaceous rocks shown by shading.

species, as in *Felis concolor* Linné. If this person's name is in parentheses, it indicates that he originally assigned the species to a different genus than the one to which it is now assigned. A name in parentheses between the generic and specific names designates a subgenus, a subdivision of the genus. A subspecies is indicated by a third Latin name, not in parentheses.

GEOLOGIC AGE AND DESCRIPTION OF FOSSIL MOLLUSKS

JURASSIC

Buchia piochii, an oyster-like fossil, has recently been collected from rocks of Late Jurassic age northeast and southeast of Del Mar (Fife, Minch, and Crampton, 1967). These are the oldest known fossiliferous rocks in the San Diego area.

CRETACEOUS

Marine fossiliferous Cretaceous rocks — sandstone and shale — are exposed and accessible at low tide on the west side and at the southern end of the Point Loma Peninsula. Fossiliferous Cretaceous rocks are also exposed north of False Point, which lies south of the La Jolla business district, and on the north side of Mt. Soledad (Plate 5). These rocks are of Late Cretaceous age (Hertlein and Grant, 1944), and contain fossil mollusks (clams, snails, and cephalopods), and also brachiopods (lamp shells) and microscopic foraminifera — protozoans. The most spectacular of these fossils are the cephalopods.

CEPHALOPOD

Pachydiscus (*Neodesmoceras*) *catarinae* (Anderson and Hanna), Plate 6.

This is a large form, flat-coiled, about 50 cm in its greatest overall diameter, with the largest individual whorl about 22 cm across. Low rounded ribs radiate from its center. The figured specimen was inked to show the sutures. It has been collected from the Cretaceous rocks at Point Loma and is also found in central California and in Baja California, Mexico.

Plate 6. Cretaceous ammonite.
Pachydiscus (*Neodesmoceras*) *catarinae* (Anderson and Hanna), x 1/5.


1431

GASTROPOD

Haliotis lomaensis Anderson, Plate 7a

If this species, which is about 80 million years old, is correctly assigned to the genus *Haliotis,* it is the oldest fossil abalone in the world. It is very small; the figured specimen from the Cretaceous rocks of Point Loma is 1.3 cm long, 0.9 cm wide, and 0.3 cm high. The specimen figured is the only one known of the species. Since it was described in 1902, the specimen has been kept in San Francisco. At the time of the earthquake and fire of 1906, it was fortunately housed in the collections of the California State Mining Bureau in the nearly unscathed Ferry Building, and therefore escaped the fate of some other scientifically priceless type specimens when the Market Street building of the California Academy of Sciences was destroyed. The specimen is now in the collections of the Academy at its headquarters in Golden Gate Park. The much larger abalones that live on the Pacific Coast today comprise several species in the same genus, *Haliotis.*

PELECYPODS

Crassatella lomana Cooper, Plate 7b

This species has a thick shell that is smooth except for concentric lines. The specimen figured is the one on which the species is based, and is therefore called the holotype. It was collected at Point Loma and also occurs at other localities in California.

Plate 7. Cretaceous snail and clam.

a) *Haliotis lomaensis* Anderson, x 5.
b) *Crassatella lomana* Cooper, x 1.

a

b

Coralliochama orcutti White, Plate 8

This unusual clam belongs to a group known as the rudistids. The right valve is greatly elongated; the left valve is much smaller and lies across the right valve to form a lid. This creature is believed to have lived in an upright position as illustrated. The figured specimen, whose total length is 25.5 cm, was collected at Punta Banda, Baja California, Mexico, and is deposited at the California Academy of Sciences. This species also occurs in the Cretaceous rocks of Point Loma and La Jolla, and at other localities in California.

Plate 8. Cretaceous clam.
Coralliochama orcutti White, x 1.

Corbis sp. aff. *C. peninsularis* Anderson and Hanna; Plate 9a

This clam is generally round in outline, and its shell is smooth except for concentric lines. The first specimen described of *Corbis peninsularis* was from Baja California. The illustrated specimen from Point Loma is identified as *Corbis* sp. aff. *C. peninsularis.* The aff. stands for affinis meaning it is similar to, but not identical with the original specimen of *Corbis peninsularis* and may prove to be a different species.

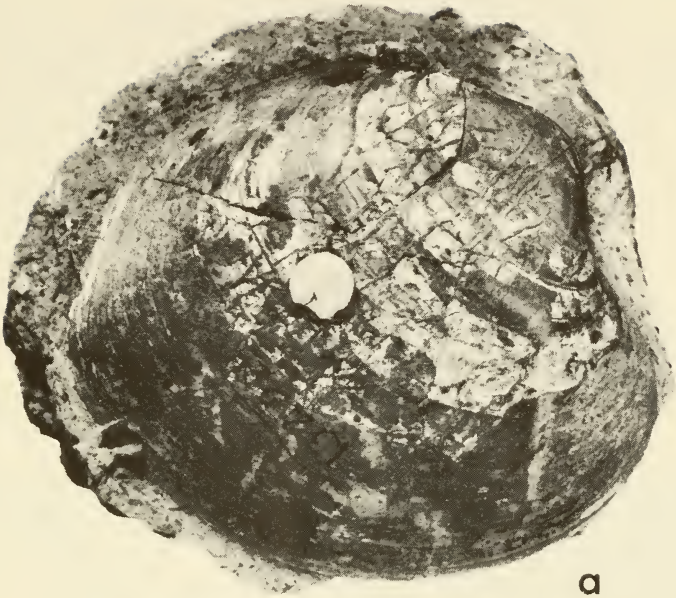
Inoceramus sp., Plate 9b

This clam has not yet been identified specifically because it is represented only by poorly preserved specimens. It is distinguished by concentric folds on the shell, the thinness of the shell, and its outline. The illustrated specimen — broken — is about 5 cm long and was collected in the Cretaceous rocks at Point Loma.

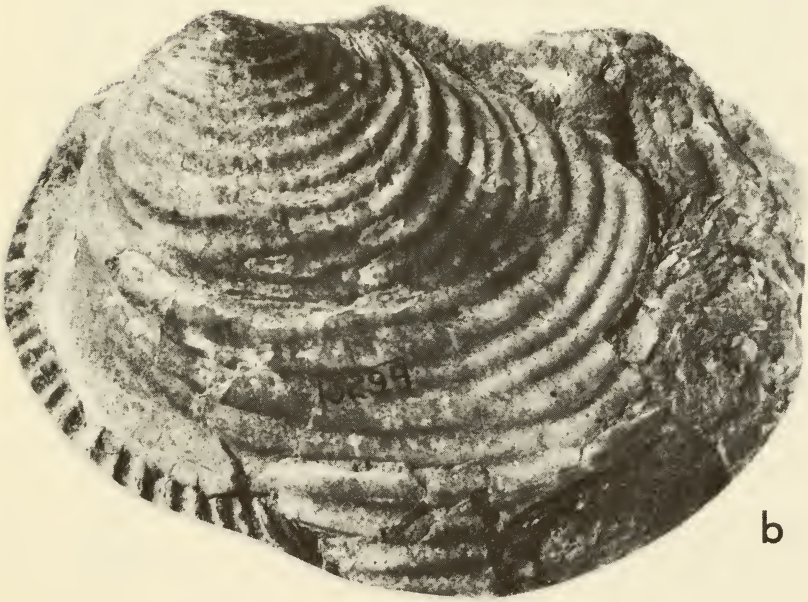
Plate 9. Cretaceous clams.

a) *Corbis* sp. aff. *C. peninsularis* Anderson and Hanna, x 1.

b) *Inoceramus* sp., x 1.



a



b

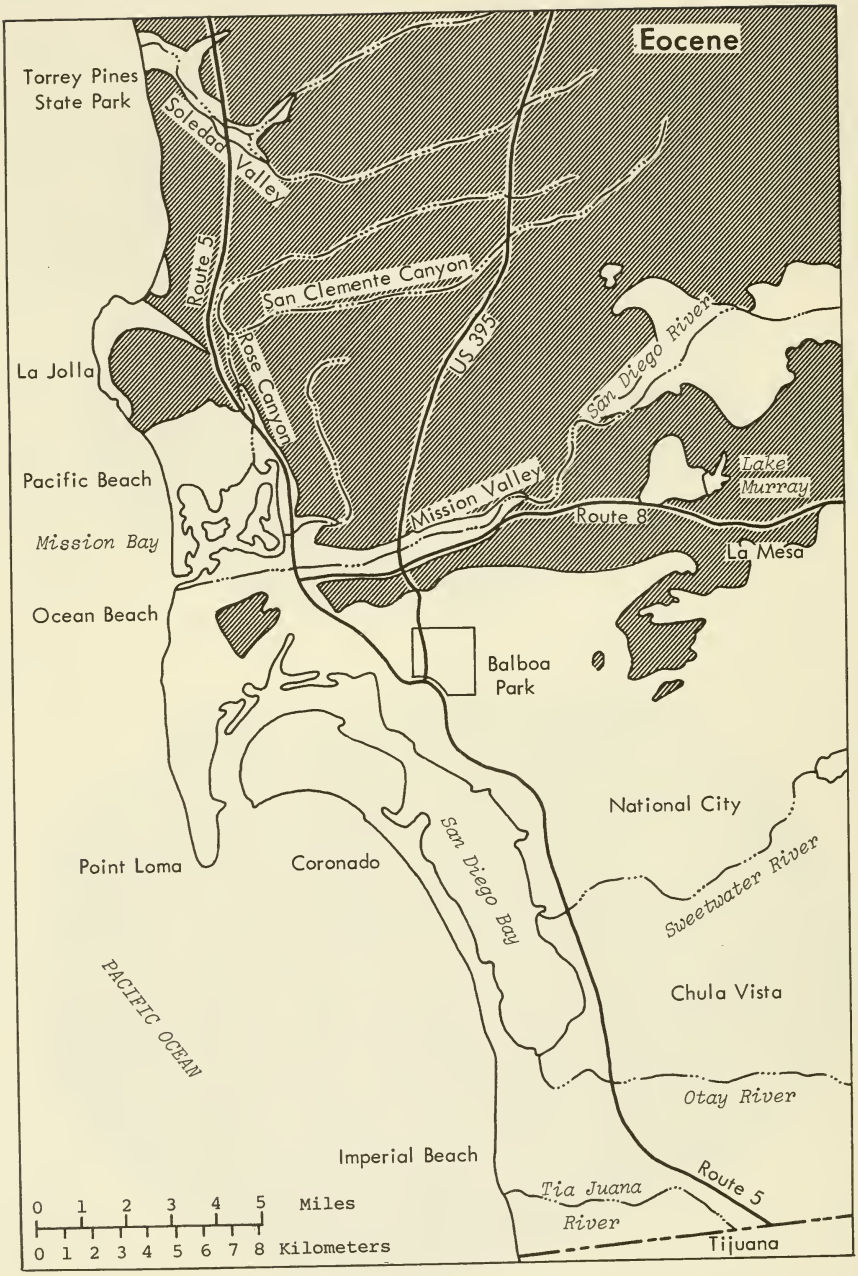


Plate 10. Area at San Diego underlain by Eocene rocks shown by shading.

EOCENE

Fossil mollusks in the Eocene rocks exposed in the La Jolla quadrangle, just north of San Diego, were studied and illustrated by Marcus A. Hanna (1926). Isolated patches of these rocks occur as far south as Mission Valley, and some of them overlie the Cretaceous rocks on the Point Loma Peninsula (Hertlein and Grant, 1944). Distribution of the Eocene rocks is shown in Plate 10. They can most readily be seen in the sea cliffs at Torrey Pines State Park and in Rose Canyon.

One of the most common fossils seen in exposures of Eocene rocks at the north end of San Diego is an oyster, *Ostrea idriaensis* Gabb. It is so common in some places that it occurs in nearly pure layers in the rocks (Figure 1).

Figure 1. A richly fossiliferous layer within Eocene rocks that crop out north of the area of plate 10 in the San Dieguito River valley, east of Del Mar.

GASTROPODS

Amaurellina moragai lajollaensis Stewart, Plate 11a

This snail is of moderate size and has a large, rather round body whorl, on which there is a shelf. Incised spiral lines may be seen to cover the entire shell of a well-preserved specimen.

The figured specimen is from Rose Canyon, in San Diego, but this species has also been found in Eocene rocks at other localities in California.

Ficopsis cooperiana Stewart, Plate 11b

This species has a large body whorl with three rows of nodes — one on the edge of each flat surface. The spire is relatively short, and there are two rows of nodes on each whorl. Basket-weave sculpture can be seen on well-preserved specimens but is not shown on the figured specimen, which is from the Eocene rocks in Rose Canyon. This species is also found in Eocene rocks at other localities in California.

Ficopsis remondi crescentensis Weaver and Palmer, Plate 11c

The entire shell of this snail is sculptured with spiral and radial threads of equal weight and spacing, forming a delicate basket-weave pattern. It has a large body whorl and a shelved spire. A flat surface on the body whorl, marked off by two slightly heavier spiral threads, can be seen just below the shoulder. The figured specimen was collected from the Eocene in Rose Canyon. The species also occurs in the Eocene rocks elsewhere in California, and in Oregon and Washington.

Loxotrema turritum Gabb, Plate 11d

This is a rather small shell with a turreted spire and with the body whorl overlapping at the suture. The body whorl is smooth near the suture and is sculptured with spiral cords near the base of the shell. The figured specimen came from the Eocene of San Clemente Canyon, but this species, which is the only one known in the genus, occurs in Eocene rocks at other localities in California and in Oregon.

Megistostoma gabbianum (Stoliczka), Plate 11e

The body whorl of this snail is large and its spire is hidden. The sculpture consists of irregular spiral threads. The specimen figured came from the Eocene of Rose Canyon. This species, which is the only one known in the genus, is also found in the Eocene rocks of Oregon and Washington.

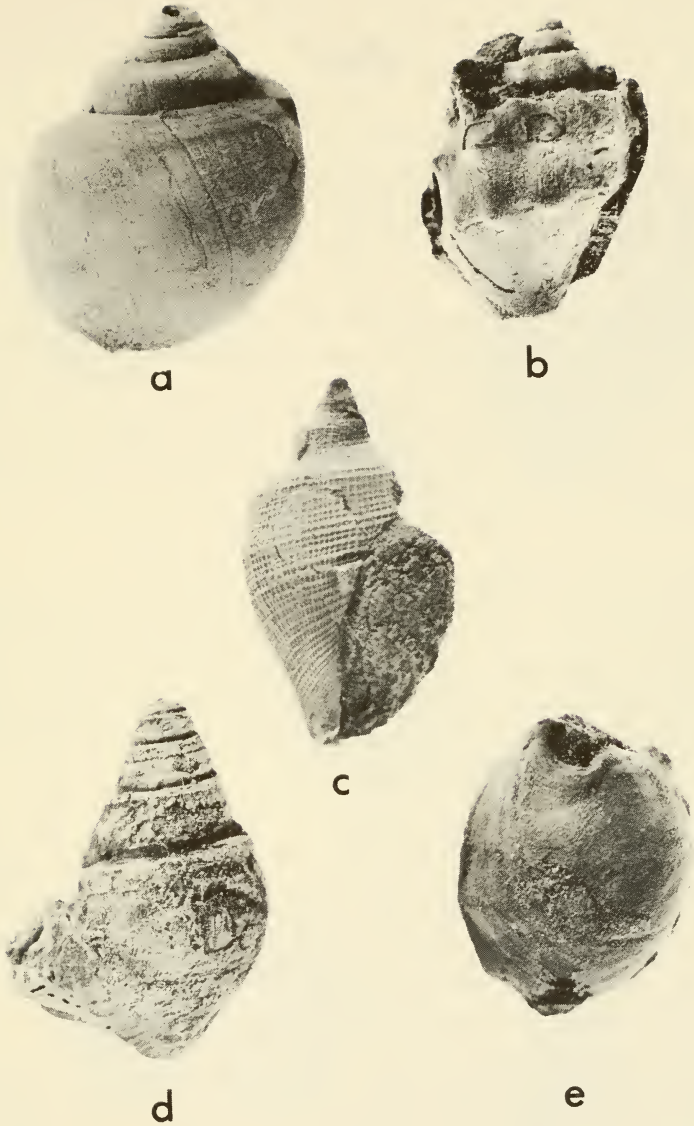


Plate 11. Eocene snails.

a) *Amaurellina moragai lajollaensis* Stewart, x 1½.
b) *Ficopsis cooperiana* Stewart, x 1½.
c) *Ficopsis remondi crescentensis* Weaver and Palmer, x 1½.
d) *Loxotrema turritum* Gabb, x 2.
e) *Megistostoma gabbianum* (Stoliczka), x 1½.

Nerita triangulata Gabb, Plate 12a

This is a small snail with the spire visible but not elevated above the body whorl. The shell is scultpured with rather strong spiral ribs. The figured specimen is from the Eocene of Rose Canyon, and this species occurs in Eocene rocks at other places in California.

Pseudoperrisolax blakei praeblakei Vokes, Plate 13b

This is a snail of moderate size, which has a long siphonal canal and bears a strong shelf on the body whorl. There are small nodes along the edges of this shelf and on the shoulders of the whorls of the spire. The figured specimen was collected in the Eocene rocks of Rose Canyon, and this species has also been collected from Eocene rocks in the Coalinga area of California.

Scaphander (*Mirascapha*) *costatus* (Gabb), Plate 12c

On all species of *Scaphander* the spire is sunken and completely covered by the body whorl. The shell is elongated and somewhat cylindrical. It is sculptured with flat spiral ribs and narrow interspaces. The figured specimen is from the Eocene rocks in Rose Canyon. This species is also found in Eocene rocks at other localities in California and in Oregon and Washington.

Sinum obliquum (Gabb), Plate 12d

This snail has a large body whorl and a very small, squat spire. *Sinum* is most easily distinguished by its squatness and by its spiral sculpture of irregular incised lines. The figured specimen, which is 1.2 cm high and 1.8 cm wide, was collected in the Eocene of Rose Canyon. This species occurs in Eocene rocks at other localities in California, and also in Oregon and Washington.

Turritella uvasana applinae Hanna, Plate 12e

Most species of *Turritella* have slim, high-spired shells sculptured with spiral ribs of varying diameters and spacings. This species is distinguished by its rounded whorls and rather widely spaced and moderately strong spiral ribs. It was originally described from specimens found in the Eocene of Rose Canyon, which is thus the type locality for the species. The figured specimen is from the Eocene of San Clemente Canyon. This species is found also in Eocene rocks at other localities in California.

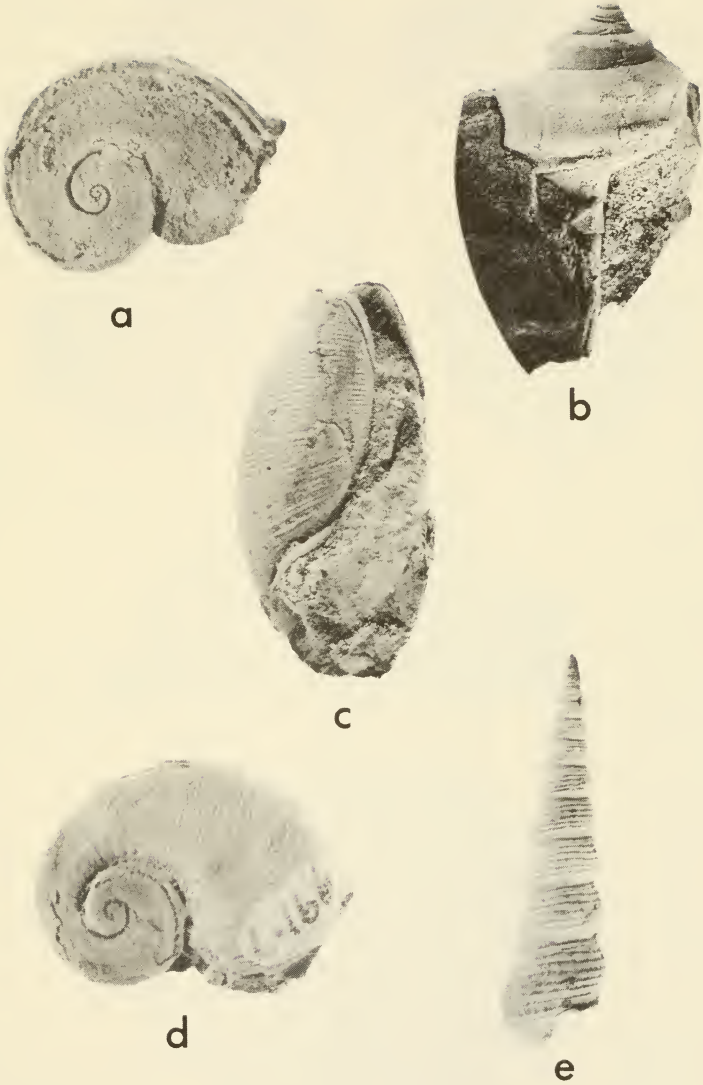


Plate 12. Eocene snails.

a) *Nerita triangulata* Gabb, x 2.
b) *Pseudoperrisolax blakei praeblakei* Vokes, x 1½.
c) *Scaphander* (*Mirascapha*) *costatus* (Gabb), x 2.
d) *Sinum obliquum* (Gabb), x 2.
e) *Turritella uvasana applinae* Hanna, x 1.

PELECYPODS

Acila (*Truncacila*) *decisa* (Conrad), Plate 13a

This is a small clam of triangular outline. Its most distinctive feature is the bifurcation of the radial ribs, which somewhat resembles the part in one's hair. The beaks are very small; the interior of the shell is pearly. *Acila* all have taxodont dentition — a row of small teeth alternating with sockets along the hinge. The figured specimen came from the Eocene of Rose Canyon. The same species occurs in the Paleocene of California and the Eocene of the Coast Ranges elsewhere in California and in Oregon and Washington.

Corbula rosecanyonensis Hanna, Plate 13b

This is perhaps the smallest fossil clam known from the Eocene of San Diego; the figured specimen, which is of average size, is only 1.0 cm long and 0.8 cm high. It is triangular in outline and sculptured with concentric lines. Rose Canyon, from which the figured specimen was collected is the type locality for the species. This species is found also in Eocene rocks in other localities in California.

Macrocallista horni (Gabb), Plate 13c

This species is rather small, the figured specimen, which was collected in Rose Canyon, being 2.6 cm long and 2.0 cm high. It is oval in outline, bears small beaks turned in toward the anterior margin, and is sculptured with concentric ridges. This species is also found in Eocene rocks in other localities in California.

Nemocardium linteum (Conrad), Plate 13d

Nearly square in outline, this shell is somewhat polished. It bears fine radial ribs covering three-fourths of its area and coarse ribs on the remainder. The presence of these coarse ribs, which are on the posterior quarter, is a distinguishing feature of the genus *Nemocardium.* The figured specimen came from the Eocene rocks of Rose Canyon; the species is also found in the Eocene of Oregon.

Venericardia (*Pacificor*) *horni* (Gabb), Plate 13e, f

This is a large thick shell of somewhat oval outline with a heavy, massive hinge plate. The outside of the shell is sculptured with broad rounded ribs separated by narrow incised interspaces. The beaks curve strongly toward the anterior end of the shell. The figured specimen came from the Eocene rocks of Rose Canyon; the species is also found in the Eocene of Oregon.

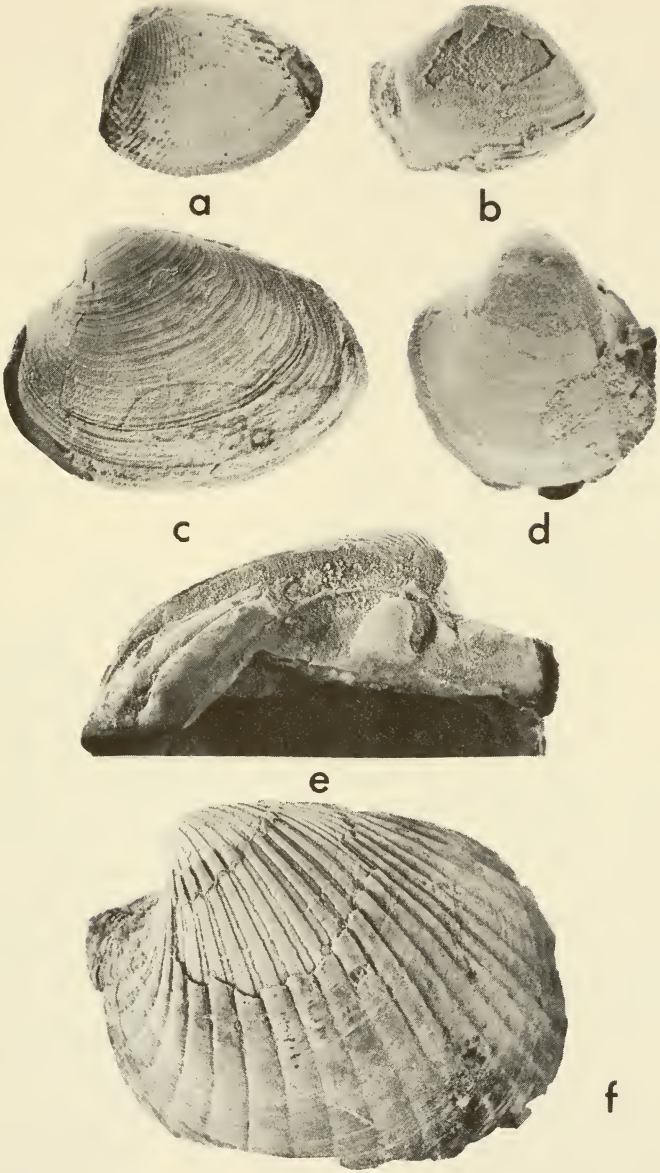


Plate 13. Eocene clams.

a) *Acila* (*Truncacila*) *decisa* (Conrad), x 2.
b) *Corbula rosecanyonensis* Hanna, x 3.
c) *Macrocallista horni* (Gabb), x 2.
d) *Nemocardium linteum* (Conrad), x 1.
e, f) *Venericardia* (*Pacificor*) *horni* (Gabb), x 1.

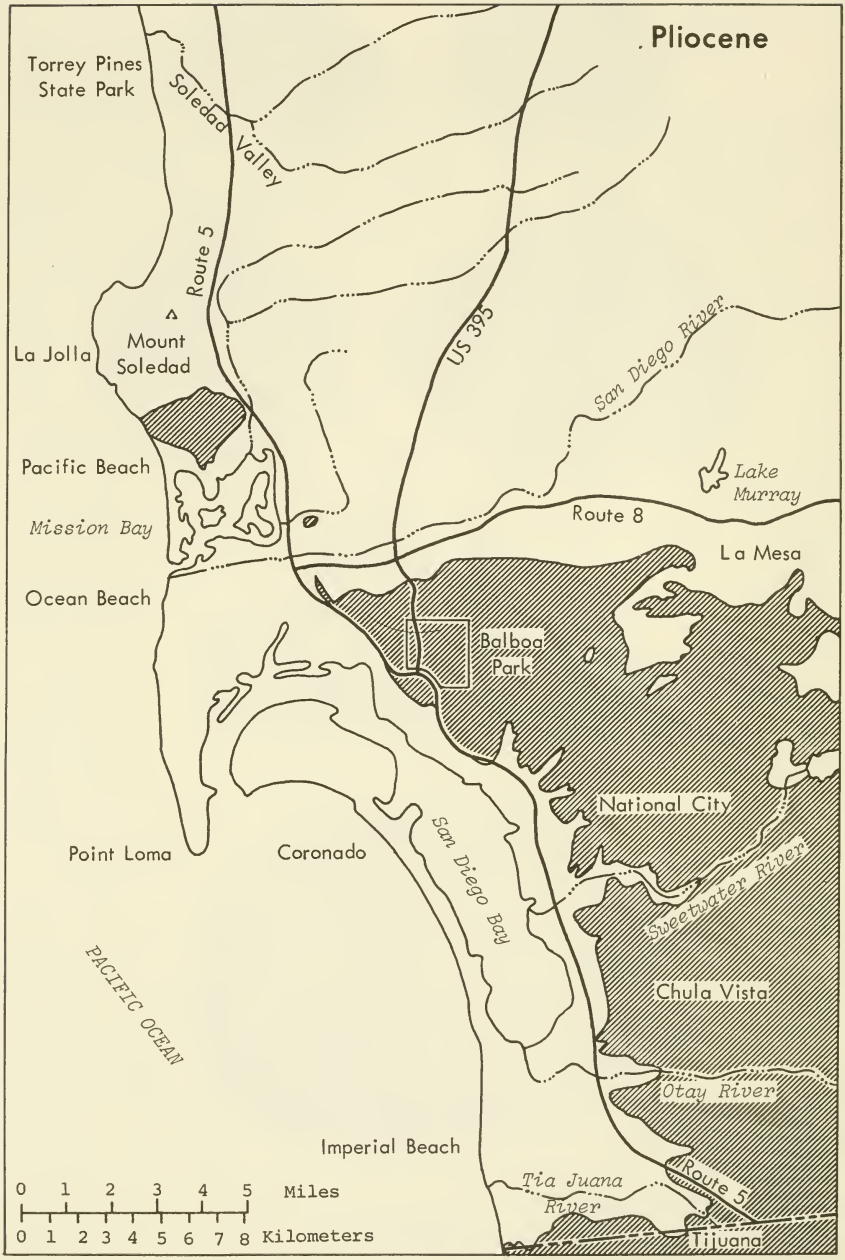


Plate 14. Area at San Diego underlain by Pliocene rocks shown by shading.

PLIOCENE

Fossils in the Pliocene rocks of the San Diego area have been studied by Leo G. Hertlein and U. S. Grant IV; their papers on the distribution of the Pliocene rocks in San Diego (1944) and on the fossil sand dollars and brachiopods found in those rocks (1960) are very useful. In 1931, U. S. Grant IV and Hoyt R. Gale published a catalogue of the Pliocene and Pleistocene fossils of California, and that book contains illustrated descriptions of many mollusks of those ages collected in or near San Diego. Leo G. Hertlein and U. S. Grant IV have in preparation a monograph on the pelecypods of the Pliocene rocks of San Diego. This will be a significant contribution to the knowledge of the fauna of these rocks.

William H. Dall (1874) when serving as paleontologist and conchologist at the U. S. National Museum, identified Pliocene fossils taken from a well in Balboa Park. This was one of the first Pliocene localities to be definitely established in California. Pliocene rocks are exposed at Pacific Beach and over a large area that lies south of Route 8 and east of Route 5 and extends across the International Boundary (Plate 14).

GASTROPODS

Crepidula princeps Conrad, Plate 15b

A smooth, rather flat shell, without a spire this species has a beak that curves toward the right if the beak end of the shell is held nearest the viewer. All species of *Crepidula* have a deck or shelf across part of the aperture on the under side of the shell.

The incomplete specimen figured, which is 3.0 cm high and 6.0 cm long, was taken from the Pliocene rocks at Reynard Way in San Diego. This species occurs in Miocene rocks in California and Pliocene and Pleistocene rocks in California, Oregon, and Washington.

Megasurcula carpenteriana (Gabb), Plate 15d, e

The body whorl is larger than the spire on this species, and each whorl of the shell overlaps the spire. The shell is sculptured with spiral threads and lighter radial threads. A moderately heavy spiral thread usually alternates with a much finer one. Small nodes project from the whorls of the spire just above the suture. The canal is notched at the basal margin. The figured specimen came from the

Pliocene rocks exposed on Reynard Way, and this species is also found in the Pliocene of Balboa Park, in the Pleistocene at Pacific Beach, and the Pleistocene of Baja California, Mexico.

Nassarius (*Caesia*) *grammatus* (Dall), Plate 15f, h

This snail has a fat shell and is sculptured with equally spaced radial and spiral threads that produce a basket-weave pattern. There is a deep groove near the base of the shell and a notch at the end of the recurved canal. This was a carnivorous animal that drilled holes in clams or snails and then ate their flesh.

This species is found in Pliocene rocks from northern California to San Diego, California. The figured specimen came from Reynard Way.

Opalia varicostata (Stearns), Plate 15a

The cone-like form and sculpture of evenly spaced, heavy radial ribs identify this snail. Variants of this species with a smooth, ribless shell also occur. The aperture is almost round and the outer lip is thickened. Very fine spiral lines may be seen on well preserved specimens. The figured specimen is from Pacific Beach. This species has also been found in the Pliocene of Fresno County, California.

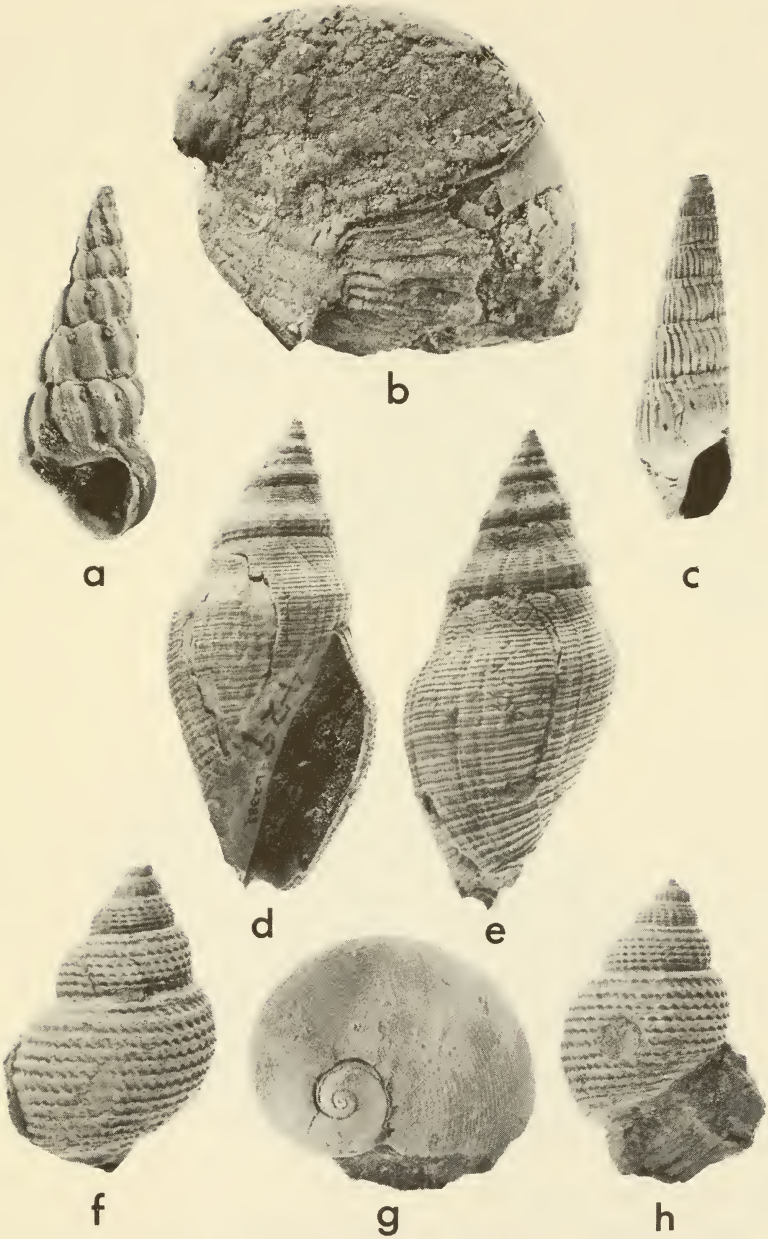
Sinum scopulosum (Conrad), Plate 15g

This species has a large fat body whorl and a small spire. The shell is sculptured with irregular flat spiral threads and interspaces of about equal width. The figured specimen, which is 1.7 cm high and 2.4 cm wide, was collected at Reynard Way in San Diego.

This species occurs in the Miocene of California, Oregon, and Washington and in the Pliocene of California and Oregon. It probably is the same species as the one called, by some authors, *Sinum californicum*. The modern species lives in the sea between the latitudes of central California and Baja California, Mexico.

Plate 15. Pliocene snails.

a) *Opalia varicostata* (Stearns), x 1½.
b) *Crepidula princeps* Conrad, x 1.
c) *Terebra* (*Strioterebrum*) *martini* English, x 1½.
d, e) *Megasurcula carpenteriana* (Gabb), x 1.
f, h) *Nassarius* (*Caesia*) *grammatus* (Dall), x 1.
g) *Sinum scopulosum* (Conrad), x 1½.


b
a
c
d
e
f
g
h

Terebra (*Strioterebrum*) *martini* English, Plate 15c

This is a slim-shelled snail with a tall spire, and each whorl is sculptured with fine radial threads that twist toward the suture. There is a collar bounded by an incised line a little below each suture. A notch is present on the posterior margin of the outer lip. The specimen illustrated is 3.1 cm high and 0.9 cm wide and was taken on Reynard Way, San Diego. This species is found also in the Pliocene of the Los Angeles area.

PELECYPODS

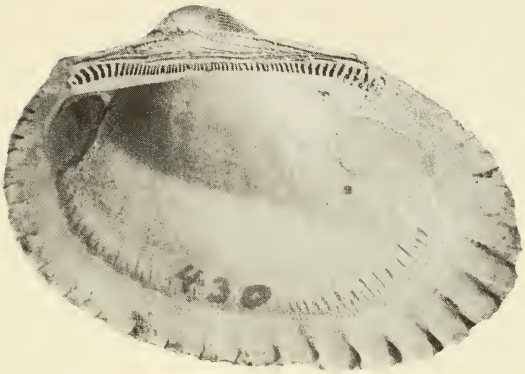
Anadara (*Anadara*) *trilineata* (Conrad), Plate 16a, b

This fossil clam is oval or sub-triangular in outline and is sculptured with grooved radial ribs. It has taxodont dentition (teeth in a row). A flat triangular area between the beaks is sculptured with chevron-like grooves; Plate 16a shows this feature.

This species is found in the Pliocene of California, Oregon, and Washington. The figured specimens are from Reynard Way, San Diego.

Plate 16. Pliocene clam.

a, b) *Anadara* (*Anadara*) *trilineata* (Conrad), x 1.



a

b

Dosinia ponderosa (Gray), Plate 17a, b

This clam is round and moderately large; it has a rather thick shell that is sculptured with equally spaced concentric grooves. The beaks are small and point toward the anterior end of the shell. The specimen figured came from a locality near the Mexican-United States boundary and one-half a mile from the ocean.

This species may be collected from the Pliocene in Balboa Park and could formerly be collected from the Pleistocene at 26th Street in San Diego. It also occurs in the Pleistocene of Baja California and is living today from Baja California to Peru.

Plate 17. Pliocene clam.
a, b) *Dosinia ponderosa* (Gray), x 1.


a
b

Lucinoma annulata (Reeve), Plate 18a, b, c

Almost circular in outline this clam is sculptured with rather widely spaced concentric ridges. In order to show the hinge plate and the interior of the valves, a modern specimen (Plate 19a, c) is figured in addition to the fossil specimen (Plate 19b). The fossil specimen was collected near the south base of Mount Soledad. The modern specimen came from San Pedro, California.

This species is found in the Pliocene and Pleistocene rocks of California and has been collected from both in San Diego. It lives today in the sea from Alaska to Baja California, Mexico.

Lucinisca nuttalli (Conrad), Plate 18d

This is a small, very pretty shell, distinguished from other lucinids in the Pliocene of San Diego by its basket-weave sculpture of concentric and radial ribs, equally spaced.

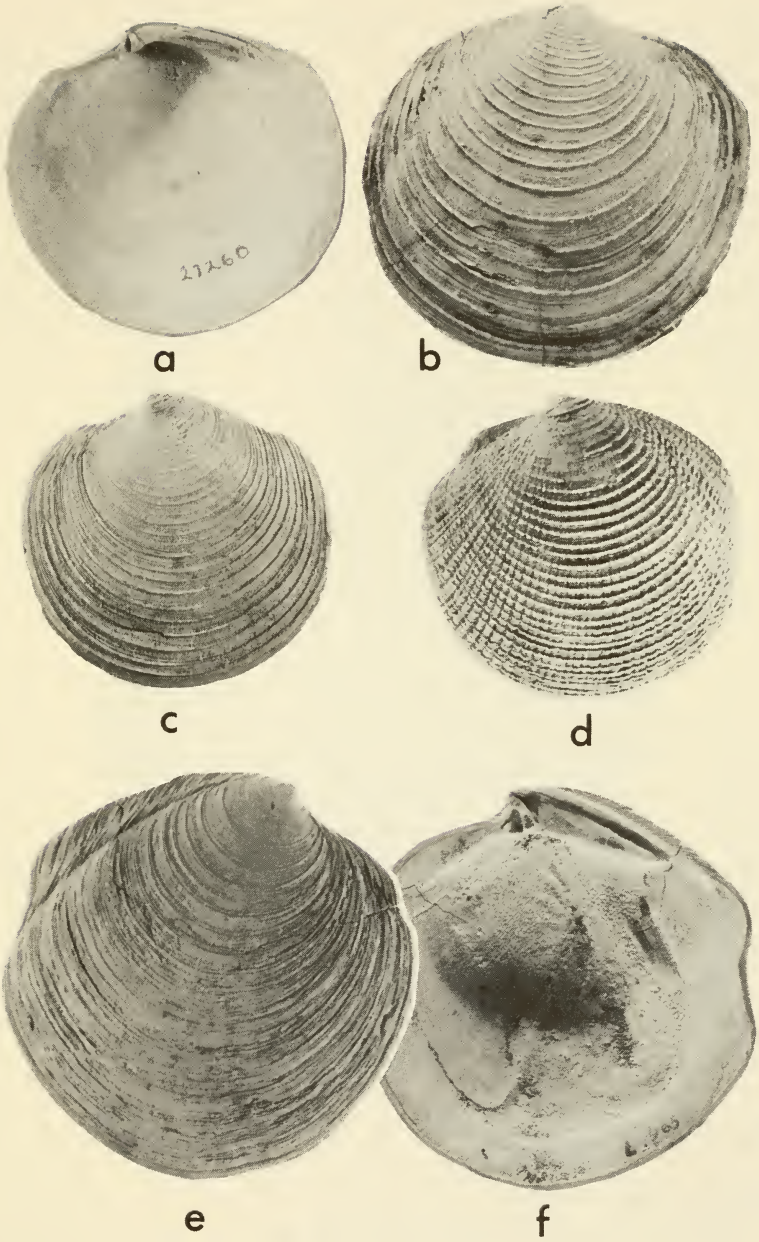
The figured specimen was collected in Balboa Park. Fossils of this species are found in the Pliocene and Pleistocene of the San Diego area and in the Miocene elsewhere in California. It lives in the sea today from Santa Barbara, California, to Manzanillo, Mexico.

Miltha xantusi (Dall), Plate 18e, f

This shell is almost flat and has small but prominent beaks. It has an anterior and a posterior indentation, both demarcated by a radial ridge; the posterior indentation is at the margin of the shell. The surface is sculptured with fine radial threads.

This species has been found in the Miocene and Pliocene of California and lives off Cabo San Lucas, Baja California, and in the Gulfo de California, Mexico, today at a depth of 60 meters or more. The figured specimen is from Pliocene rocks in Balboa Park.

Plate 18. Pliocene and Holocene clams.
a, c) *Lucinoma annulata* (Reeve), x 1.
b) *Lucinoma annulata* (Reeve), x 1½.
d) *Lucinisca nuttalli* (Conrad), x 1½.
e, f) *Miltha xantusi* (Dall), x 1.


a
b
c
d
e
f

Panope (*Panope*) *abrupta* (Conrad), Plate 19

This clam has a moderately thick shell and often reaches a large size. The specimen figured, which is near the middle of the size range, is 11.2 cm long and 6.6 cm high. Two distinguishing features of the species are the square truncation at the posterior end and the large gape of the shells.

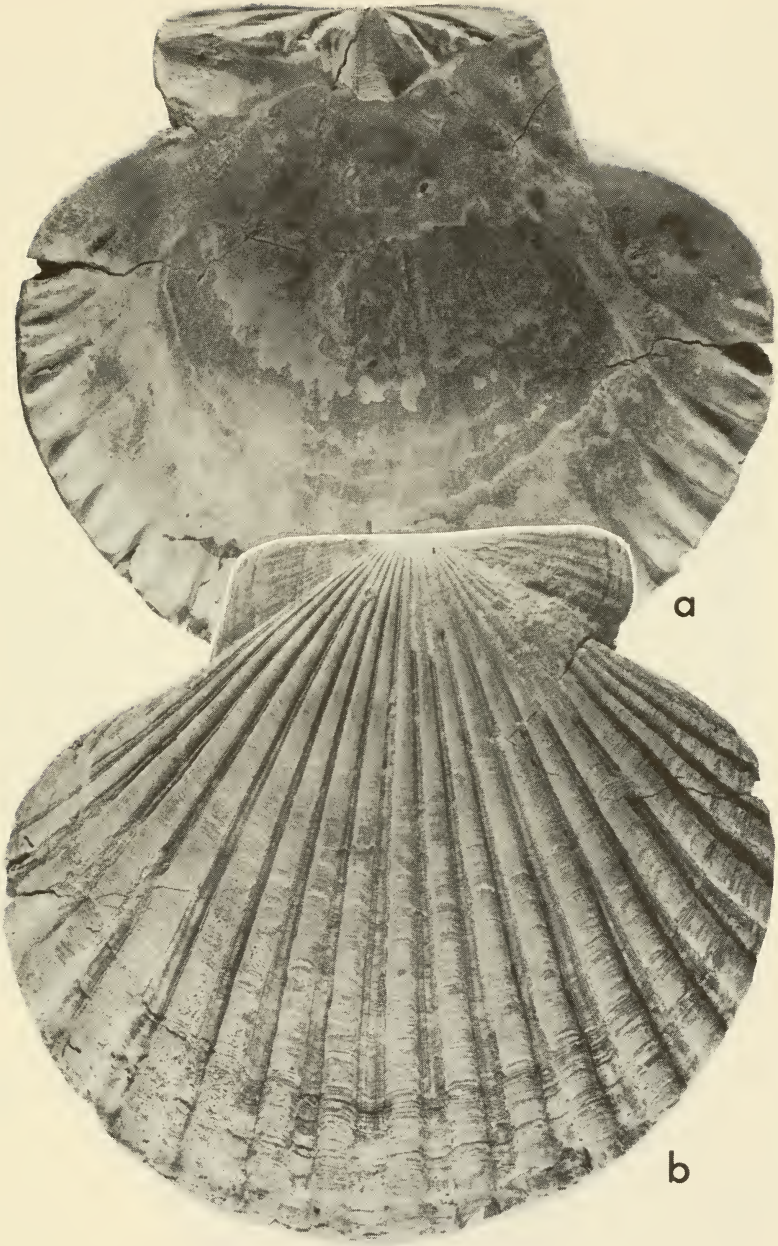
This species, which was formerly called *Panope generosa,* has been collected from rocks of Miocene to Pleistocene age in California, Oregon, and Washington. It lives in the sea today from Alaska to Baja California, Mexico. The figured specimen came from Pliocene rocks in Balboa Park.

Plate 19. Pliocene clam.
Panope (*Panope*) *abrupta* (Conrad), x 1.

Pecten (*Lyropecten*) *cerrosensis* Gabb, Plate 20a, b

This fossil *Pecten* is one of the largest known in the San Diego area; the figured right valve is 19 cm long and 17.5 cm high. The figured specimen bears 21 large rounded ribs, separated by spaces of nearly the same width as the ribs. The entire surface is sculptured with threadlike ribs. Coarse tooth-like hinge processes are present on the hinge plate. This species is rare in San Diego, but several specimens exist in the collections of the California Academy of Sciences, San Francisco, and in the Los Angeles County Museum of Natural History. The shell figured here is the right valve of a double-valved specimen collected in Chula Vista by a student and subsequently donated to the San Diego Museum of Natural History. The species has also been collected from Pliocene rocks at other localities in California.

Plate 20. Pliocene clam.
a, b) *Pecten* (*Lyropecten*) *cerrosensis* Gabb, x 1½.


a
b

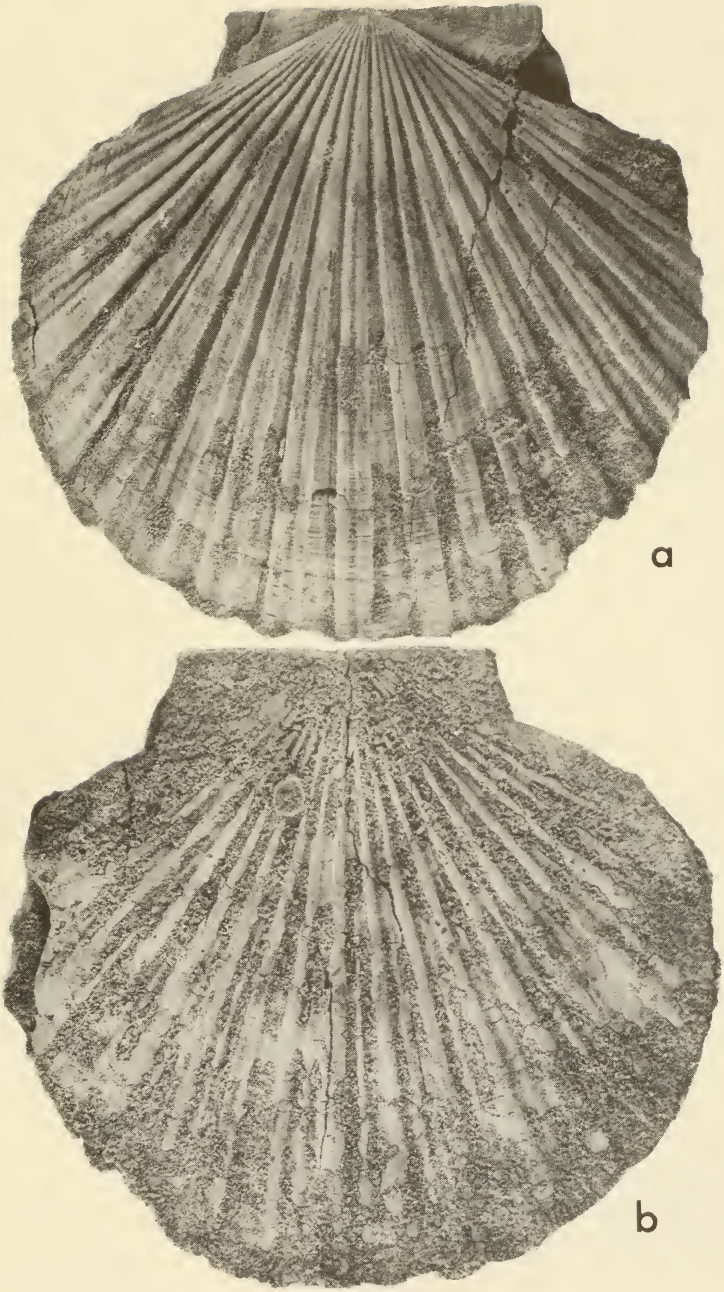
Pecten (*Patinopecten*) *healeyi* Arnold, Plate 21a, b

This is one of the largest clams found in the Pliocene of the San Diego area. The actual dimensions of the figured specimen are 18.8 cm wide and 17.0 cm high; the photograph is one half as large. The right valve is moderately convex and bears 18 square-cornered, medially grooved ribs separated by spaces of the same width. The left valve is nearly flat and bears 17 somewhat rounded ribs, between which there are wider spaces divided in some cases by a smaller rib.

This species was first collected from the Pliocene of San Diego and has also been found in the Pliocene of the Los Angeles area and in Baja California, Mexico. The figured specimen is from Pacific Beach.

Figure 2. Laminated Eocene sandstone at lower left overlain by more easily eroded *Pecten*-bearing Pliocene rocks at Tourmaline Surfing Park, Pacific Beach.

Plate 21. Pliocene clam.
a, b) *Pecten* (*Patinopecten*) *healeyi* Arnold, x ½.


a
b

Pecten (*Pecten*) *stearnsi* Dall, Plate 22a, b

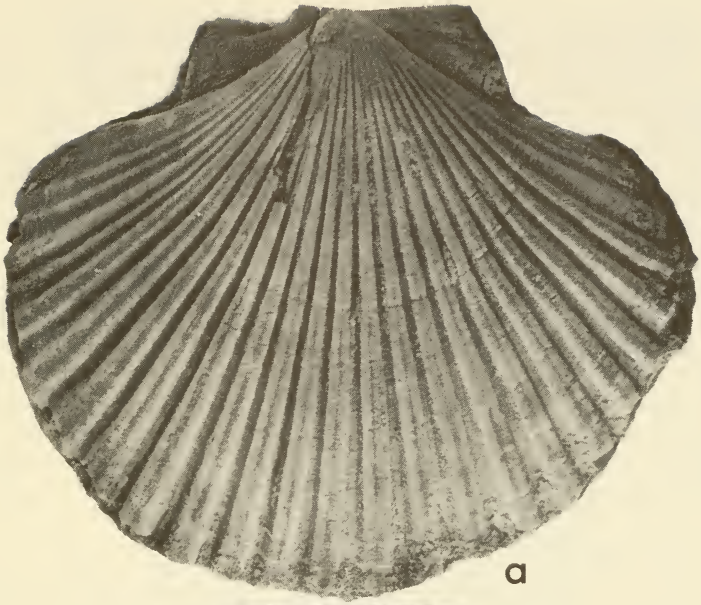
This is a moderate-sized *Pecten* with a flat left valve and a moderately convex right valve. The left valve has rounded ribs; the right valve has flat-topped ribs that are medially grooved. The right valve figured is 9.8 cm wide and 7.7 cm high; the left valve, which is broken, is 9.0 cm wide and 8.1 cm high; each bears 24 ribs.

Young individuals of species of *Pecten* that have light shells can propel themselves efficiently by opening the valves to take in water, then closing them to squirt the water out through openings at the ears.

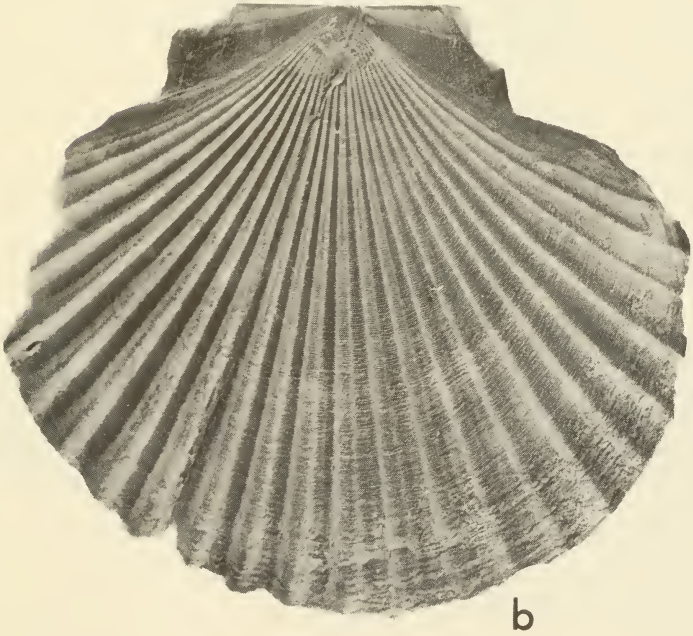
This species was first collected at Pacific Beach, as the figured specimen was, and has since been found in the Pliocene of the Los Angeles area and of Baja California, Mexico. It has also been collected in the Pleistocene at San Pedro, and a form that may be identical with it is living today.

Plate 22. Pliocene clam.

a, b) *Pecten* (*Pecten*) *stearnsi* Dall, x 1.



a



b

Pecten (*Argopecten*) *subdolus* Hertlein, Plate 23a, b

This form has low rounded ribs on both valves, and the valves are moderately and equally inflated. The anterior ear on the right valve is somewhat winglike.

The species was first collected at Pacific Beach, as was the figured specimen. It has also been collected in the Pliocene of Baja California and is presumed to be extinct.

Pecten (*Pecten*) *bellus hemphilli* Dall, Plate 23c, d

The right valve, which is convex, bears high rather flat-topped ribs; on the left valve, which is flat, the ribs and the interspaces are square-cornered. There are 14 ribs on the right valve and 12 on the left valve of the specimen figured. This subspecies was first collected from the Pliocene of San Diego, and has since been found in the Pliocene of the Los Angeles area and in Baja California, Mexico. It is believed to be extinct.

Saccella taphria (Dall), Plate 23e, f, g

This is a small shell with a recurved and pointed end. The small double-valved specimen is 1.6 cm long and 1.0 cm high. The valves when closed are almost as wide as they are high, and the shell is sculptured with equally spaced concentric ridges. In this genus the hinge bears teeth alternating with sockets, as is shown in the figure representing the interior of the shell, Plate 23g.

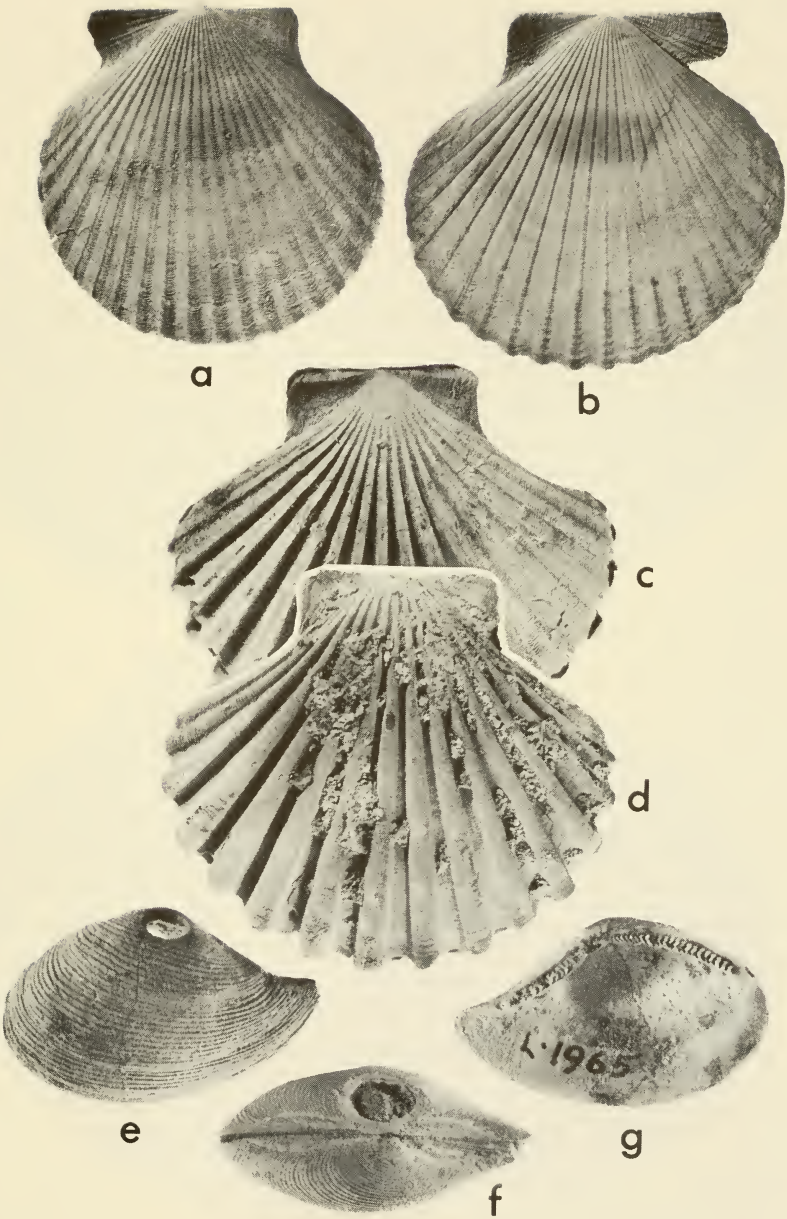
Both specimens came from the Pliocene of Balboa Park. At Pacific Beach this species occurs in both Pliocene and Pleistocene rocks, at Spanish Bight in the Pleistocene. At other places in California it is found in rocks of Miocene to Pleistocene age, and it lives today in coastal water from Bodega Bay, California, to Banco de Arena, Gulfo de California, Mexico.

Plate 23. Pliocene clams.

a, b) *Pecten* (*Argopecten*) *subdolus* Hertlein, x 1.

c, d) *Pecten* (*Pecten*) *bellus hemphilli* Dall, x 1.

e, f, g) *Saccella taphria* (Dall), x 2.

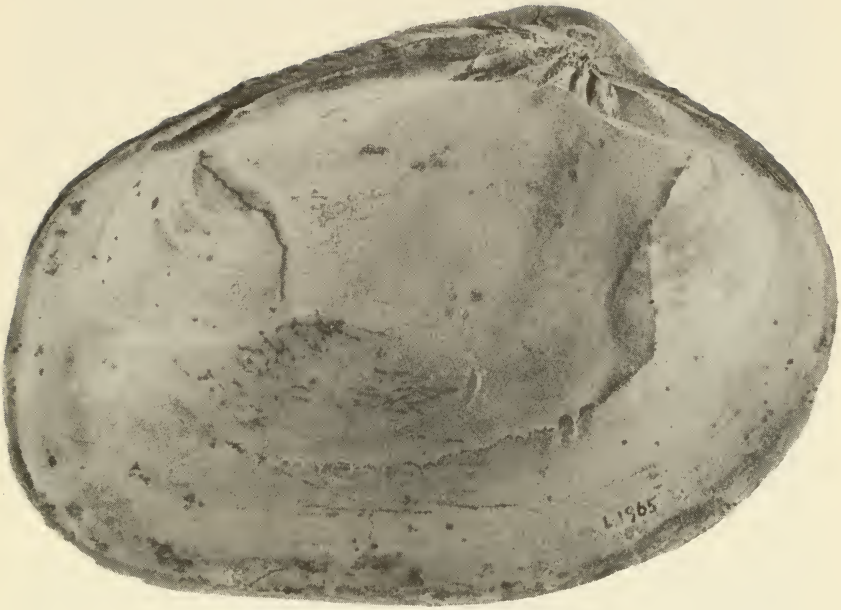

a
b
c
d
e
f
g
L·1965

Saxidomus sp. aff. *S. nuttalli* Conrad, Plate 24a, b

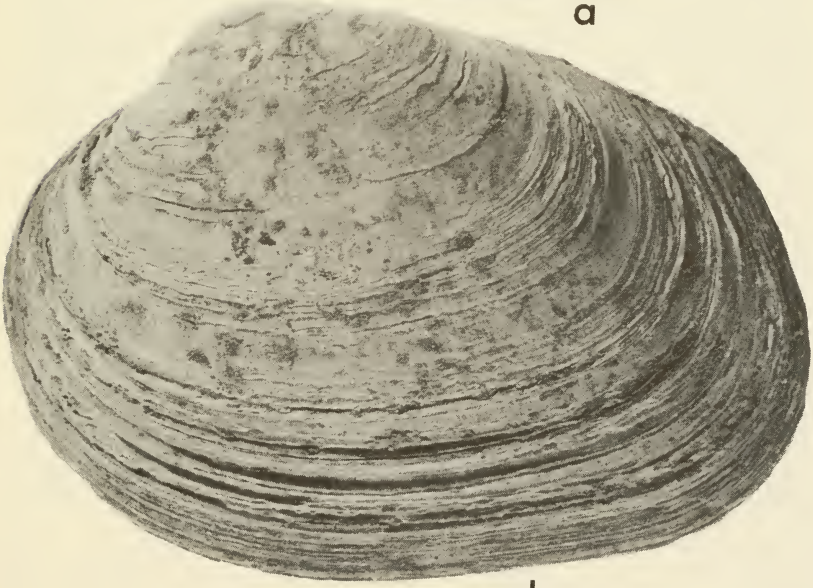
This is a moderately large clam, the specimen figured being 12.3 cm long and 9.1 cm high. It has a thick shell sculptured externally with concentric threads of shell bunched together at irregular intervals. The muscle scars are shown in the internal view (Plate 24a). The shells are said to gape as they do not completely close at the posterior end. The figured specimen was collected from the Pliocene in Balboa Park, San Diego.

The Pleistocene form is believed to differ slightly from the modern species, because it is more truncated at the posterior end, and because the hinge plate and teeth do not exactly match those of modern specimens.

Plate 24. Pliocene clam.
a, b) *Saxidomus* sp. aff. *S. nuttalli* Conrad, x 1.



a



b

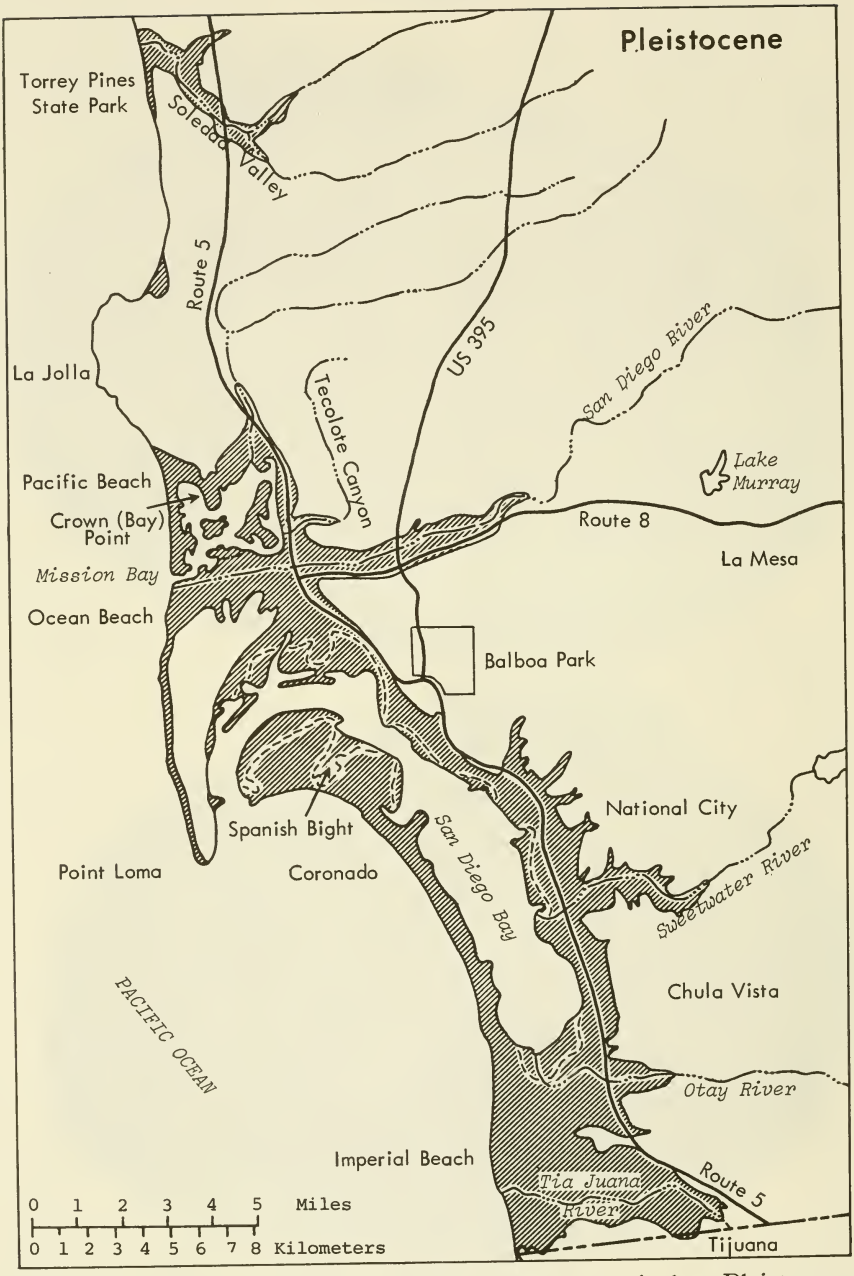
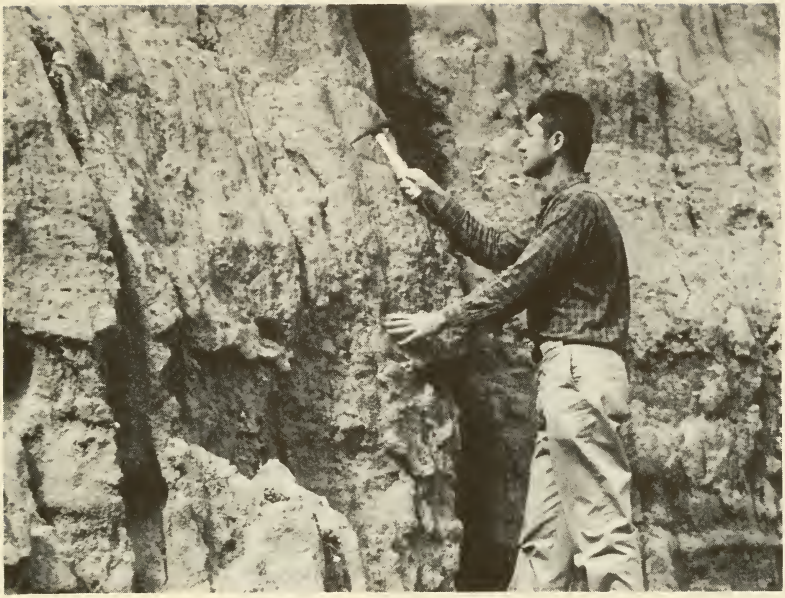


Plate 25. Area at San Diego inundated by the sea in late Pleistocene time shown by shading. Dashed line marks edge of artificial fill.



a

b

Plate 26. Pleistocene rocks.

a) A thick Pleistocene section near Del Mar Racetrack containing a shell bed marked by hammer.

b) Pleistocene molluscan shells in Carmel Valley, near Del Mar.

PLEISTOCENE

So far as is known, the marine fossiliferous Pleistocene in the vicinity of San Diego is of late Pleistocene (Sangamon) age (Wahrhaftig and Birman, 1965, p. 340). It is widely distributed west of Highway 5 (Plates 25 and 26) and is well exposed in the upper parts of cliffs along much of the coastline. It is overlain in places by shell middens left by the Indians, and shells from the two sources are not always readily separable; but many of the shell middens are underlain as well as overlain by soil, none are consolidated, and some may contain artifacts.

The Pleistocene fossils described and illustrated below were all collected at Spanish Bight, west of San Diego, which was a bay that once intervened between North Island and Coronado Island but which has now been almost completely filled, to extend the land area for construction.

GASTROPODS

Acteon traski Stearns, Plate 27a

A rather small shell, the figured specimen of this species is only 2.0 cm high and 1.0 cm wide. It is sculptured with fine spiral ribs, and the spaces between them are finely pitted. The spire is about half as high as the body whorl.

This species lives today in the sea at depths up to 30 meters off southern California and possibly as far south as Panama.

Calliostoma dolarium (Holten), Plate 27b

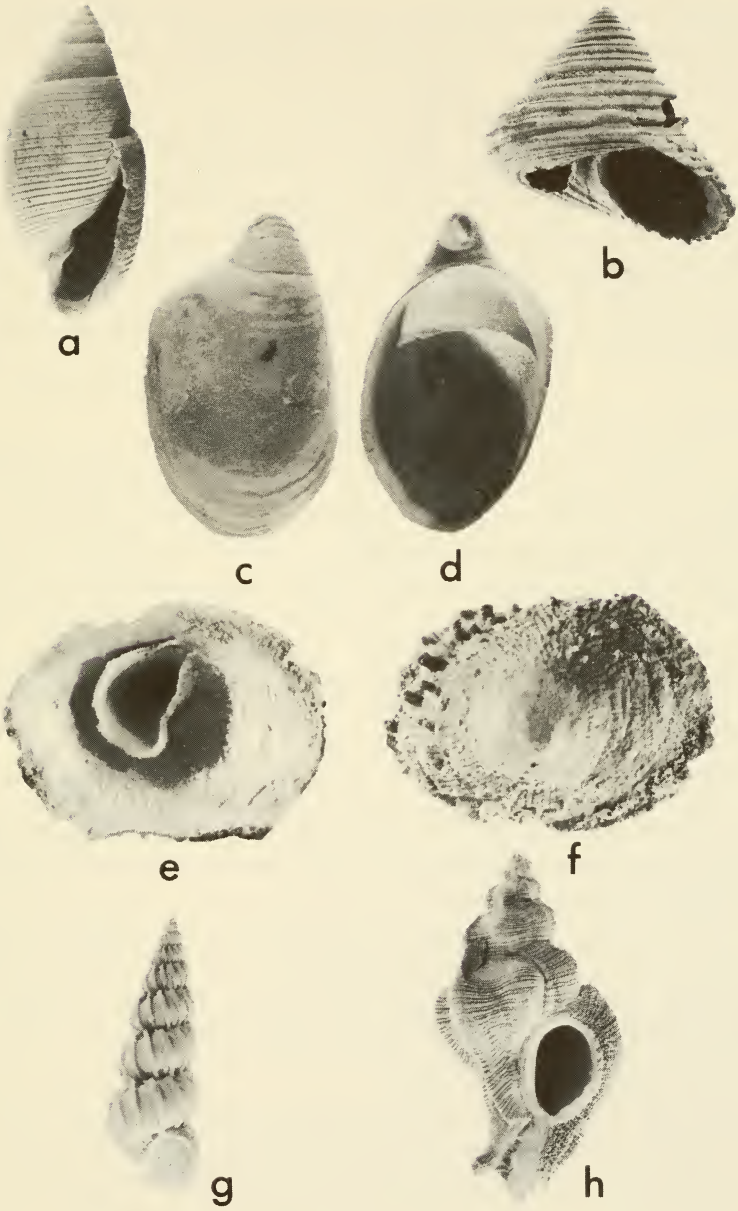
This shell is pearly inside, as are all species of *Calliostoma,* and each whorl is sculptured with spiral cords, some of which are slightly beaded.

This species, formerly cited as *Calliostoma canaliculatum* (Martyn), is found in the Pliocene of Pacific Beach as well as in the Pleistocene

---

Plate 27. Pleistocene snails.

a) *Acteon traski* Stearns, x 2.
b) *Calliostoma doliarium* (Holten), x 1.
c, d) *Crepidula adunca* Sowerby, x 2.
e, f) *Crucibulum spinosum* (Sowerby), x 2.
g) *Epitonium* (*Nitidiscala*) *indianorum* (Carpenter), x 1½.
h) *Jaton festiva* (Hinds), x 1.


a
b
c
d
e
f
g
h

of Spanish Bight. It is living in the sea today from Sitka, Alaska, to San Diego, California, and is usually found offshore on kelp.

Crepidula adunca Sowerby, Plate 27c, d

A low, rather flat, quite thin shell this species has the apex or beak near one of its margins and bears a shelf that covers about a third of the aperture. The beak is small and slightly curved.

This species lived in California during the Pliocene, and Pleistocene fossils are found at Point Loma and near the Mexican border as well as at Spanish Bight, from which the figured specimen came. It lives in the sea today from British Columbia to Baja California, Mexico.

Crucibulum spinosum (Sowerby), Plate 27e, f

The apex is twisted a bit to one side and the shell is dome shaped. The shell is sculptured with radial wrinkles bearing tubular spines. A cuplike shelf is attached to the interior of the shell at one side.

The figured specimen is from Spanish Bight. Fossils of this species are found in the Pliocene of Balboa Park and in the Pleistocene along Pacific Beach. It was also formerly collected from the Pleistocene at the foot of 26th Street, San Diego. It is now living in the sea from southern California to Chile, clinging to other shells and stones at depths of as much as 60 meters.

Epitonium (*Nitidiscala*) *indianorum* (Carpenter), Plate 27g

This lovely slender shell has numerous whorls and a round aperture. The figured specimen is 2.3 cm high and 0.9 cm wide. Each whorl bears pointed radial ribs that stop at the boundary of the whorl and are slightly bent backwards.

This species first appeared in California in the Pliocene. It also occurs in the Pleistocene near the Mexican border and lives in the sea today from Alaska to Baja California. A picture of a shell of this species is used to decorate the cover of this book.

Jaton festiva (Hinds), Plate 27h

On each whorl of this shell are three prominent ribs that are leaf-like near the shoulder, and between each pair of them is a heavy, rounded node. The siphonal canal is moderately long and turned back at the base.

This species has been collected from the Pliocene and Pleistocene at various places in California, the Pleistocene in Baja California, and lives today in the sea off southern California and Baja California, Mexico, on rocky or mud bottoms to a depth of 150 meters.

Nassarius (*Caesia*) *cerritensis* (Arnold), Plate 28a

This is a slender, high-spired species with coarse ribs that are rather widely spaced. The shell has a small hole drilled by another snail, which probably then ate this animal's flesh. The driller of the hole may have been another *Nassarius,* all species of which are carnivorous and drill holes in clams or snails. They are also scavengers.

This species is living today in the sea from Long Beach, California, to Bahía Magdalena, Baja California, Mexico.

Nassarius (*Caesia*) *fossatus* (Gould), Plate 28f

A large, fat shell, this species has noded ribs along the shoulder of the body whorl, which is higher than the spire.

This species has been found in the Pleistocene of San Diego. It now lives in the sea from Vancouver Island, British Columbia, to Isla Cedros, Baja California, Mexico.

Nassarius (*Demondia*) *mendicus* (Gould), Plate 28d

A high, slender spire and sculpture of numerous ribs help to distinguish this species. The spire is as high as the body whorl. Its sculpture is finer than that of *Nassarius cerritensis* and coarser than that of *Nassarius perpinguis.*

This species occurs in the Pliocene in Balboa Park, and in the Pleistocene at Pacific Beach and near the Mexican border as well as at Spanish Bight. It lives in the sea today from Kodiak Island, Alaska, to Bahía Magdalena, Baja California, Mexico.

Nassarius (*Caesia*) *perpinguis* (Hinds), Plate 28e

This *Nassarius* has a spire of moderate height and is finely and evenly sculptured with radial and spiral ridges that produce small nodes where they meet.

This species has been collected from the Pliocene in Balboa Park and from the Pleistocene along Pacific Beach and near the Mexican border. It lives now in the sea between Puget Sound, Washington, and Bahía Magdalena, Baja California, Mexico.

Olivella biplicata (Sowerby), Plate 28g, i

A very small spire and a relatively large body whorl help to distinguish this little shell. Its surface is smooth, with no ornamentation, and the whorls lap over one another like the pages of a twisted magazine. The neat hole on the front of the body whorl was drilled by a carnivorous snail in order that he might eat the soft parts.

This species has been collected from the Pliocene in Balboa Park and at various Pleistocene localities in San Diego. It lives today from British Columbia to Baja California, Mexico, on beach sand and in sandy bays but sometimes in water as much as 50 meters deep.

Polinices (*Neverita*) *recluzianus* (Deshayes), Plate 28b, h

This snail is one of the largest found in the Pleistocene of San Diego. It has a very large body whorl and a relatively low spire. It is somewhat oval in shape; the shell is thick, smooth and not sculptured, and there is a large plug near the aperture.

This species may have lived as long ago as the Oligocene, but in San Diego it is collected from both the Pliocene and Pleistocene, and it lives today from Monterey, California, to the Islas Tres Marias, Mexico, in shallow water and at depths of as much as 50 meters.

Terebra (*Strioterebrum*) *pedroana* Dall, Plate 28c

This shell has a slim spire about twice as high as the body whorl. The whorls are sculptured with fine spiral bands and grooves, and with radial ridges each of which ends in a node on the shoulder of the whorl.

This species has been collected from the Pliocene in Balboa Park and in the Pleistocene at several localities in San Diego. It lives today in shallow water off southern California and Baja California, Mexico.

Plate 28. Pleistocene snails.

a) *Nassarius* (*Caesia*) *cerritensis* (Arnold), x 1½.
b, h) *Polinices* (*Neverita*) *recluzianus* (Deshayes), x 1.
c) *Terebra* (*Strioterebrum*) *pedroana* Dall, x 2.
d) *Nassarius* (*Demondia*) *mendicus* (Gould), x 3.
e) *Nassarius* (*Caesia*) *perpinguis* (Hinds), x 1½.
f) *Nassarius* (*Caesia*) *fossatus* (Gould), x 1½.
g, i) *Olivella biplicata* (Sowerby), x 2.


a
b
c
d
e
f
g
h
i

SCAPHOPOD

Dentalium neohexagonum Sharp and Pilsbry, Plate 29a

A long, curved tube characterizes this shell and all shells of the genus *Dentalium*. It is rather thin and has seven flat sides separated by low ribs. The figured specimen is 3.5 cm long, 0.3 cm wide at the greatest diameter, and 0.1 cm wide at the least diameter.

This species has been found in the Pliocene of Balboa Park and Pacific Beach and in the Pleistocene at several localities in San Diego. It also occurs in the Pleistocene of the Los Angeles area and in Baja California, and lives in the present sea from central California to Central America.

PELECYPODS

Amiantis callosa (Conrad), Plate 29b, c

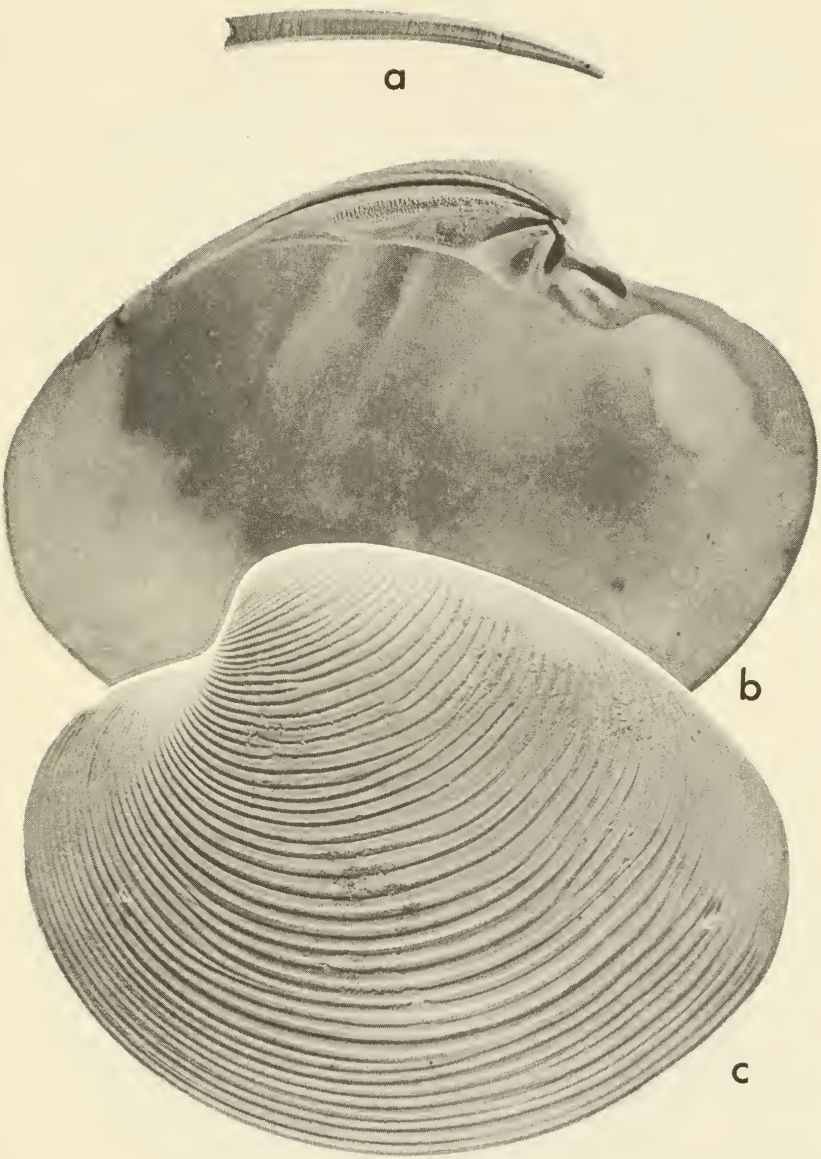
This is an ovate, porcelain-like shell that is thick and sculptured with heavy concentric ridges. The beaks are small and are turned toward the anterior end of the shell. The pallial sinus and muscle scars can be seen on the interior of the figured shell, Plate 30b.

This species has been collected from rocks of Miocene to Pleistocene age in California, from Pleistocene deposits in Baja California, and in the present sea from Santa Barbara, California, to Cabo San Lucas, Baja California, Mexico.

Plate 29. Pleistocene tusk shell and clam.

a) *Dentalium neohexagonum* Sharp and Pilsbry, x 1½.

b, c) *Amiantis callosa* (Conrad), x 1.


a
b
c

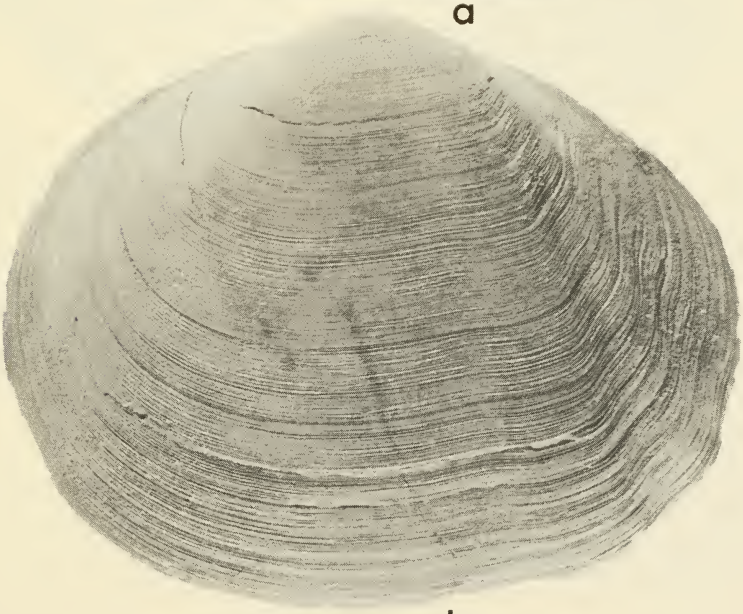
Florimetis biangulata (Carpenter), Plate 30a, b

A large shell, this species has two folds at the posterior end, as is indicated by its name *bi* (two) *angulata* (angled). It is subrounded in outline, and the exterior is sculptured with fine threads.

This species has been collected in California from rocks of Miocene to Pleistocene age, in Baja California from the Pliocene and Pleistocene, and in the present sea from Point Conception, California, to San Quintín, Baja California, Mexico. It occurs in the Pliocene at Pacific Beach and in the Pleistocene at Spanish Bight and near the Mexican border.

Plate 30. Pleistocene clam.
a, b) *Florimetis biangulata* (Carpenter), x 1.

a



b

Pandora (*Heteroclidus*) *punctata* Conrad, Plate 31a, b

This thin, pearly little shell is flat and somewhat similar in form to the side of a wooden shoe. The beaks are near the posterior end of the shell. Inside the shell, small pits can be seen where the animal was attached to it.

This species occurs in Pliocene and Pleistocene rocks elsewhere in California and in the Pleistocene at Spanish Bight and near the Mexican border, and it lives today from Vancouver Island to Golfo de California, Mexico.

Leptopecten latiauratus (Conrad), Plate 31c, d

This very small *Pecten* is 1.3 cm high and 1.2 cm wide, and both valves are 0.6 cm thick. The right and left valves are equally convex. The two ears on the left valve are almost equal in size and alike in shape; the anterior ear on the right valve looks like part of a fan and is bordered by a deep groove. Both the right and the left valves are sculptured with low, rounded ribs. This clam attaches itself to rocks by secreting long tough filaments.

The figured specimen was collected at Spanish Bight. The species also occurs in the Pleistocene at Point Loma, formerly at the foot of 26th Street, and near the Mexican border. It lives today from central California to Golfo de California, Mexico.

Petricola (*Petricolaria*) *parallela* Pilsbry and Lowe, Plate 31e

A long, slender, thin shell, this species has noded radial ribs on the anterior end. The posterior two-thirds of the shell is sculptured with fine radial lines that do not have nodes. *Petricola* lives in holes that it bores into hard clay or in holes that it finds in the rocks.

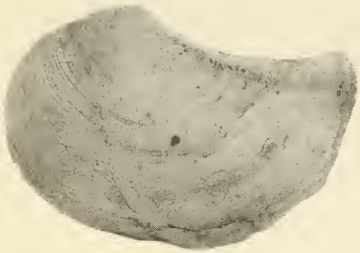
The figured specimen was collected at Spanish Bight. The species has also been collected at Tecolote Creek, San Diego, and it lives today from Laguna Scammon, Baja California, to Nicaragua at depths up to 15 meters.

Plate 31. Pleistocene clams.

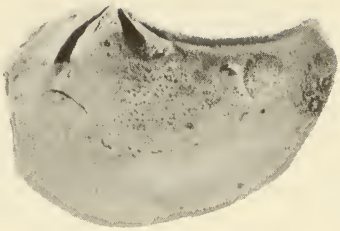
a, b) *Pandora* (*Heteroclidus*) *punctata* Conrad, x 1.

c, d) *Leptopecten latiauratus* (Conrad), x 3.

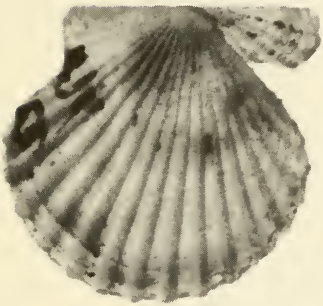
e) *Petricola* (*Petricola*) *parallela* Pilsbry and Lowe, x 1½.



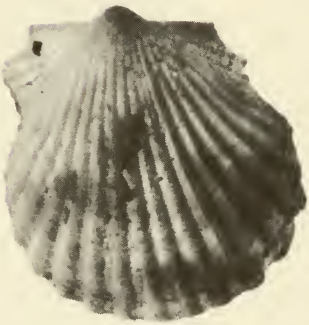
a



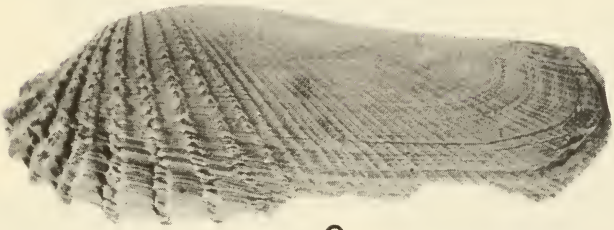
b



c



d



e

Tagelus (*Tagelus*) *californianus* (Conrad), Plate 32a

Being very long in proportion to its height, this clam resembles a closed jackknife and is therefore commonly called the jackknife clam. The shell is thin, and its exterior surface is sculptured with fine concentric threads. When the valves are closed, the shell gapes.

This species occurs in the Pliocene and Pleistocene of California and in the Pleistocene of Baja California, Mexico. It has been found in the Pliocene in Balboa Park and in the Pleistocene at Spanish Bight, near Tecolote Creek, and formerly at 26th Street, in San Diego. It lives today from Monterey Bay, California, to Golfo de Tehuantepec, Mexico.

Trachycardium (*Mexicardia*) *procerum* (Sowerby), Plate 32b, c

This shell is somewhat heart shaped in profile, and both valves are strongly convex. It is sculptured with many subrounded ribs separated by square-cornered interspaces. The beaks are centrally located and curve inward. The interior margin is crenulated.

This species has been found in the Pleistocene at the foot of 26th Street in San Diego and in Baja California. It lives today from Baja California to Peru.

Yoldia cooperi Gabb, Plate 32d, e

Although this shell looks a little like shells of *Pandora* (Plate 31), the genera may be instantly told apart if the interior can be seen, because *Yoldia* has a row of many small teeth alternating with sockets along the hinge, whereas *Pandora* has but one to three radiating teeth. The exterior of *Yoldia cooperi* is sculptured with incised concentric lines that tend to be bunched at the pointed posterior end. The beaks are located two-thirds of the distance from the anterior end.

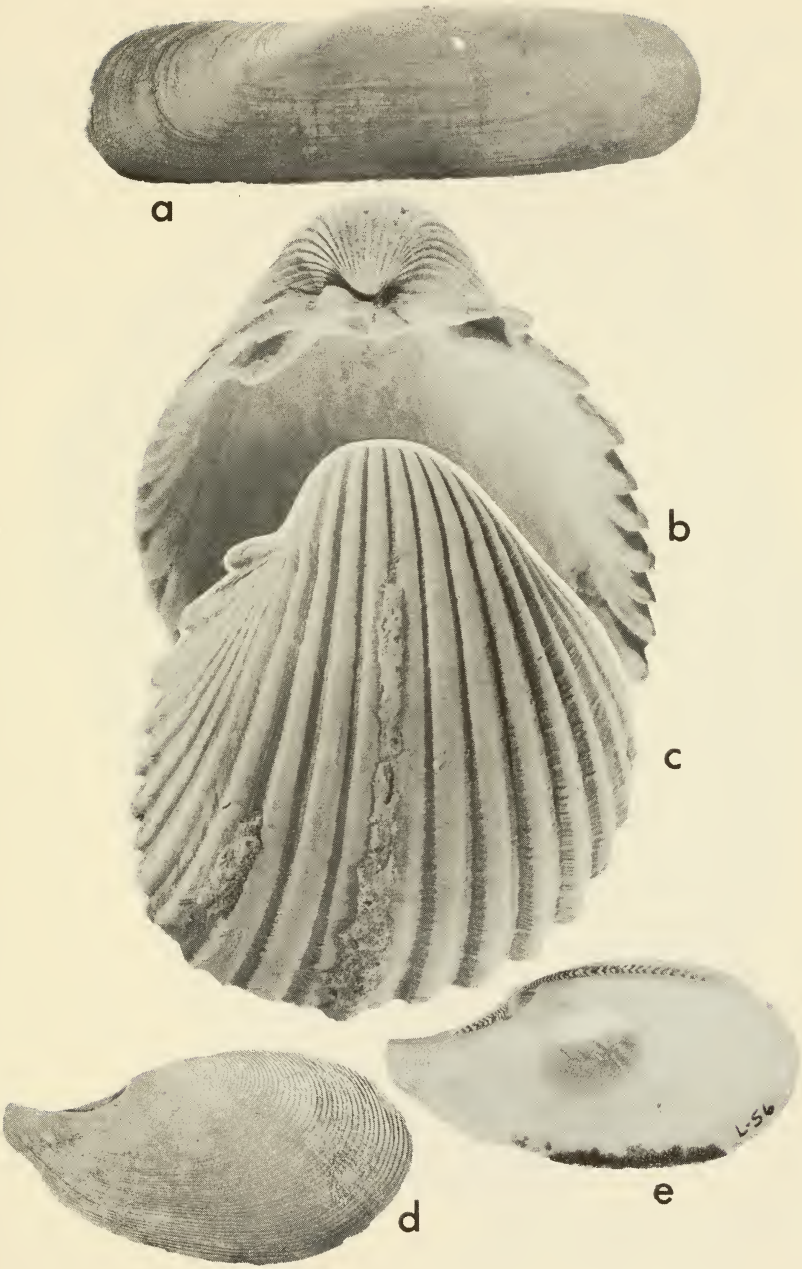
In the San Diego area this species has been found in the Pleistocene only, but elsewhere in California it occurs in rocks of Miocene and Pliocene as well as Pleistocene age. It lives today from San Francisco Bay to San Diego.

Plate 32. Pleistocene clams.

a) *Tagelus* (*Tagelus*) *californianus* (Conrad), x 1.

b, c) *Trachycardium* (*Mexicardia*) *procerum* (Sowerby), x 1.

d, e) *Yoldia cooperi* Gabb, x 1.


a
b
c
d
e
L-56

Tresus nuttalli (Conrad), Plate 33, Plate 34

This is one of the largest of the Pleistocene clams; the specimen figured is 15.0 cm long and 9.8 cm high but is only of moderate size for the species. The shell is thick and is truncated at the posterior end, and if the two valves are together and closed it gapes at the posterior end. The pallial line and muscle scars can be seen in the interior view, Plate 34.

This species has been collected from Miocene, Pliocene, and Pleistocene rocks in California and from the Pleistocene of Baja California. It lives today off central and southern California and Baja California, Mexico.

Plate 33. Pleistocene clam.
Tresus nuttalli (Conrad), x 1.

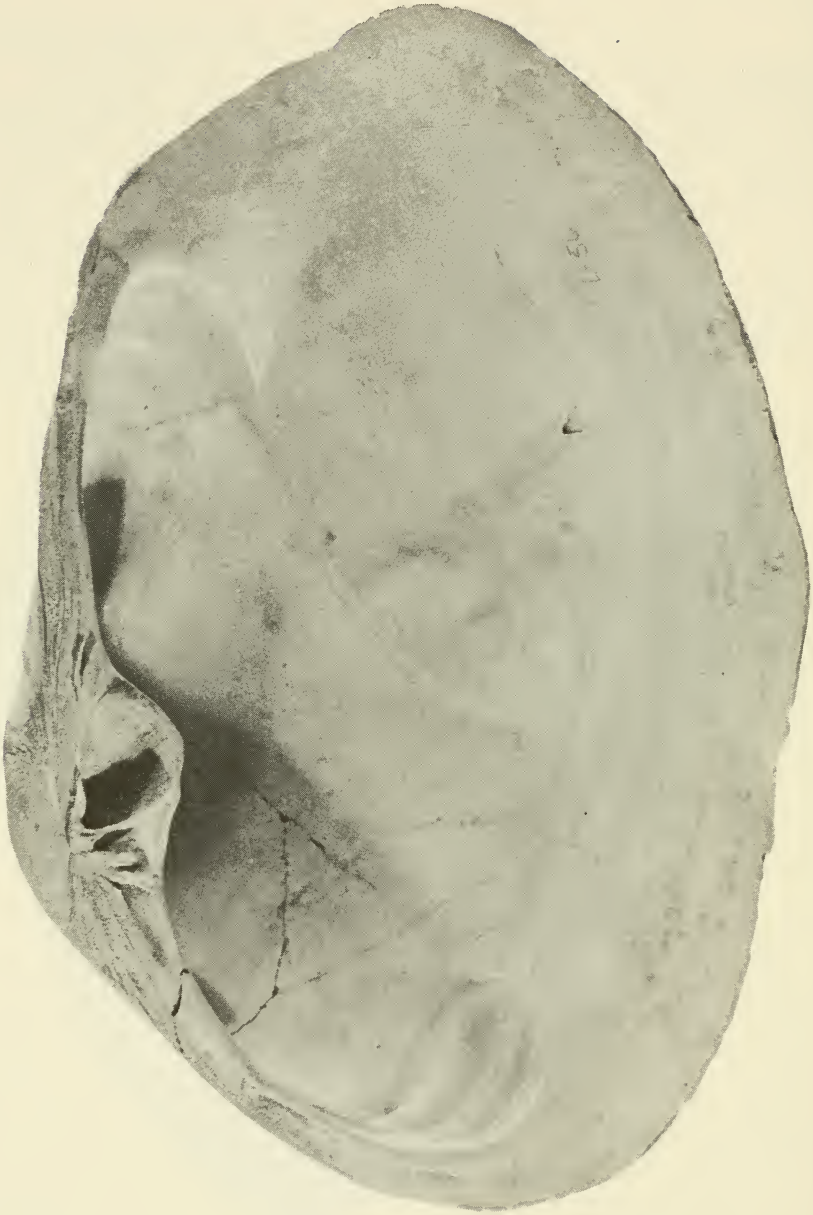


Plate 34. Pleistocene clam.
Tresus nuttalli (Conrad), x 1.

REFERENCES

Abbott, R. T.
1954. American seashells. New York, D. Van Nostrand Co., Inc., 541 p., 100 figs., 40 pls.

Addicott, W. O., and Emerson, W. K.
1959. Late Pleistocene invertebrates from Punta Cabras, Baja California, Mexico. Amer. Mus. Novitates 1925, p. 1-33, figs. 1-8.

Anderson, F. M.
1902. Cretaceous deposits of the Pacific Coast. California Acad. Sci. Proc., ser. 3, v. 2, p. 1-152, pls. 1-12.

Anderson, F. M.
1958. Upper Cretaceous of the Pacific Coast. Geol. Soc. Amer. Mem. 71, 378 p., 75 pls.

Arnold, Ralph
1903. The paleontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California. California Acad. Sci. Mem., v. 3, 420 p., 37 pls.

Arnold, W. H.
1965. A glossary of a thousand-and-one terms used in conchology. The Veliger, v. 7, suppl., 50 p., 155 figs.

Conrad, T. A.
1854. Descriptions of new fossil shells of the United States. Acad. Nat. Sci. Philadelphia Jour., ser. 2, v. 2, p. 299-300.

Cooper, J. G.
1894. Catalogue of Californian fossils (pts. II-V). California State Mining Bur. Bull. 4, 65 p.

Dall, W. H.
1874. Notes on some Tertiary fossils from the California Coast, with a list of the species obtained from a well at San Diego, California, with descriptions of two new species. California Acad. Sci. Proc., v. 5, 296-299.

Emerson, W. K.
1956. Pleistocene invertebrates from Punta China, Baja California, Mexico, with remarks on the composition of the Pacific Coast Quaternary faunas. Amer. Mus. Nat. Hist. Bull., v. 111, p. 313-343, 1 figs., pls. 22-23.

Emerson, W. K., and Addicott, W. O.
1953. A Pleistocene invertebrate fauna from the southwest corner of San Diego County, California. San Diego Soc. Nat. Hist. Trans., v. 11, p. 429-444, 1 map.

Emerson, W. K., and Chace, E. P.
1959. Pleistocene mollusks from Tecolote Creek, San Diego, California. San Diego Soc. Nat. Hist. Trans., v. 12, p. 335-346, figs. 1-3.

Fife, D. L., Minch, J. A., and Crampton, P. J.
1967. Late Jurassic age of the Santiago Peak Volcanics, California. Geol. Soc. Amer. Bull., v. 78, p. 299-304, 5 figs.

Gabb, W. M.
1864. Description of the Cretaceous fossils. California Geol. Survey Palaeont., v. 1, p. 58-81, 102-236, pls. 9-31.

Grant, U. S., IV, and Gale, H. R.
1931. Catalogue of the marine Pliocene and Pleistocene Mollusca of California and adjacent regions. San Diego Soc. Nat. Hist., Mem., v. 1, 1036 p., 32 pls.

Hanna, M. A.
1926. Geology of the La Jolla quadrangle, California. Univ. California Pub. Geol. Sci., v. 16, p. 187-246, pls. 17-23.

Hanna, M. A.
1927. An Eocene invertebrate fauna from the La Jolla quadrangle, California. Univ. California Pub. Geol. Sci., v. 16, p. 247-398, pls. 24-57.

Harland, W. B., Smith, A. G., and Wilcock, B., eds.
1964. The Phanerozoic time-scale. Geol. Soc. London Quart. Jour. v. 120s, 458 p.

Hertlein, L. G., and Grant, U. S., IV
1944. The geology and paleontology of the marine Pliocene of San Diego, California, pt. 1, Geology. San Diego Soc. Nat. Hist. Mem., v. 2, p. 1-72, 18 pls.

Hertlein, L. G., and Grant, U. S., IV
1960. The geology and paleontology of the marine Pliocene of San Diego, California, pt. 2a, paleontology (Coelenterata, Bryozoa, Brachiopoda, Echinodermata). San Diego Soc. Nat. Hist. Mem., v. 2, p. 73-133, pls. 19-26.

Keen, A. M.
1958. Sea shells of tropical west America. Stanford, California, Stanford Univ. Press, 624 p., 1709 figs.

Kennedy, M. P.
1967. Preliminary report, engineering geology of the City of San Diego, California. California Div. Mines and Geology Open-file Rept., 21 p., 4 pls.

Moore, R. C., Lalicker, C. G., and Fischer, A. G.
1952. Invertebrate fossils. New York, McGraw-Hill Book Company, Inc., 766 p., illus.

Moore, R. C., ed.
1957, 1960, 1964, and in preparation. Treatise on invertebrate paleontology, (I) Mollusca 1 (1960), (J) Mollusca 2 (in preparation), (K) Mollusca 3 (1964), (L) Mollusca 4 (1957), (M) Mollusca 5 (in preparation), (N) Mollusca 6 (in preparation). Geol. Soc. America and Univ. Kansas Press, illus.

Peterson, G. L., Gastil, R. G., and Allison, E. C.
1966. Geology of the Peninsular Ranges, *in* Albers, J. P., and others, Mineral and water resources of California. Washington, U. S. Senate Comm. Interior and Insular Affairs, p. 70-73.

Stephens, Frank
1929. Notes on the marine Pleistocene deposits of San Diego County, California. San Diego Soc. Nat. Hist. Trans., v. 5, p. 245-256, 1 fig.

Stewart, R. B.
1927. Gabb's California fossil type gastropods. Acad. Nat. Sci. Philadelphia Proc., v. 78, p. 287-447, pls. 20-32.

Stewart, R. B.
1930. Gabb's California Cretaceous and Tertiary type Lamellibranchs. Acad. Nat. Sci. Philadelphia Spec. Pub. no. 3, 314 p., 17 pls.

Strand, R. G.
1962. San Diego-El Centro Sheet. California Div. Mines and Geology, Geol. Map of California.

Valentine, J. W.
1959. Pleistocene molluscan notes. I. The Bay Point Formation at its type locality. Jour. Paleontology, v. 33, p. 685-699, 7 figs.

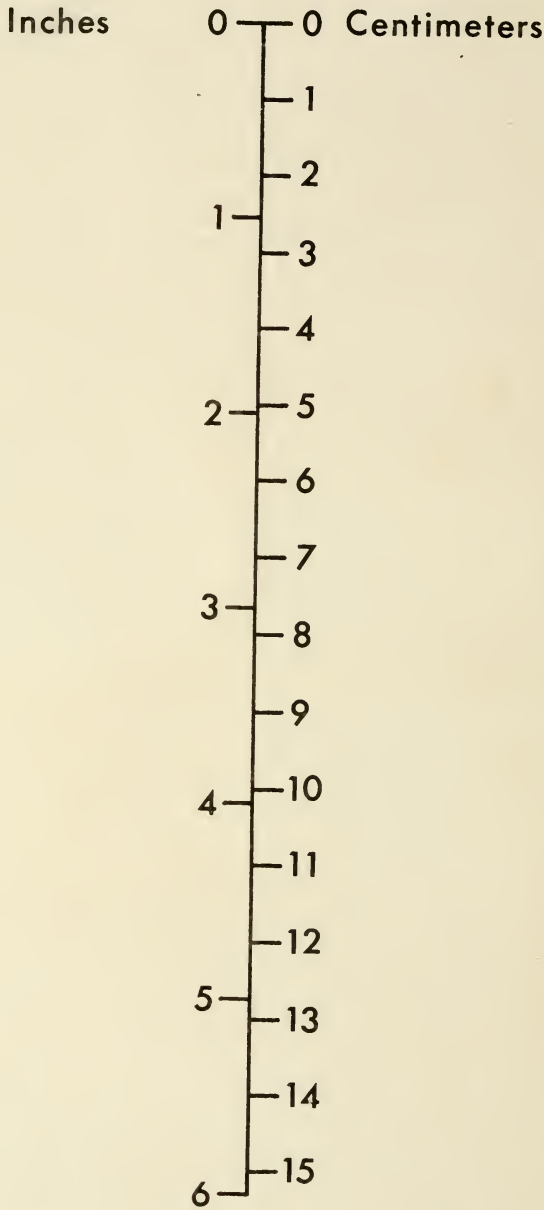
Valentine, J. W.
1960. Habitats and sources of Pleistocene mollusks at Torrey Pines Park, California. Ecology, v. 41, p. 161-165.

Wahrhaftig, C., and Birman, J. H.
1965. The Quaternary of the Pacific mountain system in California, *in* Wright, H. E., Jr., and Frey, D. G., eds., The Quaternary of the United States. Princeton, New Jersey, Princeton Univ. Press, p. 299-340.

Webb, R. W.
1937. Paleontology of the Pleistocene of Point Loma, San Diego County, California. San Diego Soc. Nat. Hist. Trans., v. 8, p. 337-348.

Weber, F. H., Jr.
1963. Geology and mineral resources of San Diego County, California. California Div. Mines and Geology County Rept. 3, 309 p., 11 pls.

Whitaker, T. W., ed.
1964. Torrey Pines State Reserve. La Jolla, California, Torrey Pines Assoc., 63 p., 23 figs., 1 map.



Cover Design: Dallas Clites