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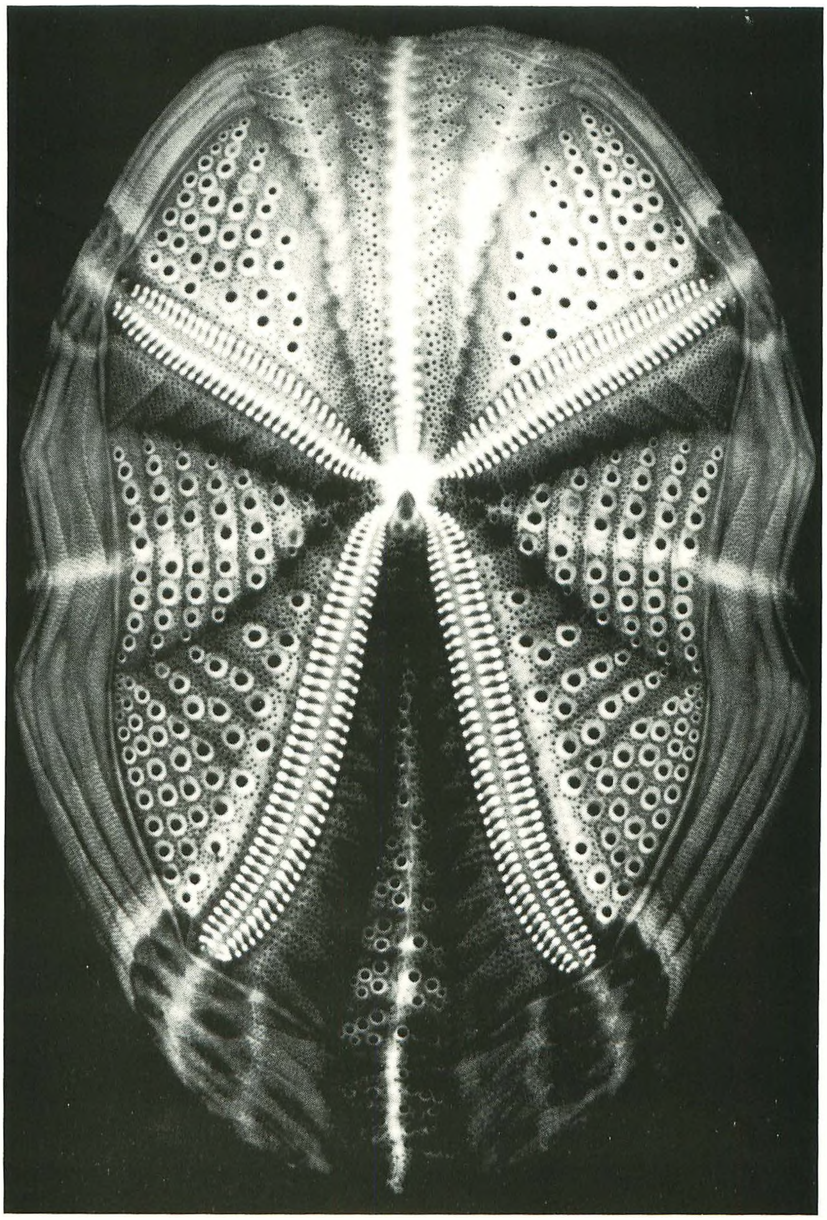

A LOVE OF FOSSILS BRINGS US TOGETHER

ACKNOWLEDGEMENT

Two years ago at EXPO VII this special ECHINOID EXPO EDITION of MAPS DIGEST was a dream.

One year ago at EXPO VIII MAPS member, Carlos Bazan, accepted the responsibility to organize and then to write letters asking MAPS echinoid enthusiasts to contribute to this issue. The dream began to take form.

The pages that follow are the fruit of Carlos' labors. Each author could tell a little story in addition to the precious pages which include his/her article. Some of the articles simply arrived in the mail with no contact from Carlos. Each article is a gift, and the whole is what happens when dedicated, generous people share their expertise.

Special mention must be made here of Mrs. Yvonne Albi and Porter M. Kier, Retired. These two people graciously submitted articles even though they are not members of MAPS.

It is a pleasure to recognize the MAPS members, Mrs. Albi, and Dr. Porter M. Kier, all of whom contributed to this special ECHINOID EXPO EDITION. The following pages are eloquent testimony to a dream that became a reality.

The Front Cover: *Plagiobrissus grandis* (Gmelin)

Irregular Echinoid (Elongate)
Diver and photographer: Robert W. Cooper
5012 Pfeiffer Rd.
Peoria, Illinois 61607

30 feet deep off Looe Key, Atlantic side, Florida Keys.

The Back Cover: *Lytechinus variegatus* (Leske)

Regular Echinoid (Round)
Diver and photographer: Robert W. Cooper
5012 Pfeiffer Rd.
Peoria, Illinois 61607

5 to 10 feet deep off Atlantic side of Little Torch Key, Florida Keys.

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MAPS DIGEST EXPO IX EDITION -- ECHINOIDS

Table of Contents, Cont'd.

Note: John Taylor, Dr. A. Vadet, and Debbie Durnal-Corso, in addition to Yvonne Albi and Porter M. Kier, are all very much a part of helping this EXPO ECHINOID EDITION dream become a reality.

They were omitted in error from the inside cover of the DIGEST which was printed a few days ahead of the rest of the issue.

Madelynne Lillybeck, Editor

FOSSIL ECHINOIDS - THE GEMS IN A FOSSIL COLLECTION

Porter M. Kier
Curator of Fossil Echinoderms
Director National Museum Natural History, Retired
Washington, D.C.

Echinoids have been prized by fossil collectors for thousands of years. Primitive man surrounded his grave with Cretaceous echinoids from the Chalk of England. Victorian naturalists always included echinoids in their "cabinets". And the fossils which starred in the "French Lieutenant's Woman" were echinoids from the Jurassic cliffs of Dorset. Paleobiologists prize them because of the evolutionary story revealed in their tests. Stratigraphers treasure them as index fossils in the Mesozoic and Tertiary. Why all this adulation?

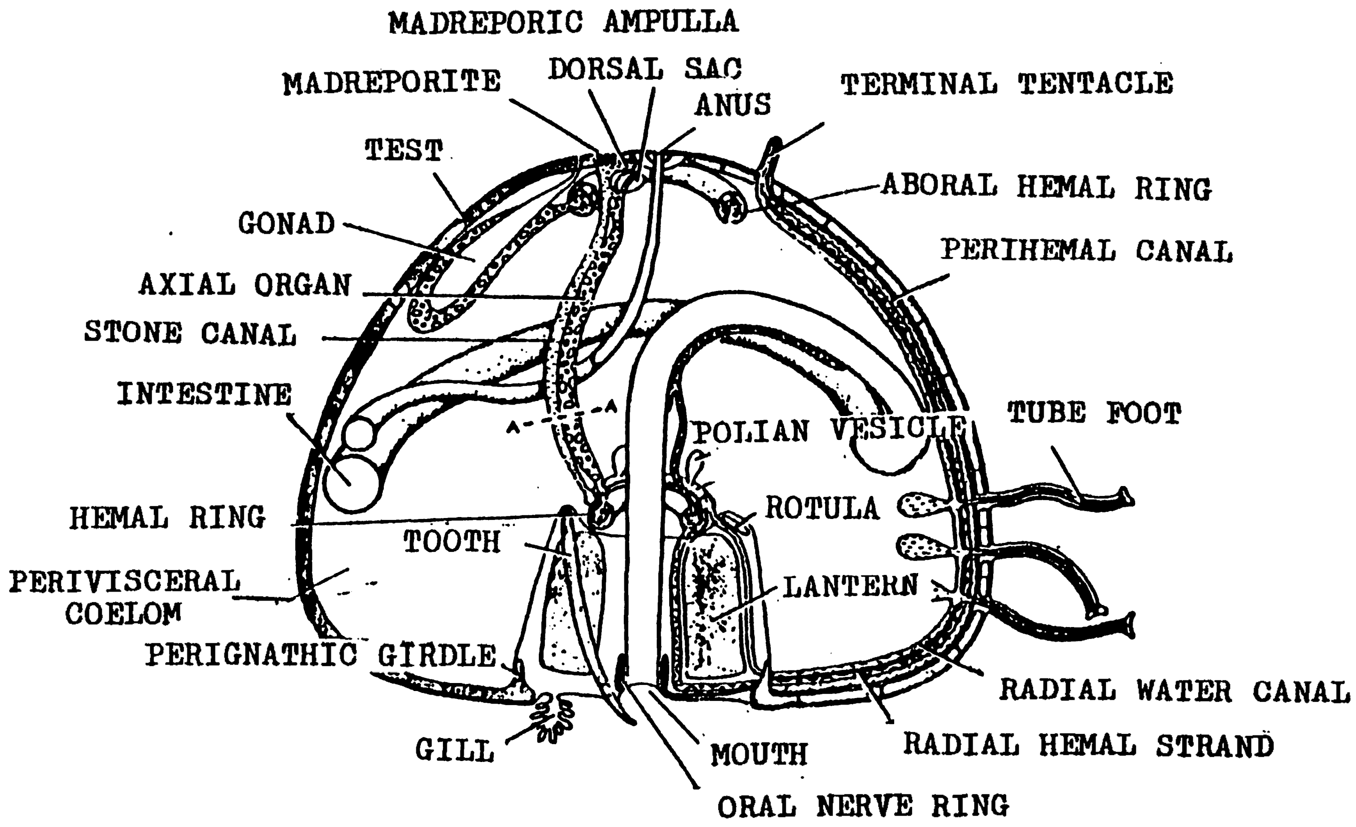
First, a fossil echinoid is a thing of beauty with the starlike impression of the petals on an irregular echinoid or the pentametry of a regular. Each specimen is composed of hundreds or even thousands of intricately welded together calcite plates arranged in patterns distinctive to each species. Good specimens are rare enough to challenge and entice the search, but common enough to permit the hope of discovery. They are excellent index fossils because they are relatively short ranged time-wise, with a fairly wide geographic distribution. Their functional morphology is well understood making it possible to predict the living habits of the fossil species and the environment in which they lived.

The major events in their evolutionary history are now known, with their origin in the Ordovician followed by a rapid diversification in the Devonian and Mississippian. Many very different kinds appeared but by the end of the Paleozoic only one main type remained. In the Early Jurassic, an evolutionary burst occurred with the development of the irregular echinoids and the subsequent appearance of the heart urchins and sand dollars. They now live in the oceans from the strand to the greatest depths all over the world.

As fossils they are most common in the Mesozoic and Tertiary. In the United States they are prolific in the Eocene and Oligocene of Florida and in the Cretaceous of Texas. In Europe they are abundant in the Jurassic and Cretaeous of France and England, and particularly sought after in the Chalk where they are important zone markers. Paleozoic specimens are rare except at a few Mississippian localities, although spines are frequently found.

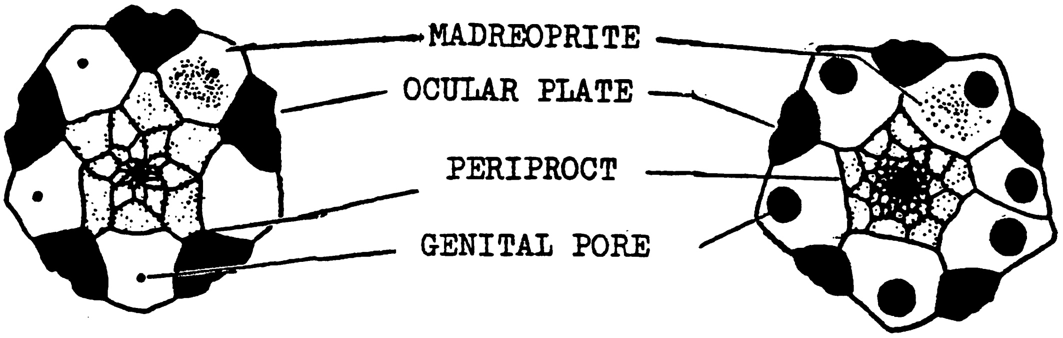
DIAGRAMMATIC VERTICAL SECTION OF REGULAR ECHINOID, BASED ON <u>ECHINUS</u>

From MAPS Echinoid Slide Presentation -- Thanks to Gil Norris

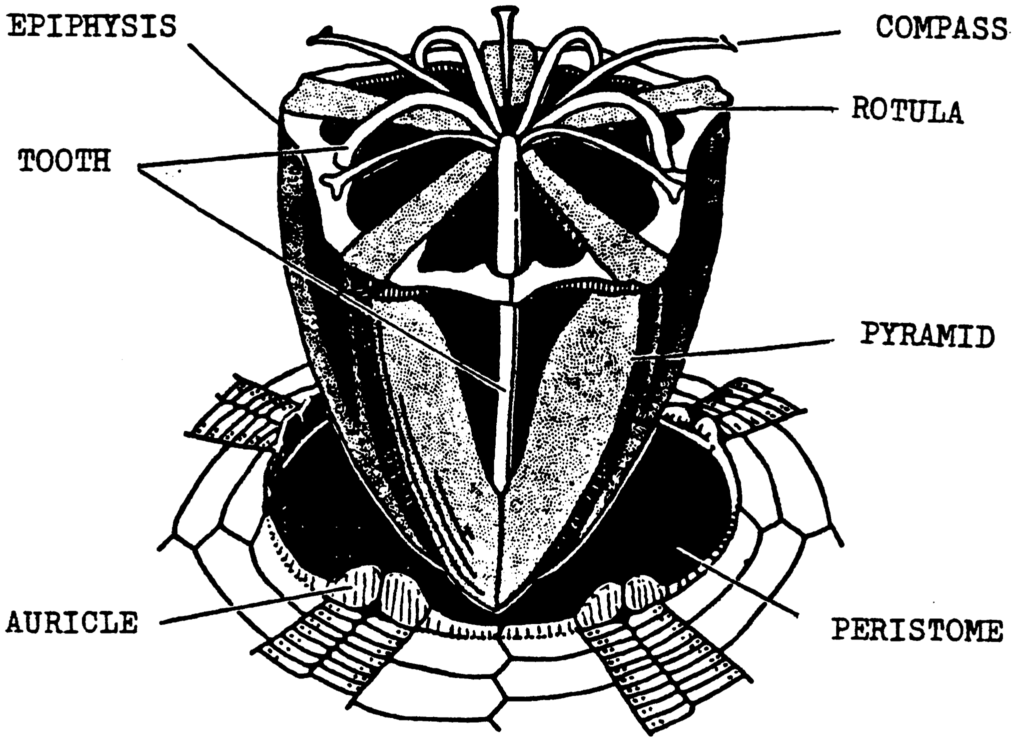


APICAL SYSTEM

From MAPS Echinoid Slide Presentation -- Thanks to Gil Norris

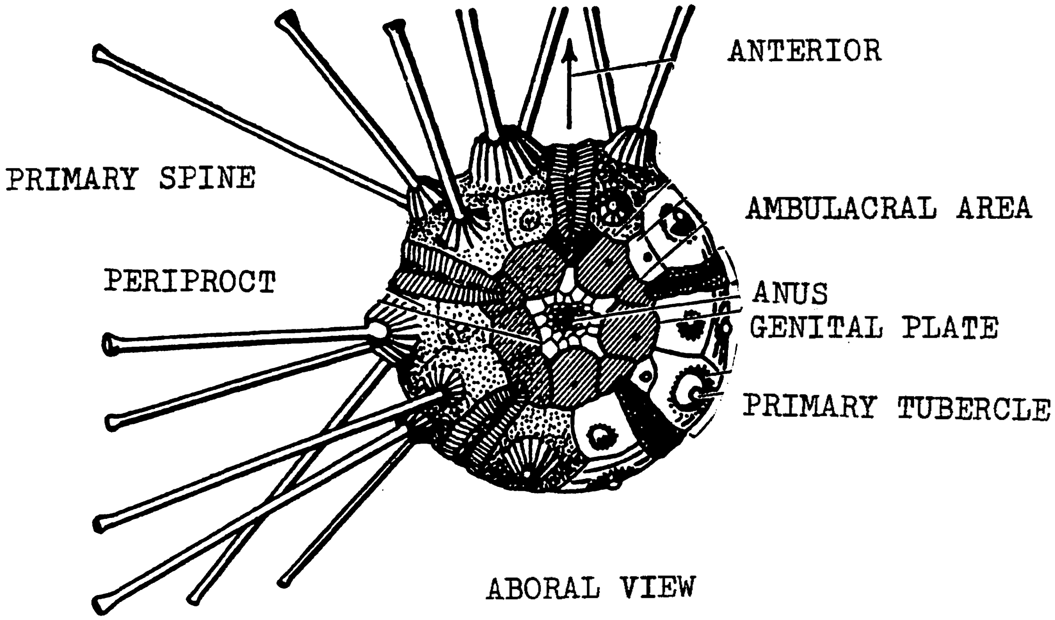


ARISTOTLE'S LANTERN

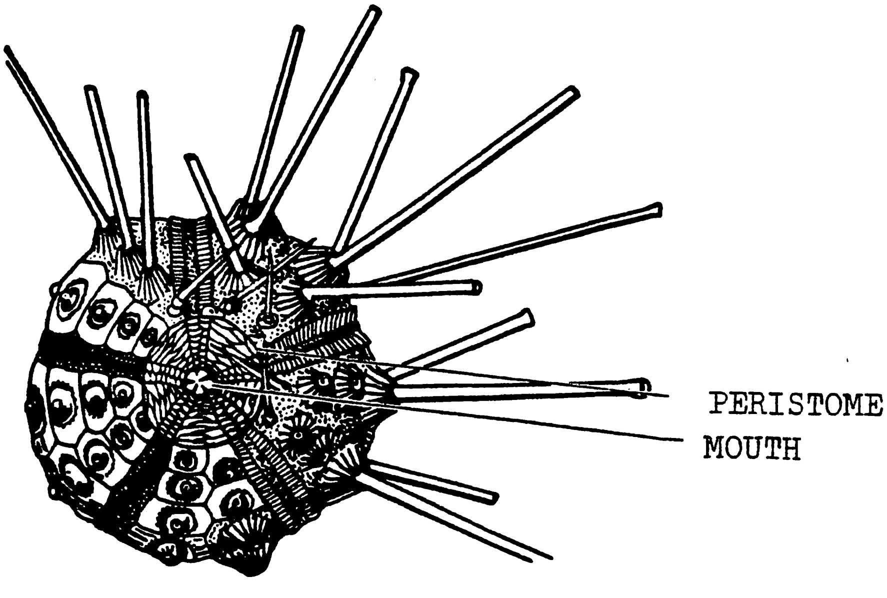


CIDAROID ECHINOID MORPHOLOGY

From MAPS Echinoid Slide Presentation -- Thanks to Gil Norris



ABORAL VIEW



ORAL VIEW

MORPHOLOGY

(This section of this EXPO EDITION of the Digest is a part of "Texas Cretaceous Echinoids", Texas Paleontology Series Publication No. 3. This is a "Publication in Progress" by the Paleontology Section, Houston Gem Mineral Society. This publication has a Copyright pending.)

The echinoids are globular to heart shape animals covered with calcareous interlocking plates that protect the internal organs. The surface of living echinoids are, in turn, protected by spines which articulate and are used for defense and locomotion.

Major descriptive terms used for both echinoid subclasses are shown in Figure 4. Top, bottom and side views are given along with height, width and length dimensions, and anterior, posterior, up and down locations. The Perischoechinoidea are older in origin have a slightly less complicated structure while the Euechionidea are newer and are more complex.

The test is composed of ten total areas. Five are termed ambulacral (amb) areas which contain pores of the water vascular system. The other five are called interambulacra (interamb) areas. The apical system is associated with reproduction and contains the madreporite which is also part of the water vascular system. The peristome is the mouth opening and the periproct is the anal opening. Gill slits, indicating the presence of exterior gills for breathing, may be present. The fasciole is a groove or band where small spines are located to aid water movement.

The typical echinoids shown in Figure 4 do not present all of the important features of all echinoids. Additional terminology will be found in the Illustrated Glossary to help the reader understand the descriptions of species and higher classification groups.

Orientation

Your fossil must be properly oriented so you can find its parts for identification. The widely accepted Loven system is used in this publication and is shown in Figure 5 for both echinoid subclasses. Amb areas are marked in Roman numerals and interamb areas are given in Arabic numerals both rotating counter clockwise when viewed from the top. Amb III is always anterior or at the top. The madreporite is the key in the Perischoechinoidea and it lies in interamb area 2. In the Euechionidea the unpaired amb is III, by definition, and the madreporite also lies in interamb 2. The apical system faces up and the peristome is down.

Apical System

The apical system contains some of the major identifying features. Two typical apical systems are shown in Figure 6. They are composed of five ocular plates (at the head or top of the ambs) and usually five genital (reproductive) plates. The ocular plates are usually smaller than the genital plates and are perforated by a pore. One of the genital plates is perforated for the water vascular system and is called the madreporite. The madreporite is usually larger than the other genital plates and its presence is essential for proper orientation of the Perischoechinoidea. The remaining genital plates become perforate only upon sexual maturity.

Figure 4

NAMES OF ECHINOID HARD PARTS

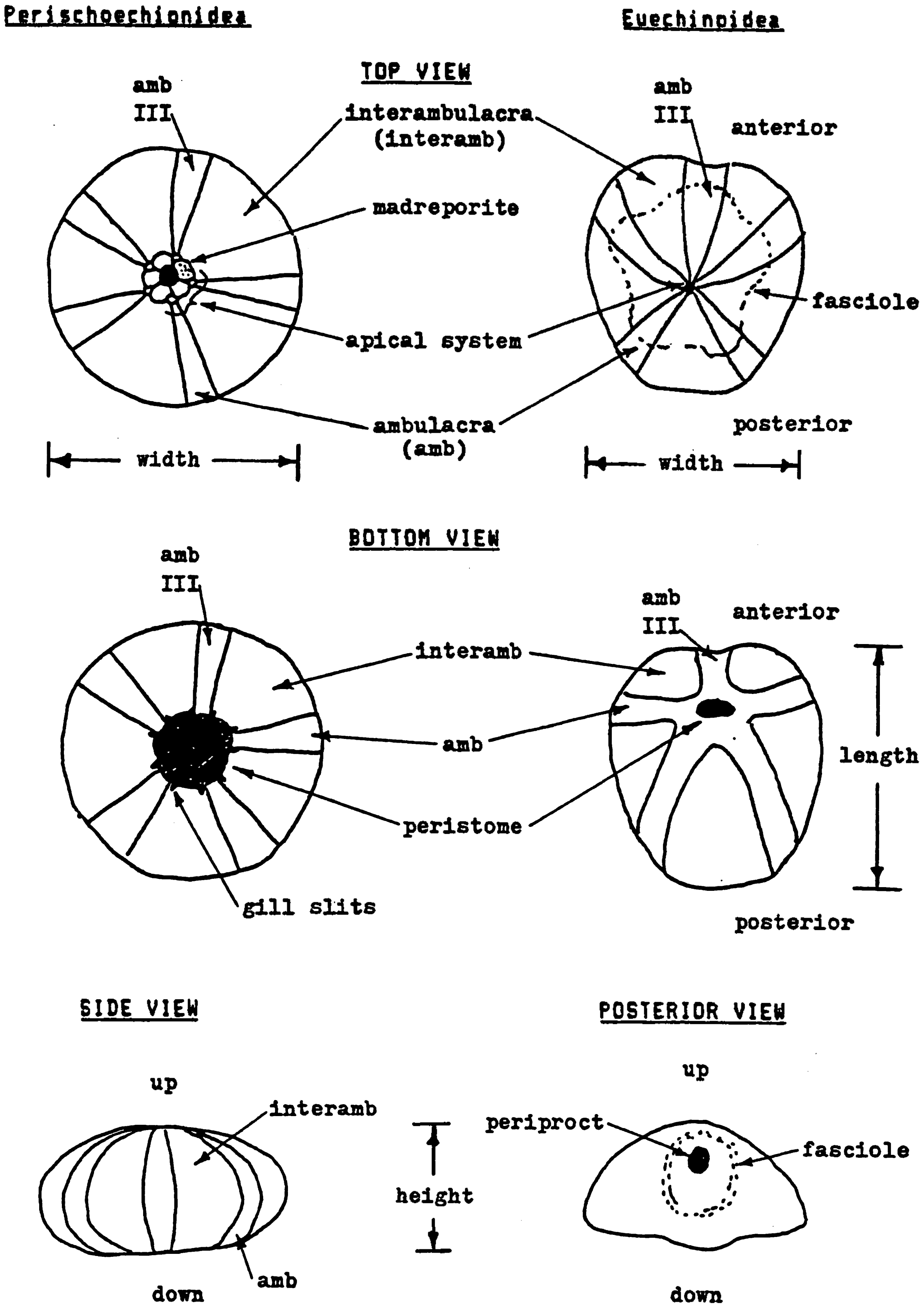


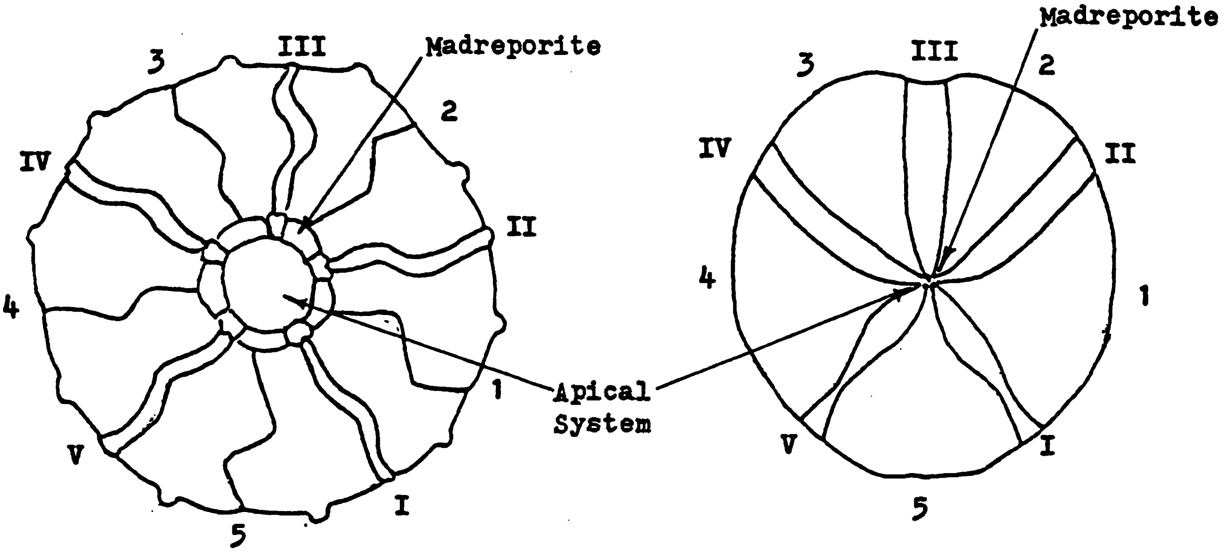
Figure 5

LOVEN ORIENTATION SYSTEM

Perischoechinoidea
(Stereocidaris)

Euechinoidea
(Hemiaster)

TOP VIEW



BOTTOM VIEW

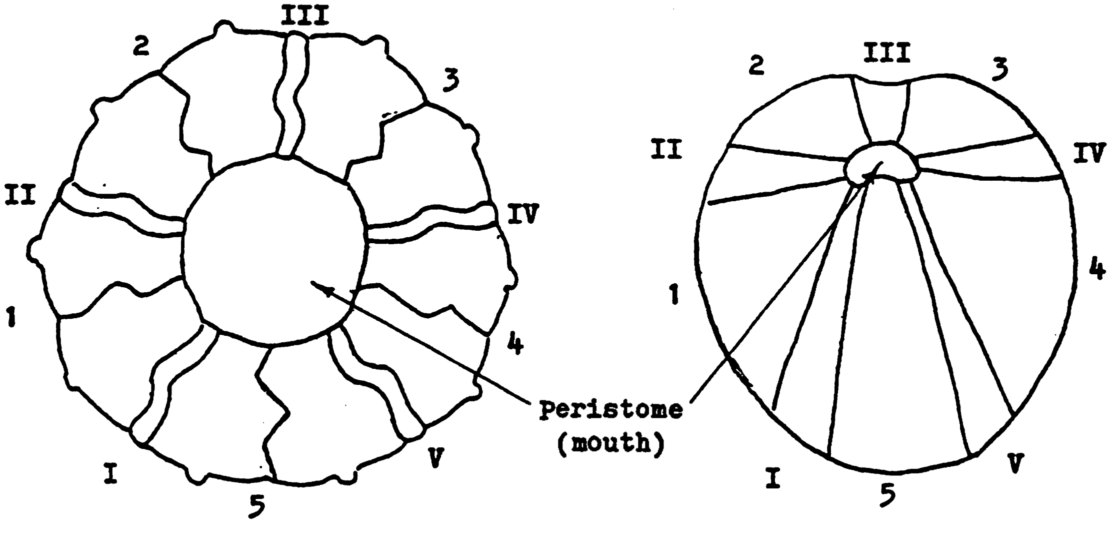
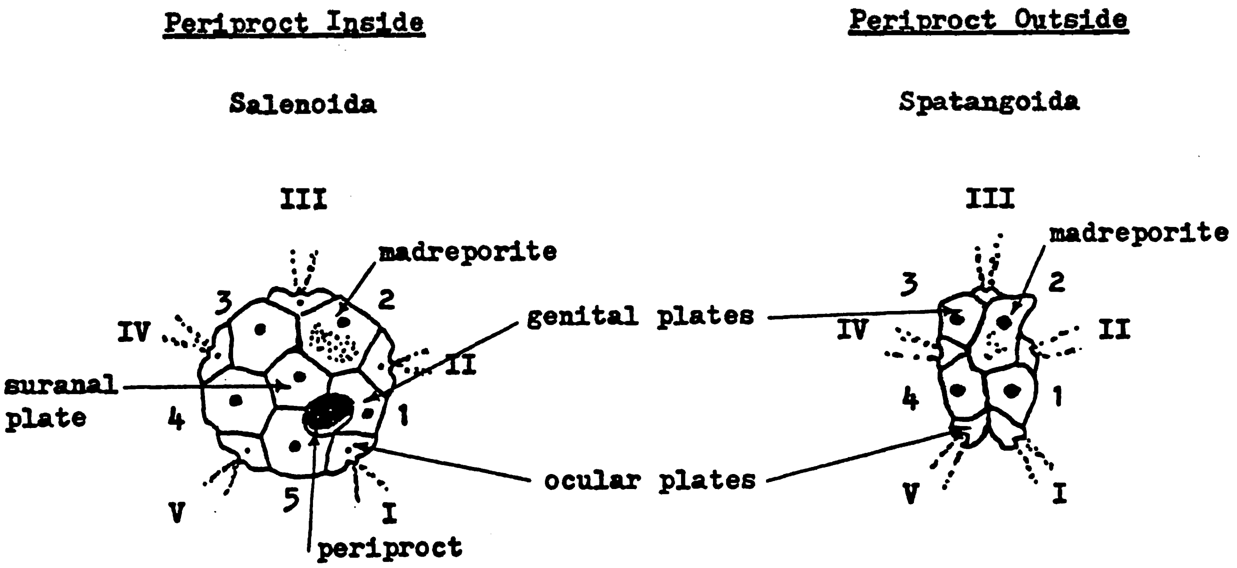


Figure 6

TYPICAL APICAL SYSTEMS



Periproct Inside

Salenoida

Periproct Outside

Spatangoida

The ocular plates and genital plates are numbered the same as the closest amb or interamb. Ocular I would be adjacent to Amb I and Genital 5 would be adjacent to Interamb 5.

The apical system is termed monocyclic if the ocular plates are in contact with the periproct. The apical system is termed dicyclic if only the genital plates are in contact with the periproct. In the Euechinoidea the posterior genital plate may be missing which reduces the total number of genital plates to four in some orders. Typical apical systems from each order of fossils found in the Texas Cretaceous are shown in Figure 7. The top nine examples have the periproct within the apical system while the bottom six do not.

Amb Pore/Plate Differences

Ambs consist of two or more columns of plates extending from the ocular plates to the edge of the peristome. Each simple plate is perforated by two pores (pore pair) which gives passage to one tube foot that is part of the water vascular system. These pores vary in shape and are important identification features. Examples of the various types of amb plates are given in Figure 8. Simple amb plates are unsutured and undivided and they are termed primary.

The Cidaroida have a narrow, sinuous amb and the plates are of simple construction. Diadematoid amb plates are composed of three primary plates with the middle one reduced in size. Arbacoid plates has each group of three plates with the upper and lower of the three being a demiplate, which touches the interamb but not the inside amb suture. The echinoid plate has more demiplates and becomes even more complex. The Phymosomatoida plates are even more complex as are those in the Euchinoidea. Amb plates with elongate pores called petaloid.

Figure 7

TYPICAL APICAL SYSTEMS OF TEXAS CRETACEOUS ECHINOIDS

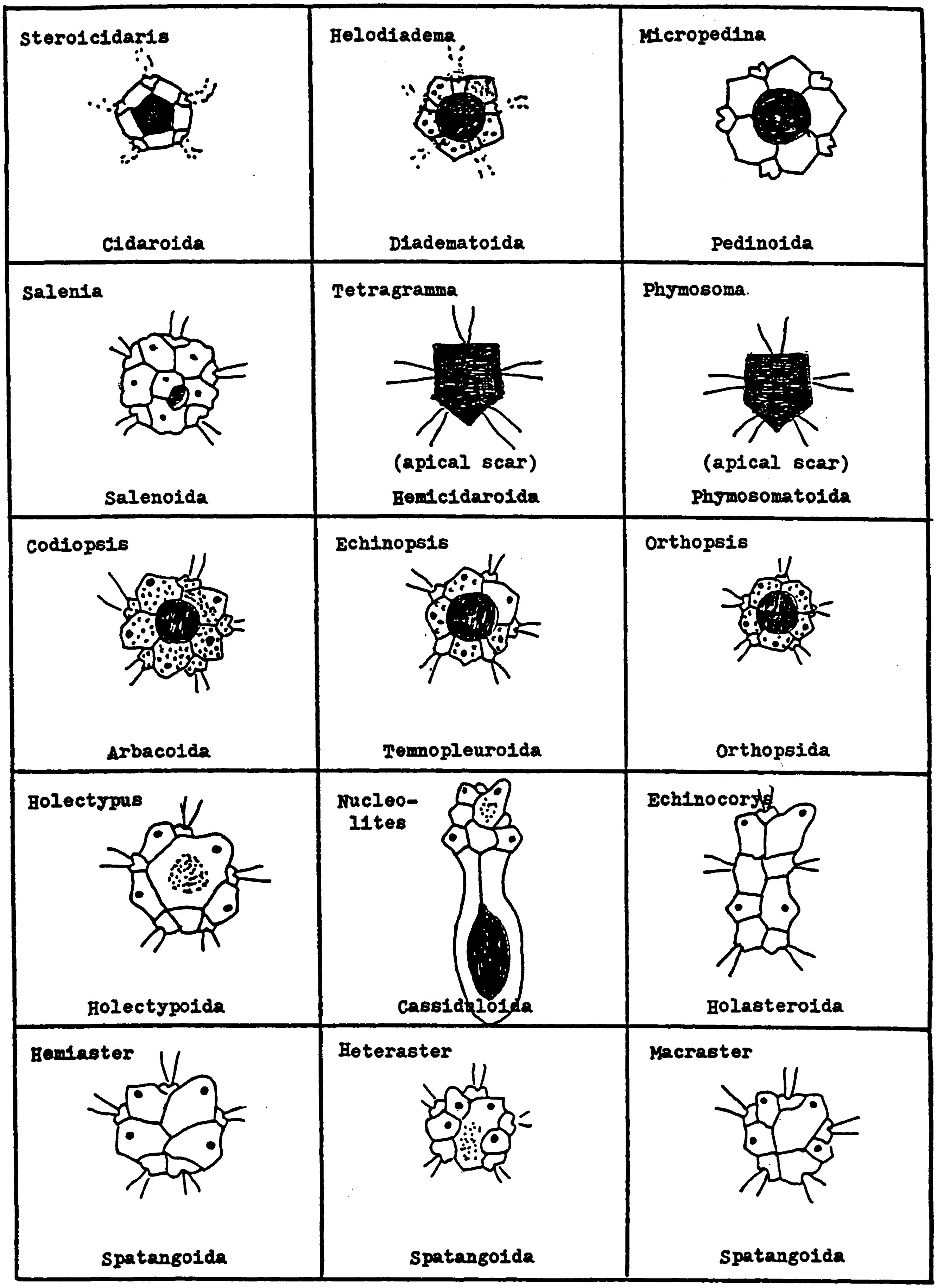
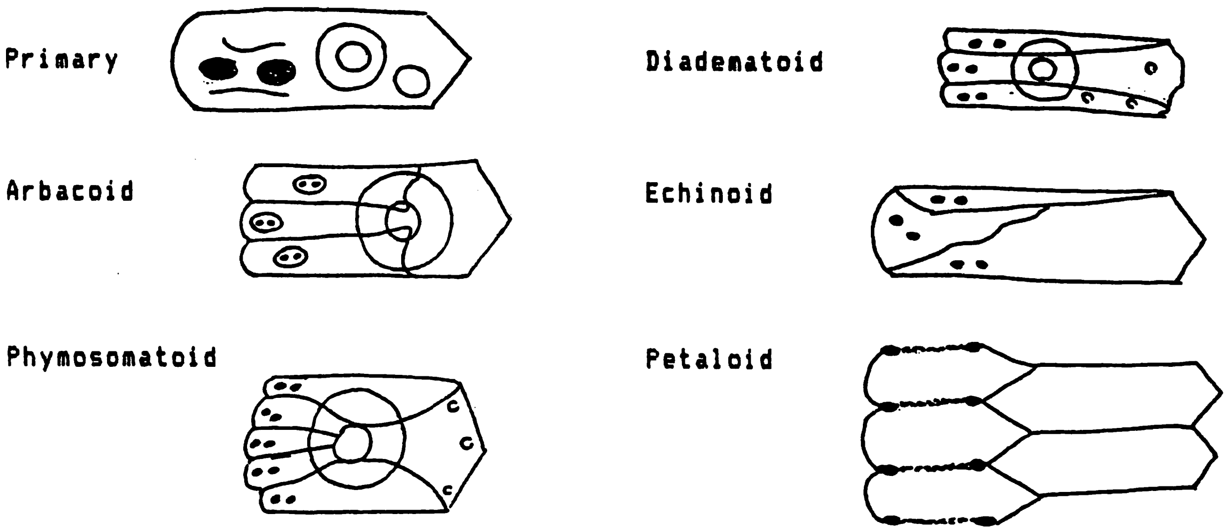


Figure 8

TYPICAL AMB PLATE STRUCTURES



Interamb and Tubercle Structure

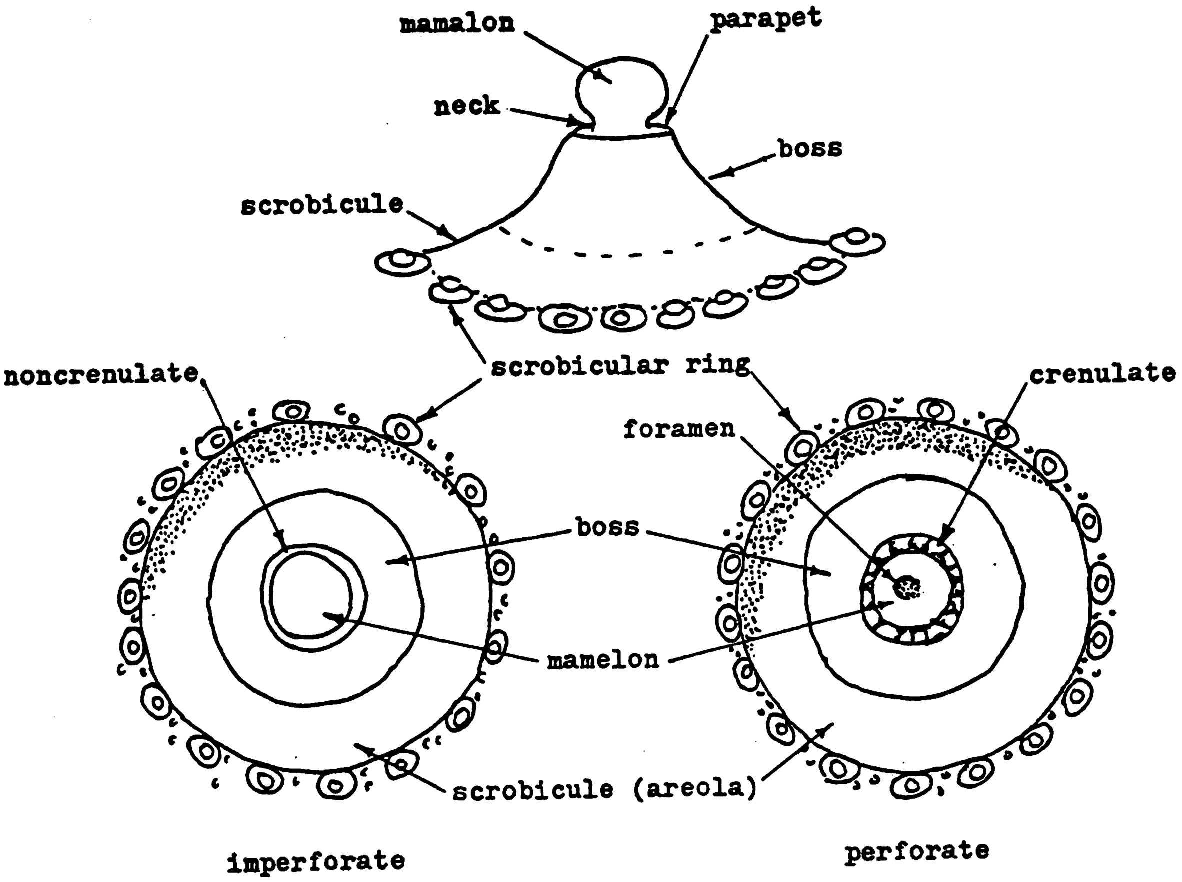
The primary function of the interamb is defense and locomotion, which is accomplished by spines. The interamb is composed of two columbs of staggered plates and, in the Euechinoidea, is notched on each side by gill slits. The spines articulate on tubercles which become an identifying features. A typical primary tubercle is illustrated in Figure 9. It sits in a smooth area called a scrobicule on areole where the spine muscles attach. The scrobicule is surrounded by the scorbicular circle of secondary tubercles. The tubercle consists of the globular mamelon which may have a central pit and may be perforate or imperforate. This perforation may also be termed the foramen. The mamelon sits on the parapet which may be smooth or crenulate. Below the parapet is the base, then the scorbicule or areola which is surrounded by the scorbicular ring of small tubercles.

Fasciole

The test in newer, more evolved echinoids may have strongly ciliated areas, named a fasciole. This is shown on the test by a groove or band of fine and dense tuberculation. These bands may occur around the amb petals, around the periproct and/or near the margin of the test. Typical examples of fascioles are given in Figure 4.

Figure 9

DETAILS OF A PRIMARY TUBERCLE

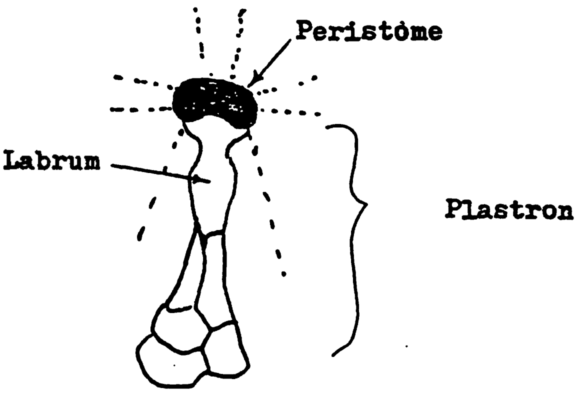


Plastron

The plastron is a descriptive term for a collection of plates below the peristome. It is primarily found in the Holasteroids and Spatangoids.
The first plate of the posterior interamb (Interamb 5) is narrow and elongate. In more advanced echinoids the plate becomes hammer shaped and extends into a lip, called the labrum. Both the labrum and the following plates of this interamb are called the plastron. An example of a plastron and labrum in Spatangoids is shown in Figure 10.

Figure 10

LABRUM AND PLASTRON IN SPATANGOIDS



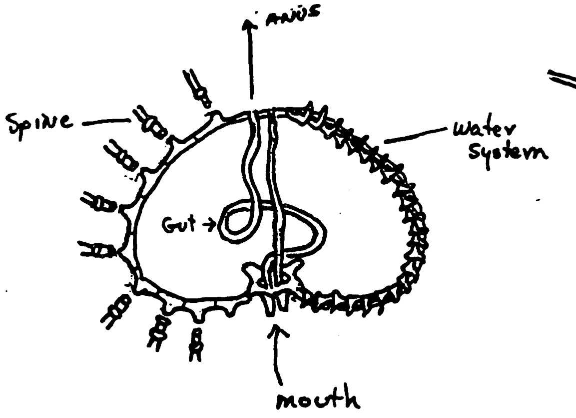
Periproct

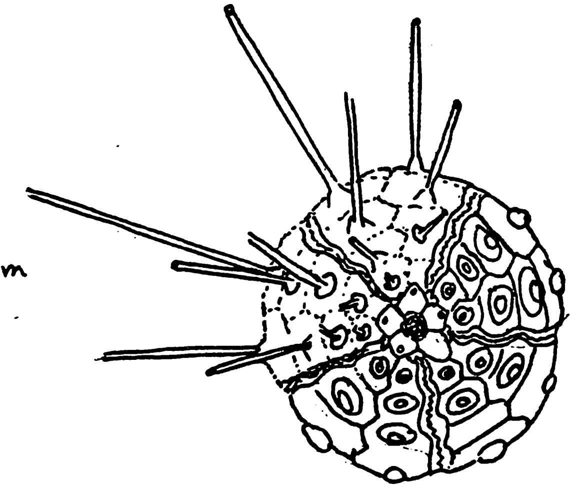
The position of the periproct is an important identifying feature. The periproct or anus can be located anywhere from the center of the apical system to the posterior of the test and may even be underneath the posterior margin. The periproct, in most cases, was originally covered with dislocated plates and a surrounding membrane. These plates are rarely preserved in place. An exception is a periproctal plate in the Salenoida which is preserved and this large suranal plate displaces the periproct.

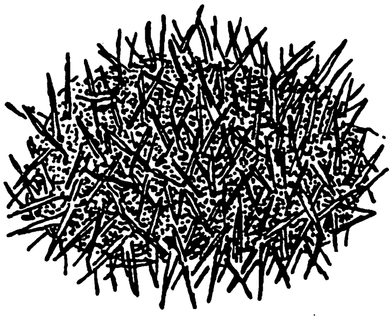
Peristome

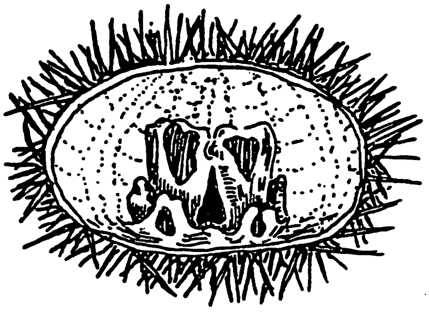
The peristome or mouth is located on the lower side of the test, closest to the substrate. The mouth may be central or may have moved anteriorly as in the Spatangoida. The peristome may be round or oval in shape. The interamb near the peristome can be simple as in the Cidaroida or become more complex as in the Holasteroida and the Spatangoida.

Aristotles lantern lies beneath the peristome in some orders and serves as jaws for food preparation. The lantern and its associated structures are rarely preserved together with the echinoid fossil and will not be discussed in this publication.









SOME ECHINOIDS OF FLORIDA

Charles E. Howlett
620 Iris Road
Casselberry, FL 32707

Geologically speaking Florida is an infant. So new is it that it didn't even fill out the full Cenozoic era. There are no outcroppings of the Paleocene or earliest Eocene.

In spite of this shortcoming, we do have in Florida one of the best representations of Echinoid fauna. From the Middle Eocene to the Present we have some 79 species; 60 extinct and 19 extant.

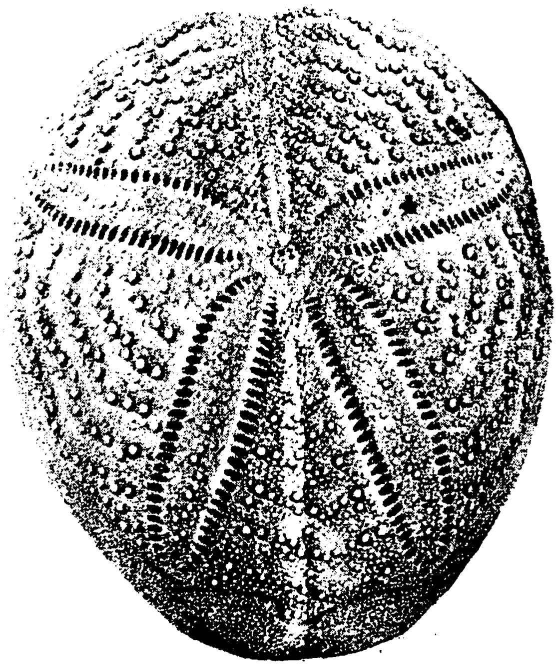
To attempt to describe such a large variety in one short article would be impossible. I will attempt a description of those genera and species found in the Ocala limestone. Outcroppings of this formation are readily found in the 10 counties near the Gulf of Mexico where Florida bends from the Peninsula into the Panhandle.

This formation is a cross-bedded shallow marine fossiliferous zone consisting of limestone and finely crystaline dolomite.

Most abundant among the Echinoid fauna in this formation is Eupatagus antillarum. This species is noted for its well defined ornamentation. No other species in this formation is as easily recognized as this one.

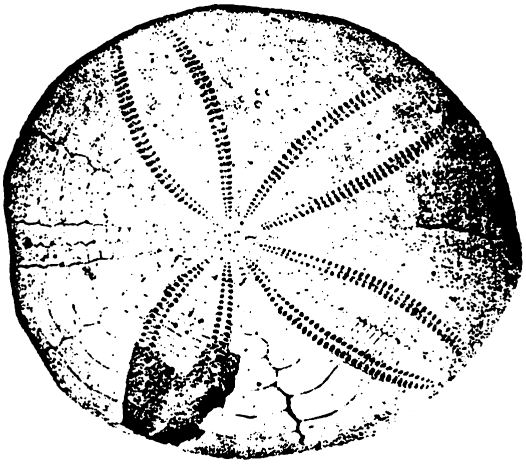
CLASS	Echinoidea
ORDER	Spatangoida
SUBORDER	Micrasterina
FAMILY	Brissidae
GENUS	Eupatagus
SPECIES	antillarum
AUTHOR	Cotteau
AGE	Eocene
FORMATION	Ocala Limestone
LOCATION	Barge canal Inglis, FL.

EUPATAGUS ANTILLARUM



In association with the above is Eupatagus clevei. This one much larger than its generic counterpart is almost always found in dolomite. This accounts for the fact that this species is almost always found as a cast. The test of echinoids found in dolomite recrystalize and upon further immersion in the sea, losses its structure leaving only the cast we find today. (I have found one E. clevei complete with test in a limestone quarry. It is now being studied at the University of Tennessee.)

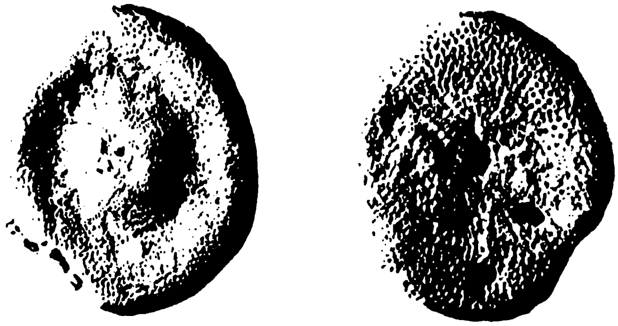
EUPATAGUS CLEVEI



CLASS	Echinoidea
ORDER	Spatangoida
SUBORDER	Micrasterina
FAMILY	Brissidae
GENUS	Eupatagus
SPECIES	clevei
AUTHOR	Cotteau
AGE	Eocene
FORMATION	Ocala Limestone
LOCATION	Barge Canal Inglis, FL

Next in number is Durhamella floridana. This is a very small Clypeaster measuring about ½ inch in diameter. They are most plentiful in this formation.

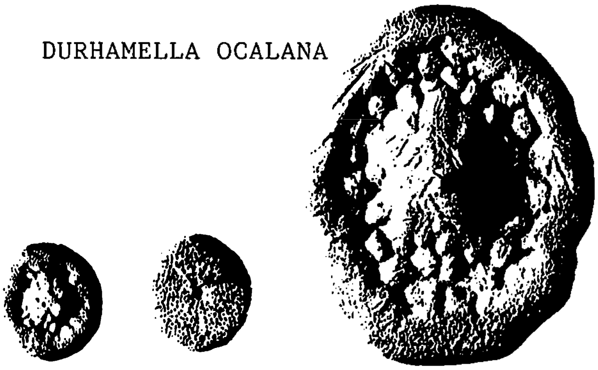
DURHAMELLA FLORIDANA



ORDER	Clypeasteroida
FAMILY	Neolaganidae
GENUS	Durhamella
SPECIES	floridana
AUTHOR	Twitchell
PERIOD	Eocene
FORMATION	Ocala Limbestone
LOCATION	Yankeetown, FL

Durhamella ocalana a most easily recognized species is found in abundance. It is recognized by its tumid plates surrounding the ambulacra. It is rarely found with D. floridana

DURHAMELLA OCALANA

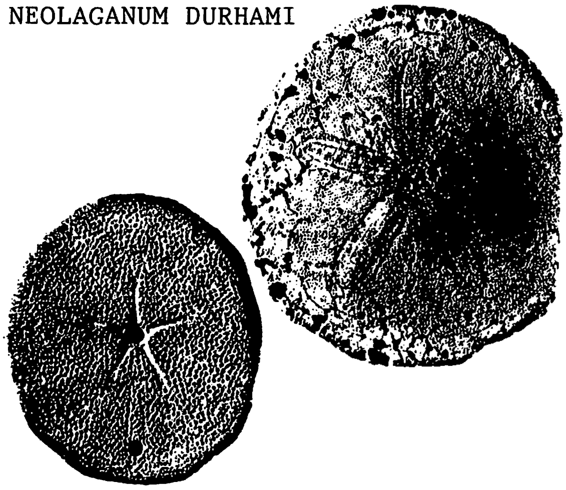


ORDER	Clypeasteroida
FAMILY	Neolaganidae
GENUS	Durhamella
SPECIES	ocalana
AUTHOR	Cooke
PERIOD	Late Eocene
FORMATION	Ocala Limestone
LOCATION	St. Catherine, FL

Neolaganum durhami a nice sized specimen ranging from 1-2 inches in diameter with well defined ornament is well represented.

ORDER	Clypeasteroida
SUBORDER	Laganina
FAMILY	Neolaganidae
GENUS	Neolaganum
SPECIES	durhami
AUTHOR	Cooke
PERIOD	Late Eocene
FORMATION	Ocala Limestone
LOCATION	Dolime Mine Inglis, FL

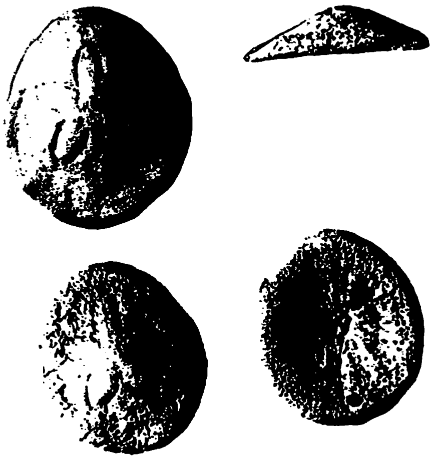
NEOLAGANUM DURHAMI



Weisbordella cubae is similar to the above except that someone gave it a kick in the pants. It is quite concave on the lower side.

CLASS	Echinoidea
ORDER	Clypeasteroida
SUBORDER	Laganina
FAMILY	Neolaganidae
GENUS	Weisbordella
SPECIES	cubae
AUTHOR	Weisbord
AGE	Late Eocene
FORMATION	Ocala Limestone
LOCATION	St. Catherine, FL

WEISBORDELLA CUBAE



The next three species are studied together. Many choose these Oligopygoids to separate into three biozones: the Inglis, Williston and Crystal River members of the Ocala Limestone.

Oligopygus phelani is found in the Inglis member and is marked by its small size. Its peristome is round and its periproct is inframarginal (see picture)

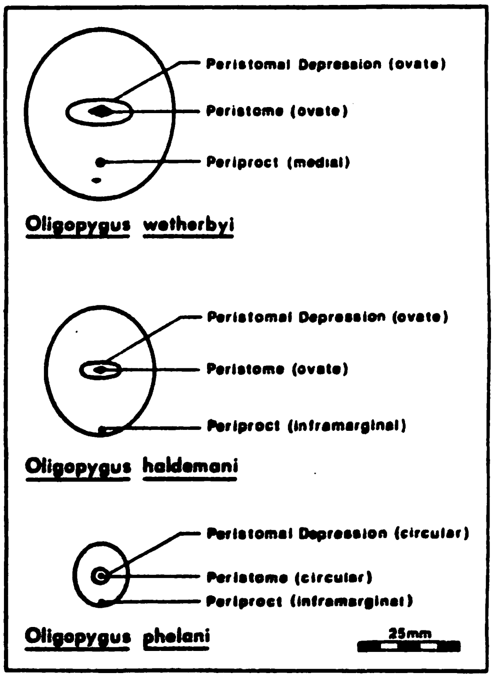
Oligopygus haldemanis is larger and is found in the Williston member. O. haldemani has an ovate peristome and its periproct is the same as O. phelani, inframarginal.

Oligopygus wetherbyi is the largest. It is found in the Crystal River member. The peristome is ovate but different from the rest; its periproct is medial.

OLIGOPYGUS PHELANI

CLASS	Echinoidea
ORDER	Holectypoida
SUBORDER	Conoclypina
FAMILY	Oligopygidae
GENUE	Oligopygus
SPECIES	phelani
AUTHOR	Kier
AGE	Eocene
FORMATION	Ocala Limestone
LOCATION	Yankeetown, FL

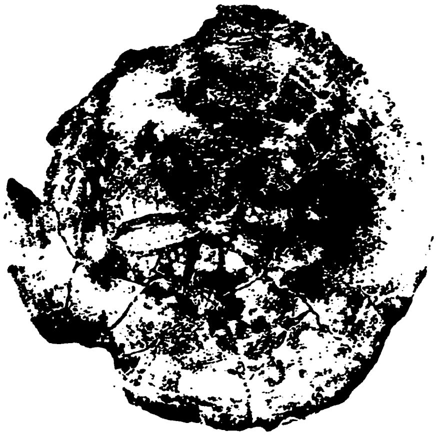
Period:	**Tertiary**		
Epoch:	**Late Eocene**		
Stage:	**Jackson**		
Group:	**Ocala Limestone**		
Formation:	**Inglis**	**Williston**	**Crystal River**
Oligopygoid Biozonation:		**O. phelani** **O. wetherbyi**	**O. haldemani**



Periarchus lyelli, a large clypeaster is also found in the Ocala Limestone. It has been my experience that this is the hardest of all the above to clean and restore. This species is famous for its this fragile margin. All too often cleaning, if carried too far results in a clean specimen in many pieces. Recently I have come up with a solution to this problem. I try to clean the oral surface first. Once done I pour a thin coat of epoxy resin over it. This leaves me with a good view of this surface and also makes it possible to bring to view the ambulacral petal. (This might also be tried on some of those California Dendrasters and Astrodapsis specimens.)

PERIARCHUS LYELLI FLORIDANUS

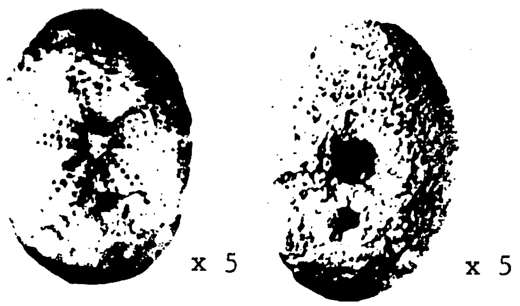
ORDER	Clypeateroida
FAMILY	Scutellidae
GENUS	Periarchus
SPECIES	floridanus
AUTHOR	Fischer
PERIOD	Late Eocene
FORMATION	Ocala Limestone
LOCATION	Withlacoochee River Inglis FL



Fibularia vaughani is a species that may be a lot more plentiful than surveys show. It is only about the size of a grain of rice and is easily overlooked, unless you hund lying down close to your work.

ORDER	Clypeasteroida
SUBORDER	Laganina
FAMILY	Fibularidae
GENUE	Fibularia
SPECIES	vaughani
AUTHOR	Twitchell
PERIOD	Eocene
FORMATION	Ocala Limestone
LOCATION	Yankeetown, FL

FIBULARIA VAUGHANI



This does not cover all the Ocala limestone Echinoid fauna but does account for some of the species found in open collecting areas. Many of Florida's best collecting sites are closed. Many are now under hotels or homes. Some are closed for past abuses while others are closed down for reasons of insurance.

There are still a few places left open for the collector. None of them are at my back door but I will take you out if we can work it into a weekend trip. Drop me a line.

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Raymond C. Moore Editor
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Oligopygoid Echinoids and the Biostratigraphy
of the Ocala Limestone of Peninsular Florida
Michael L. McKinney
Douglas S. Jones
Published at Duke University
Durham N.C.

Index Fossils of North America
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DIVING AMONG MY AMBULATORY "PIN-CUSHIONS"
or
THE ADVENTURES OF AN ECHINOID LOVER

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INTRODUCTION

One of the goals of a paleobiologist is to resurrect fossils from their rocky graves. An invaluable aid in this resurrection is the knowledge of comparable modern organisms. Fossil echinoids have intrigued students of the earth for centuries, but their Recent congeners have often been neglected by these same workers. This is unfortunate because many genera have long geological ranges so knowledge of modern species is vital to their understanding. This neglect of echinoids is due, in part, to a false notion that they are uncommon and hard to find. On the contrary, there are lots of echinoids in many places, but you must know their tricks to locate them.

My observations at many places, particularly around the west side of Florida and the Florida Keys, for over thirty-five years have given me insight and taught me how to collect and study all five classes of echinoderms. My greatest affection has been for the echinoids and a knowledge of their modern representatives has helped me greatly with fossil forms. A fossil collector may have started out with trilobites, ammonites, or other extinct groups, but if he stays a little flexible he will gain interest in some of the other things he is finding and have living counterparts to relate to. These include groups such as forams, bryozoans, brachiopods, echinoderms, corals, sponges, mollusks, arthropods, annelids, echiuroids, and priapuloids. Holding a living brachiopod or crinoid in your hand can give you a thrill I can't explain! In the following paper, I would like to relate to you a few of my observations and thoughts concerning the admirable echinoids or ambulatory pin-cushions. I will devote most of my space to my old stomping ground, Florida, but may occasionally stray to more remote locales.

BASIC ECHINOID ARCHITECTURE

The echinoid skeleton or test is a thing of beauty. It is composed of numerous interlocking plates that are usually rigidly joined to one another (fig. 1).

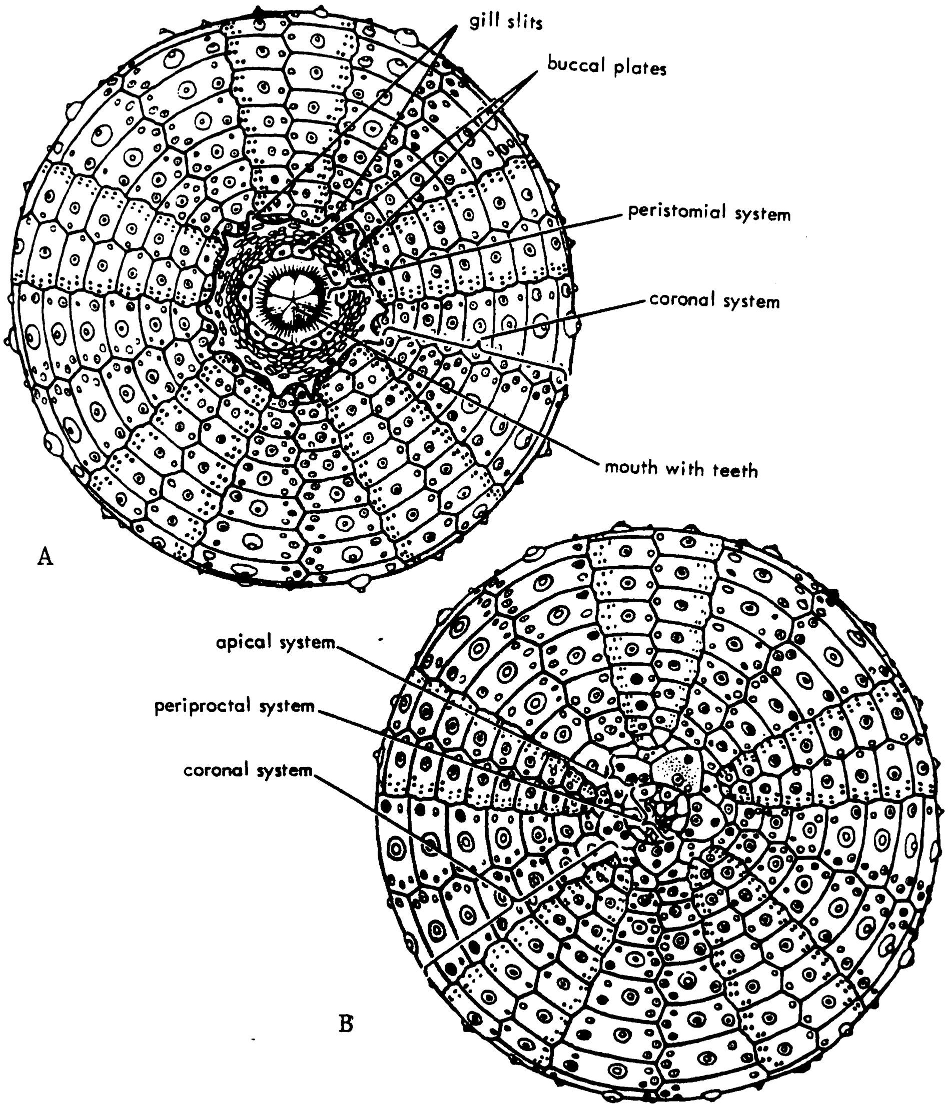

Fig. 1 Plate systems of echinoid test illustrated by *Echinus*

A. - Oral surface (after Durham, 1966)

B. - Aboral surface (after MacBride)

These plates usually bear moveable spines (fig. 2) of varying sizes and shapes.

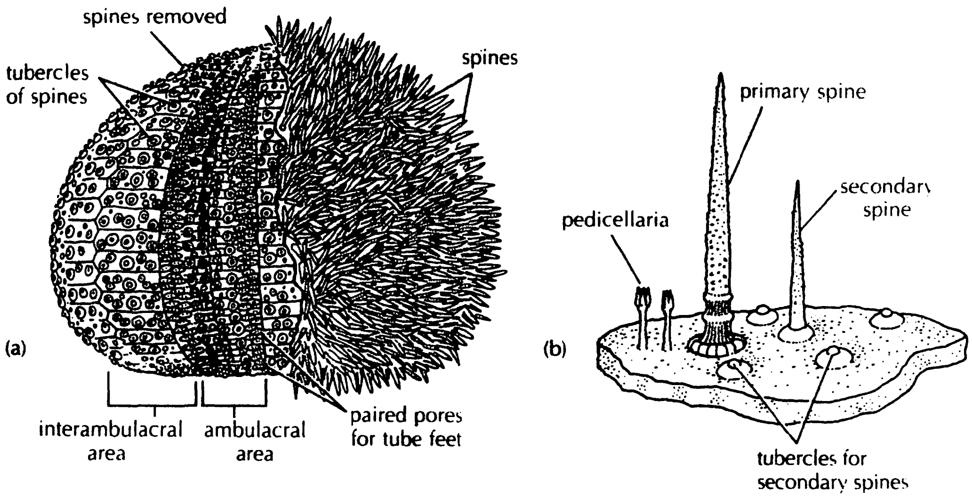

Fig. 2 A. Echinoid test with spines removed from the left half

B. Piece of echinoid test showing the spines, tubercles, and pedicellaria

The plates of the test can be divided into four groups: the coronal plates, the apical plates, the periproctal plates, and the peristomial plates (See fig. 1).

The coronal plates consist of twenty rows of plates arranged in pairs that run from the top to the bottom of the test. Ten rows are perforated by pairs of pores for the tube feet. These plates are called ambulacral plates. The other ten rows of plates are not perforated by pores and are called interambulacral plates. These two types of plates alternate in pairs with five pairs of each type.

The apical plates are a ring of ten plates (See fig. 3) on the top of the test. Five of these are called genital plates and are in interambulacral positions. One of the genital plates is greatly enlarged and perforated to serve as intake for the water vascular system. This plate is called the madreporite. The other usually smaller five plates alternate in position with the genital plates and are called ocular plates.

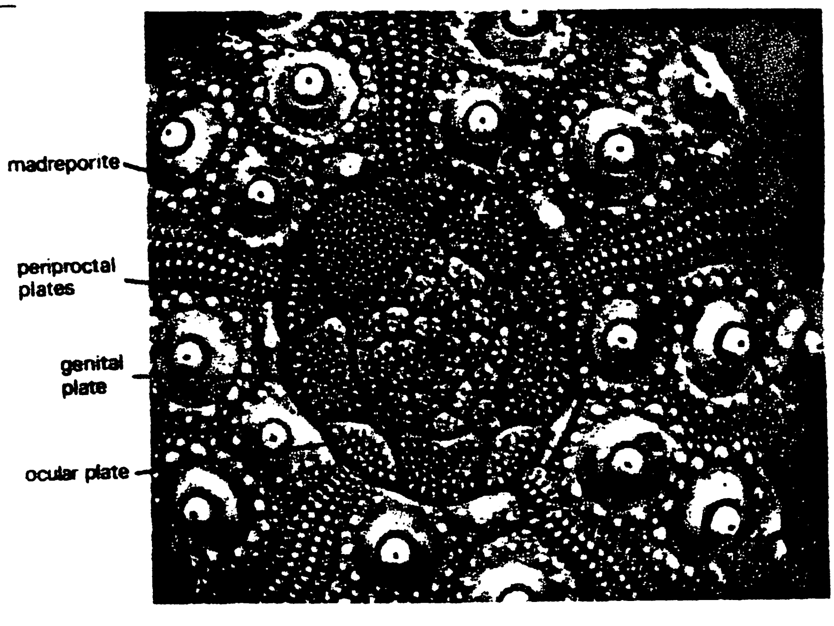

Fig. 3 Apical system of the Recent regular echinoid Eucidaris metularia X3
(photograph by Porter Kier)

The periproctal plates (See fig. 3) occur on a membrane around the anus. The peristomial plates occur on a membrane around the mouth. In most fossil and empty modern tests the periproctal and peristomial plates are missing leaving two holes called respectively the periproct and the peristome (See fig. 4). Getting your hands on a few live specimens will help correct the problem of losing the plates that cover these two holes.

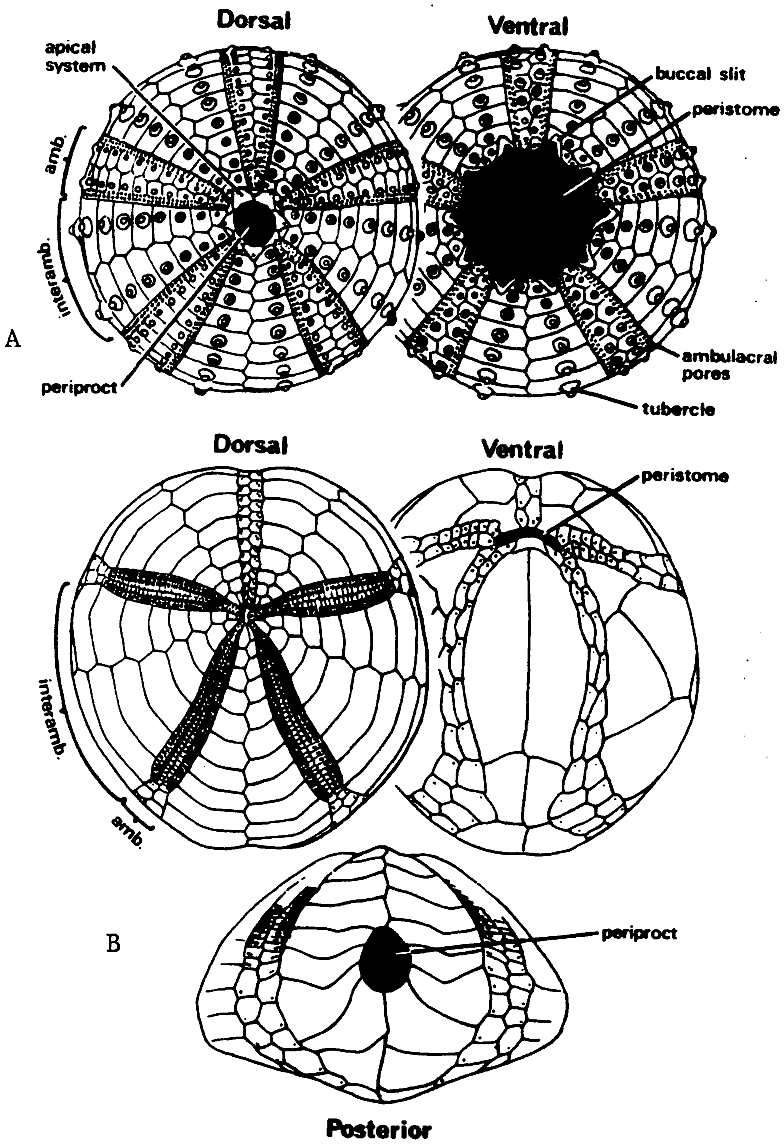

Fig. 4 General morphological features of the tests of (A) a regular echinoid Echinotiara and (B) an irregular echinoid Linthia (after Smith, 1984)

Many echinoids have a chewing device called Aristotle's Lantern (fig. 5). It is the most complicated skeletal-musculature structure in the entire animal kingdom.

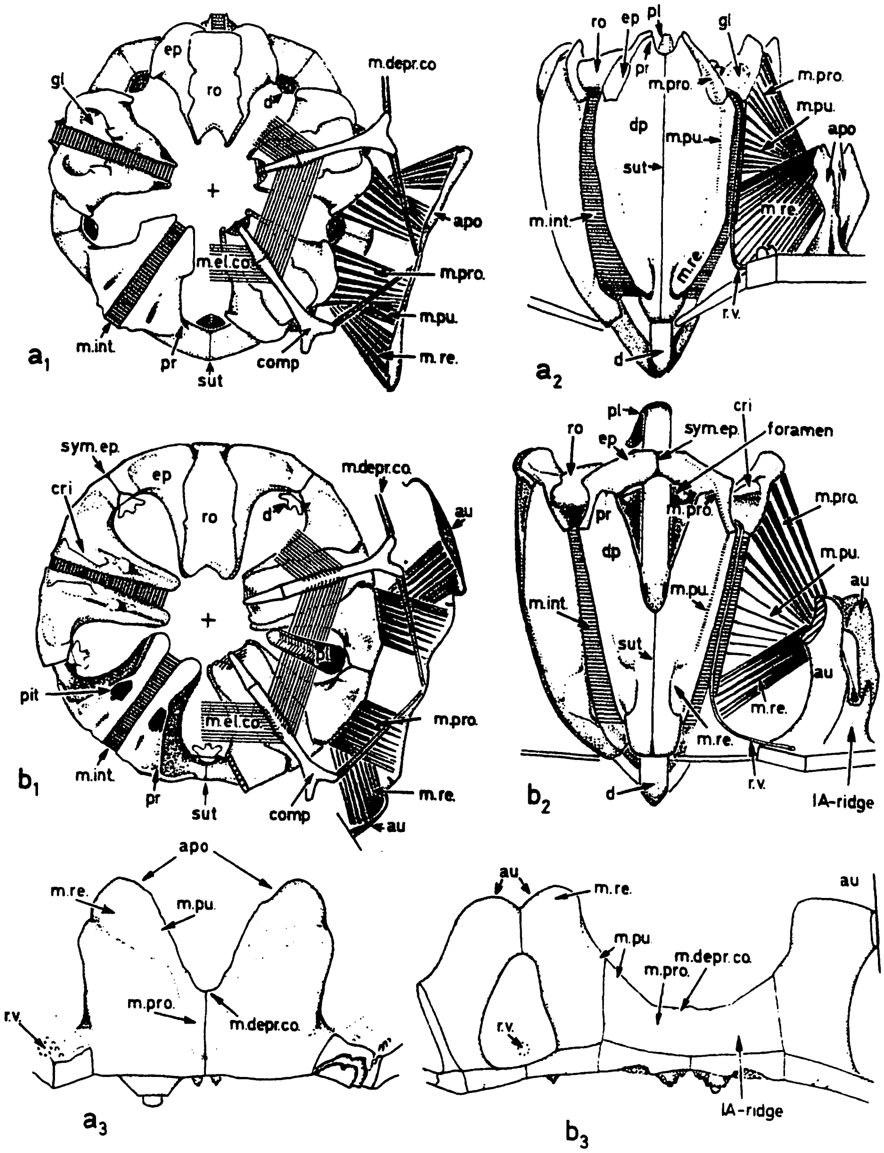

Figure 3.26 Structure of the lantern and perignathic girdle in (a) a cidarid and (b) a camarodont. (1) Apical view; (2) lateral view; (3) perignathic girdle (from Märkel 1981, courtesy of Springer Verlag).

Key

apo	apophysis	m. el. co.	compass elevator muscle
au	auricle	m. int.	interpyramidal muscle
comp	compass	m. pro.	protractor muscle
cri	crista	m. pu	postural muscle
d	tooth	m. re.	retractor muscle
dp	hemi-pyramid	pl	plumule of tooth
ep	epiphysis	pr	super alveolar process
gl	glenoid cavity	ro	rotula
IA	interambulacrum	r.v	radial water vessel
m. depr. co.	compass depressor muscle	sut	intrapyramidal suture

Fig. 5 Structure of the Aristotle's lantern and perignathic girdle in (a) a cidarid and (b) a camarodont. (1) apical view; (2) lateral view; (3) perignathic girdle (from Märkel, 1981)

MAJOR ECHINOID STUDIES

Past studies of modern echinoids are rather disjointed and incomplete. Some good general works include Durham et al (1966), Hyman (1955), Mortensen (1928-51), and Smith (1984). My favorite area, the Florida Keys was best studied by Kier and Grant (1965) who studied the echinoids off Key Largo. They used diving equipment available to all of us. They made population, feeding, habitat, and many other studies. They found seventeen different echinoid species.

ECHINOID GROUPS

There are no widely accepted formal group names between the class and order level in echinoids. Many workers use the informal divisions "regular" echinoids and "irregular" echinoids for dealing with this interval. Regular echinoids or "sea urchins" or just "urchins" (fig. 4a) are echinoids with a strong radial symmetry, with their anus (and surrounding) periproctal plates within the apical plate ring, with a centrally located mouth on their lower surface, with tube feet that are almost all suckered and identical, and with a well-developed Aristotle's Lantern. Irregular echinoids (fig. 4b) have strong bilateral symmetry superimposed on their radial symmetry, anus and periproctal plates that are outside the apical plates (they may even be on the side or lower surface of the test!), a mouth that is centrally located or even towards the anterior of the lower surface, tube feet that are very diverse in form (those on the top of the test serve a respiratory function and form distinctive areas called <u>petals</u> (see fig. 4b), and an Aristotle's Lantern that is reduced or absent. There is no common name for irregulars, but the heart-shaped members of the order Spatangoida are often called "heart urchins" and the flat members of the order Clypeasteroida are called "sand dollars".

The regulars and irregulars tend to inhabit two distinctly different adaptive zones. The regulars are epifaunal carnivores, herbivores or omnivores. The irregulars are infaunal suspension or deposit-feeders.

COLLECTING AND PRESERVING ECHINOIDS

Collectors take vacations that bring them at or near salt water. This makes it easy to collect echinoids. The Atlantic Coast, the West Coast, Gulf of California, Hawaii, and Europe all host many echinoids. You are not going to hurt the populations of most echinoid species by taking a few specimens because they are abundant.

When you collect echinoids with long spines be sure to wear gloves to protect your hands. All kinds of echinoderm tissues seem to cause discomfort and inflammation when they get under human skin. Echinoid spines have the greatest chance of getting under your skin.

If you collect specimens, but don't have time to deal with them because you are collecting additional specimens, you should put them in a container of sea water that can be put in the ocean. If you are on a boat, this container can be hung over the side. You should replace the water in your container with fresh salt water at frequent intervals.

When you get your catch back to where you are staying or are parked, you must preserve and pack them for the trip home. First pick off excess debris from your echinoids and rinse them off with fresh salt water. To preserve the echinoids, you need either 70% rubbing alcohol or a 5% solution of formalin (formaldehyde). You can buy small amounts of these chemicals at drug stores or take them along with you. Soak the specimens in alcohol for at least two days or bring them home in the alcohol.

The same goes for formalin. If you intend to transport your catch home in large plastic buckets, you must wrap each specimen in wet scrap rags. I have used pieces of things such as old sheet, T-shirts, shorts, or towels. You can stockpile this sort of rag before you leave on your vacation trip. If you don't wrap your echinoids they will rub against one another. This will cause loss of spines. Grooves may be made in or other damage done to your sand dollars.

After you arrive home and have time to work with your specimens, remove them from their containers and treat them in the following manner. Carefully remove the rags surrounding them and set them up to dry in a place where no sunlight or animals can get to them.

If you want, you may keep some wet in your preserving solutions. These can be used for dissection studies to examine the soft parts. You may wish to practice with your specimens until you have learned something about them. It is possible, with the utmost care, to remove all the spines, the Aristotle's Lantern, and all the internal organs from an echinoid. A well-cleaned naked test can aid greatly in the identification of a specimen to the generic and specific levels.

COLLECTING AND OBSERVING

Florida. - As I mentioned previously, at least seventeen live echinoid species occur off Florida. Many of the ordinal and generic names here will be familiar to the strictly fossil echinoid collector - *Cidaris*, *Diadema*, *Clypeaster*, *Encope*, *Meoma*, cassiduloids, spatangoids, and many others. They can be collected from 2 to 30 feet. I stopped my discussions here at 30 feet because many collectors would not want to dive deeper.

Mainland Florida. - On Florida's west coast from Fort Myers south, you can easily find the regular echinoid *Lytechinus variegatus* and irregular sand dollar *Mellita quinquiesperforata*. The sand dollars that you find with a white color on the shore or in very shallow water are dead and may not be of much help with your studies. Under a half inch to an inch of sand, you will find the live ones. They leave outlines or indentations in the wet sand. That is your clue. Once I was standing on a sand bar near Marco Island with a friend from Illinois. We were all dressed and geared up to do some fancy collecting of mollusks and other invertebrates. Noticing some telltale sign of sand dollars around my friend's feet I asked my friend standing there on the wet sand if he would like some sand dollars and he replied yes. I took my shelling rake (4 tines-4 inches long-6 inches wide with handle) and raked a circle around where he was standing. In the process, I turned over at least twenty living sand dollars. My friend was amazed. Since that time, he and his wife have become very good collectors of mollusks and echinoids.

The Florida Keys. - If you are staying for one day or a month, you can get fantastic living echinoids in the Keys. They inhabit a wide variety of habitats (see table 1). I prefer the lower half of the Keys, but hunting is good all the way from Key Largo to Key West. Large populations of echinoids abound throughout the length of this chain.

For shallow water hunting, you need a bucket, a rake, and good tough shoes or boots. Because of the hot sun, you should wear blue jeans even though they get wet.

Table 1 - Occurrence of Echinoids off Key Largo, Florida (after Kier and Grant, 1965)

Bottom type / Depth and location		Sand bottom		Rock bottom		
		Bare sand	**Turtle grass**	**Living coral**	**Rock and dead coral**	**Broken rock**
INTER-TIDAL 2-6'	NEAR SHORE				Diadema antillarum Echinometra lucunter Lytechinus variegatus	Diadema antillarum Echinometra lucunter Lytechinus variegatus
	OFF SHORE					Diadema antillarum Echinometra lucunter Eucidaris tribuloides Tripneustes ventricosus
NEAR SHORE 4-8'		Clypeaster rosaceus	Clypeaster rosaceus Lytechinus variegatus			
INSHORE EDGE HAWK CHANNEL, RODRIQUEZ KEY 4-15'			Clypeaster rosaceus Diadema antillarum Echinometra lucunter Echinometra viridis Lytechinus variegatus			
HAWK CHANNEL 10-18'			Arbacia punctulata Clypeaster rosaceus Diadema antillarum * Lytechinus variegatus			
BACK REEF CHANNEL 10-20'			Arbacia punctulata Clypeaster rosaceus Diadema antillarum Eucidaris tribuloides Lytechinus variegatus Tripneustes ventricosus *			
WHITE BANK 10-12'		Clypeaster rosaceus Clypeaster subdepressus Encope michelini Leodia sexiesperforata Meoma ventricosa Plagiobrissus grandis *	Clypeaster rosaceus Diadema antillarum Eucidaris tribuloides Lytechinus variegatus Tripneustes ventricosus			
INTERREEF CHANNEL 15-35'		Clypeaster rosaceus Clypeaster subdepressus Encope michelini Leodia sexiesperforata Lytechinus variegatus * Meoma ventricosa Plagiobrissus grandis * Schizaster (P.) floridiensis * Tripneustes ventricosus *	Brissus unicolor * Clypeaster rosaceus Diadema antillarum Eucidaris tribuloides Lytechinus variegatus Meoma ventricosa Tripneustes ventricosus			
REEF	SHOREWARD PATCHES 5-10'		Clypeaster rosaceus	Arbacia punctulata Diadema antillarum Echinometra lucunter		
	MAIN REEF 10-35'	Clypeaster subdepressus Diadema antillarum Meoma ventricosa Schizaster (P.) floridiensis		Diadema antillarum	Diadema antillarum Echinometra viridis	Brissus unicolor Echinoneus cyclostomus Eucidaris tribuloides
	SEAWARD PATCHES 110'			Diadema antillarum		
SEAWARD TERRACE 80-85'		Astropyga magnifica Clypeaster subdepressus Diadema antillarum Eucidaris tribuloides Meoma ventricosa Plagiobrissus grandis * Schizaster (P.) floridiensis *				Diadema antillarum

Pick a spot on the Atlantic side of a key with few humans and shallow water. Then watch for lumps with pieces of seashells or grasses stacked on their top. Pick one of these lumps up and you will probably find that you have your first urchin. You may find one of the "regulars" such as Lytechinus variegatus or Tripneustes ventricosus or an "irregular" such as Clypeaster rosaceus. If you go to deeper areas with a more rocky bottom, you can find the "regulars" Diadema antillarum and Eucidaris tribuloides occurring either on or under the rocks. Be particularly wary of Diadema antillarum because its spines can go through your boots into your feet. If you fall onto this species, its extremely sharp spines can completely pierce your hands or chest cavity before you know what is happening.

To hunt echinoids in deeper water you need a boat and at least some simple diving equipment. Take your boat out to open water where there is clean white sand at a depth of ten to thirty feet. If you dive here, you may find beneath lumps or dips, the outlines of echinoids. In this sort of situation, you can often find large spatangoids, clypeasters, and three different uncommon species of sand dollars buried within the sand. To get these buried echinoids run your gloved hand under these lumps and dig out your echinoid. Sometimes you will come across a large Helmet snail eating large echinoids.

The name Diadema is enough to send a chill down the spine of the experienced tropical diver. Members of this genus are noteworthy in having extremely long sharp spines. The spines can be two or three times the length of the maximum dimension of the test. I have seen spines that were as much as 16 inches long. When a group of individuals of this species are together they form a formidable wall of spines. The spines, besides being long and extremely sharp are ridged in such a way that they go in, but not out of your skin. They are also extremely brittle. Because of their ridged nature and brittleness, they rarely slide back out of your body once they have gone in. Diadema species are said to be venomous, but there is no scientific proof of this. They unquestionably produce extreme pain. When you approach Diadema underwater their spines move so that they are always pointing at you - like some eerie radar-controlled rocket launchers. This animal is the reason I recommended diving over white sand. Elsewhere your chances of encountering them is much greater.

As a science diver, I go many places I shouldn't and take some chances in quest of specimens that I shouldn't. I dive around hard natural walls and human bridges and pier pilings that host thousands of Diadema antillarum. They are often so thick here that you cannot find enough space to put your hand down. In areas such as these tidal currents can push an off guard diver against these banks of echinoids with enough force that the spines pierce your lungs, heart, and kidneys and result in death. In these areas, I usually keep my body away from the spines using a diver's rake. Despite precautions, I have had some very close calls and injuries. As a rule, never dive or hunt for Diadema around pilings or pier or on any vertical surface that is tougher than your skin. If you need to collect Diadema in undesirable locales, rent a boat and guide your boat over them. Lower a rake down with metal part on the bottom, slide your rake under and lift slowly. I have seen populations of Diadema one block wide and three blocks long. They were so thick that you couldn't miss one with your rake. So hunt there!

Hawaii. - I have gone underwater for echinoids off the southeast end of the island of Maui. I found and collected a diverse array of beautiful echinoids. They included the slate pencil urchin whose spines are often seen in wind chimes.

Echinoid danger also lurkes in scenic Hawaiian waters. On one occasion, I was caught in an undertow that pulled my body horizontally as I held onto two heads of live scleractinian corals. The force became so great that the coral heads broke and I did a backwards somersault and came down with my back onto at least fifty small urchins covering shore lava. As I lay there looking over my injuries, my wife asked me if I was hurt. I replied that I didn't know, but that I felt like an Indian fakir on his bed of nails. In truth, I had over 100 spines of a Diadema driven into my right hand. They had entered the fat side of my hand, crossed the palm, and came out between my thumb and forefinger. The spines took nine weeks to rot out of my hand. You cannot easily remove the hollow spine fragments that break off under the skin. Some fragments fester out - others just lie rotting in your flesh for weeks. My hand was straight and stiff as I sat there on the lava. It took all the courage I had to quickly make a fist so that the spines inside would break enabling me to bend my hand. Take heart! I went right back into the ocean and gathered up all the urchins that had ripped from my catch bag during the accident as well as collecting a few new specimens.

CATASTROPHIC ASSEMBLAGES

By observing the modern environment, we can see some of the ways in which rich fossil echinoid beds are created. In 1960, the hurricane Donna swept through the Keys and Florida's west coast. As it did so, it covered many of my favorite echinoid beds with many feet of carbonate sand and gravel. It is easy to see how, if these sediments become lithified, they would form rich fossil echinoid beds comparable to many seen in the geological record. These places are real estate today. New collectors to Florida would never know they existed. This was only two days of fury by a hurricane in 1960. Try to imagine how many times this has happened over millions of years - exposing some fossil echinoids for us and starting new locations a mile down the beach.

CONCLUSIONS

Don't let my emphasis on a few echinoid dangers in this account, deter you from your hunt for echinoids. Just use good judgement and take precautions. If you can't dive for echinoids yourself, there are generally divers or a divers' club in the area that will help you out.

Lest you think echinoid study and collecting is all danger and tragedy, I would like to introduce a bit of humor. On some occasions, I have seen collectors stack up living sand dollars and urchins they have collected at the water's edge while they go off after other beasts. Later they return to find all of their catch gone. Naturally, they start looking to see who has stolen their animals. Little do they realize that the "fuzz" on their sand dollars are hundreds of small moveable spines that they can use to bury themselves in a matter of minutes. The regular echinoids can also wander away little worse for their experience.

In conclusion, if you wish to enrich your fossil collecting and study with a whole new dimension, add modern organisms to your concerns. I have had countless meaningful encounters with the living echinoids that have broadened and deepened my life. You can do the same with these art forms of nature. Get out there!

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SALENIA TEXANA

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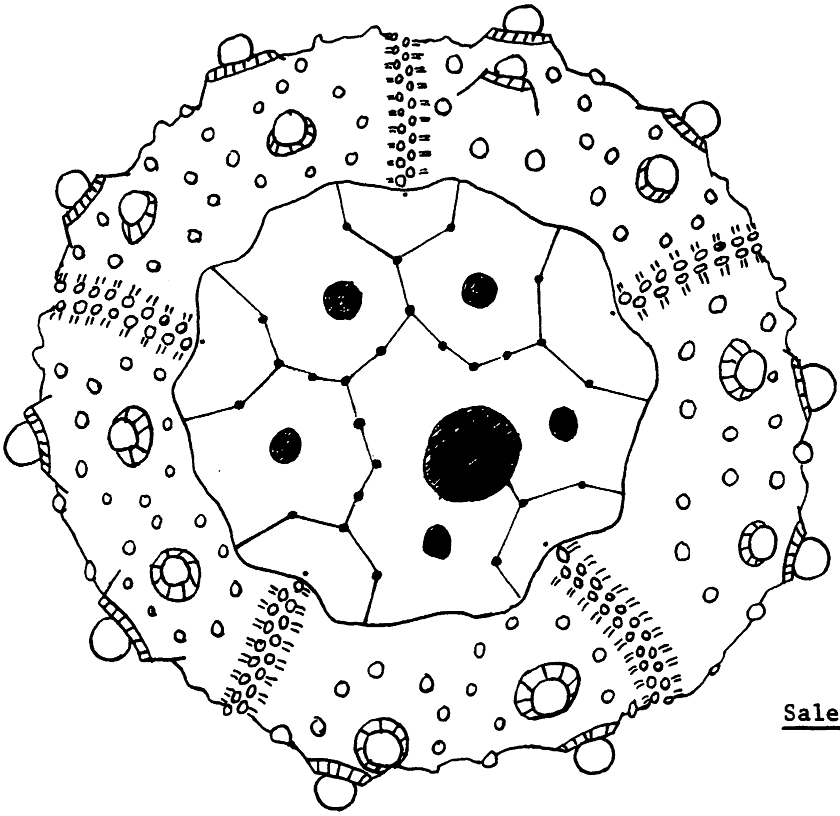
Regular echinoids are some of my favorite fossils. The echinoid test ("shell") is made of numerous plates arranged in a pentameral symmetry. When viewed from above the test is divided into five ambulacral and five interambulacral sections which radiate from the periproct (Fig. 1). On the surface of the plates are tubercles to which spines were attached when the echinoid was alive. The tubercles are termed perforate when there is a central depression in the mamelon (Fig. 2) and imperforate when there is no depression. If the area around the mamelon is ridged, the tubercle is crenulate; if the area is smooth, the tubercle is noncrenulate.

Normal position for a reular echinoid is with the oral ventral side down. The oral surface of the test has a large central opening, the peristome, which contains the mouth. Along the edge of the peristome are ten interambulacral notches, the gill slits (Fig. 3). The upper dorsal surface, aboral aspect, contains two sets of plates which make up the apical system (Fig. 4). The apical system encloses the periproct, the opening which contains the anus. The inner set consists of five genital plates. In mature echinoids genital plates have a large pore through which gametes are released. The outer set of plates are termed ocular plates. These plates are the terminal plates of the ambulacra and have a small pore through which the end of the radial vessel protrudes.



<u>Salenia</u> <u>texana</u>

Salenia texana is a regular echinoid of the family Saleniidae. This echinoid family is characterized by a large apical system with suranal plate (Fig. 5), posteriorly displaced periproct (by the suranal plate), and imperforate primary tubercles. The genus Salenia has bigeminate ambulacra which are relatively straight with one primary noncrenulate imperforate tubercle and two pore pairs on each compound plate. The interambulacral primary tubercles are crenulate and imperforate. The periproct is displaced posterodextrally towards ocular I, positioned to the right of the anterior-posterior axis which passes through ambulacrum III and interambulacrum 5. When well preserved, the test is hemisperical in shape. The peristome is relatively large with small gill slits. The primary spines are long and slender (Fig. 6).

The Saleniidae first appeared in the upper Jurassic and radiated during the Cretaceous to a near world wide distribution. By the start of the Paleocene the saleniids were dramatically reduced in number and distribution. Today only two genera of saleniids exist: Salenia and Salenocidaris. Salenia is found in Caribbean and Indoneasian waters. Salenocidaris is found along the mid Atlantic ridge.

Several species of Salenia can be found in the Cretaeous of Texas. Salenia texana is the species which I most often collect. It occurs in outcrops of the lower Cretaceous Glen Rose formation in roadcuts near San Antonio, Texas. The Glen Rose is a limestone formation which ranges from a very dense to loose consistency.

Most of the echinoids found in the Glen Rose are deformed. This is especially so for the irregular echinoids like Heteraster. At least in some locations the Salenia are better preserved with some specimens showing almost no deformity. Long slender Salenia spines can be found in the same outcrops but they are usually fragmentary. Rarely a complete unbroken spine can be found in matrix.

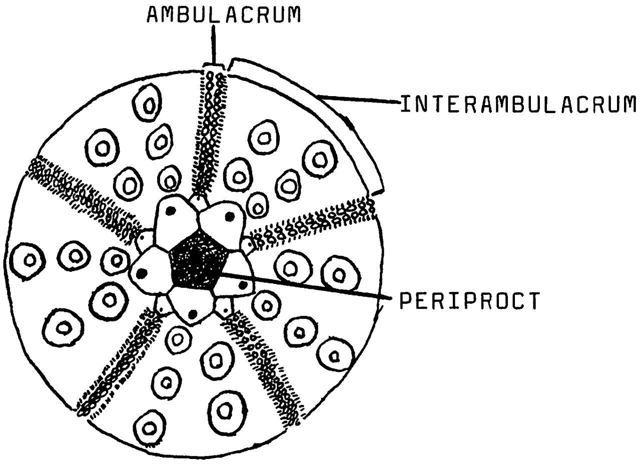


Fig. 1

TUBERCLES

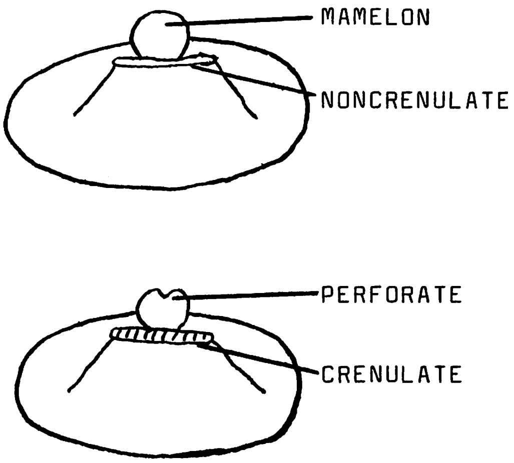


Fig.2

VENTRAL ORAL SURFACE

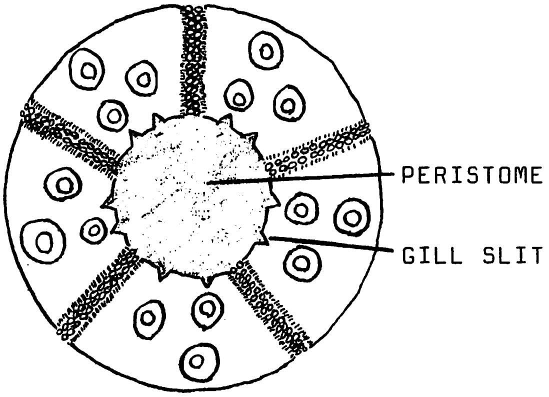


Fig. 3

DORSAL ABORAL SURFACE

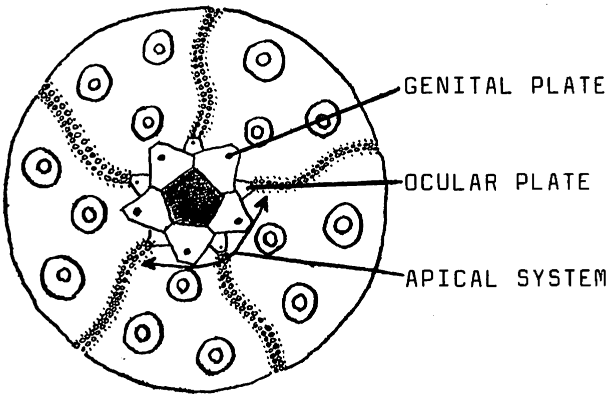


Fig. 4

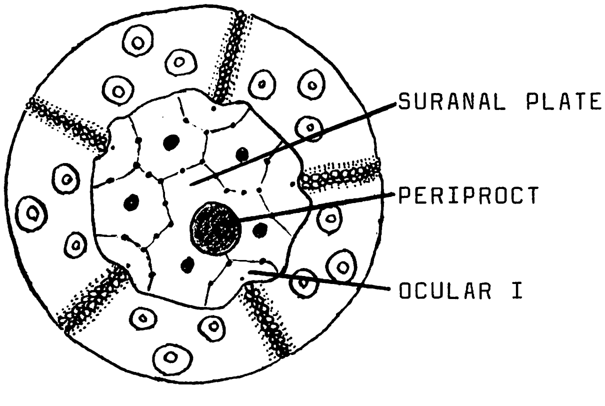


Fig. 5

Fig. 6

<u>Salenia</u> SPINE

THE HUMAN CONNECTION

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I can honestly say that I have never engaged in any activity in life that has given me more interest and pleasure than getting out, hunting, and finding good fossils. Nothing beats, for me at least, the thrill of finding an outstanding fossil. I also feel that we too often get carried away in the technical aspect of fossils and overlook the human side of fossil collecting, and with that thought in mind, I have titled this little article, The Human Connection. There have been in my lifetime, several people who have influenced me deeply in connection with my love of fossils. I will list five and say a few words about each.

First and foremost, there was my very good friend, in fact, I counted him as my best friend, James P. Conlin of Ft. Worth. Jim was my teacher and my mentor, and if there was ever a genius, he was it. His speciality was ammonites, and he corresponded with all the great ammonite experts of the world, loaning many of them some of his most prized specimens for description and study. He knew as much about ammonites as Harrell Strimple did about crinoids. I never failed to take Jim an ammonite for identification but that he either knew right away what it was, or new exactly where in his volunious library to get the identification. Jim taught me the importance of stratigraphy, and though ammonites were his thing, he collected all kinds of fossils and was eminently knowledgeable about them. I am deeply indebted to him for my own limited knowledge of paleontology. He and I spent many happy hours in the field together, and I'm also indebted to him for many of my good echinoid localities. He revered all nature and was especially kind to animals. Jim passed away ten years ago with cancer of the pancreas, and to this day I miss his friendship, his counsel, and his companionship. Jim and I planned to write a book on Texas fossils--his ammonites and my echinoids--but while it was still in the planning stages, Jim got sick and never recovered, so I guess it was a good thing we never got around to starting the book. Prior to his death he donated his huge collection to the USGS in Denver, but left me quite a few things that I had admired.

Next I mention Harrell L. Strimple. I knew him back in the very early days of his crinoid studies when he worked for Phillips Petroleum in Bartlesville, Oklahoma. In my job as part owner and salesman for an oil field trucking company, I traveled often to Tulsa, Bartlesville, and Ponca City, and I always managed to finish up my work on Friday afternoon so that I could spend Saturday and Sunday collecting crinoids in Northern Oklahoma and Southern Kansas with Harrell. We enjoyed many, many good trips together. Harrell was a good friend and a great inpiration to me. His knowledge of crinoids was tremendous, and he was always willing to share this knowledge, and also his time with his friends. I sort of lost track of Harrell when he moved to Iowa, but I feel sure I received the last letter he ever wrote. While I was in the hospital myself here in Dallas, I wrote to him regarding the series of articles he was writing at the time in the MAPS DIGEST, thanking him for his work and his interest. He wrote me back from the hospital saying he was dying of cancer and told me how much he appreciated my letter and our friendship through the years. Harrell will be sorely missed by all of us. It was through his invitation that I joined MAPS.

I next list Dr. Mario Sanchez-Roig of Havana, Cuba. I got acquainted with Dr. Sanchez through correspondence in connection with our mutual interest in echinoids. It was about two years before Castro took over the country and ruined it for Americans. Dr. Sanchez was the world's foremost authority on the echini of Cuba, and part of his extensive collection was in the National Museum in Havana. My wife, my son, and I went down to see Dr. Sanchez and were never treated so royally in our lives. One incident in particular stands out in my memory. We had been invited to visit Dr. Sanchez and his family in his home, which was located in the historic part of Havana. He sent his chauffeur to our hotel to pick us up, and while he was showing me his extensive echinoid collection, he was having a servant prepare us an exquisite drink called guanabana. It was the consistency of a thick milkshake and was prepared from the fruit of the guanaban tree by simple removing the peeling and the large seed and putting the meat of the fruit in a Waring blender. The fruit is about the size of a small watermellon, is green like an avocado, but instead of growing on small branches like most fruit, it grows on a short stem right out of the upper part of the tree trunk. Prior to his making us the guanabana drink, my son, then 8 years old, saw a cocoanut in the top of the large cocoanut tree growing in the patio of the house, and like children will do, told Dr. Sanchez he would like to have it. We appropriately shushed him up, but unknown to us and while we were sipping our cool guanabana drink, Dr. Sanchez had sent next door and got the neighbor boy to climb up the the top of the tree and bring down the cocoanut for our son. I tried my best to help Dr. Sanchez sell his echinoid collection, but I was unable to accomplish it. Had I known then what I know now, I would have borrowed the money and bought it myself. I don't know what happened to it after Castro took over. We learned from the daughter-in-law of Dr. Sanchez--she lives in Houston--that two weeks before he was to leave Cuba on the Mariel boat lift, Dr. Sanchez died of a heart attack. He authored five books on Cuban echini, all of which he autographed and gave to me, along with a substantial collection of Cuban echinoids.

Another person who made a strong impression on me was my geology and paleontology teacher, Dr. W. M. Winton of TCU, Ft. Worth. He authored and co-authored with Dr. W. S. Adkins several books on Texas paleontology which are classics today. I enjoyed his courses more than any others I took while attending night school for 21 years at TCU. While attending his course on historical geology, I took down in shorthand every single lecture, together with every one of his blackboard drawings. I transcribed this material into a book, and it is now one of my prized possessions. He mixed humor and anecdotes in with his lectures, and I can truly say that Dr. Winton was the greatest college professors I ever knew.

The fifth but by no means the last of my paleontology friends was Victor L. Bergeron, better known as "Trader Vic", of San Francisco. Trader owned all the Trader Vic restaurants all over the world, and was quite wealthy. He lived next door to Bing Crosby in Hillsborough, a suburb of San Francisco. He would come to Dallas about twice a year to check on his restaurant at the Hilton Inn on North Central Expressway, and while he was here I would take him out on fossil hunts. I had to be careful to take him to easily accessible places because he had an artificial leg and couldn't do too much walking. I remember taking him on one occasion to one of my echinoid and ammonite localities on a creek in Grayson County, and I liked to have never got him back up the steep bluff. He was particularly fond of collecting the huge ammonite Eopachydiscus laevicanaliculatum out of the Duck Creek formation. These things sometimes get as big as a wash tub, and he always took along the manager of his local restaurant to carry his fossils. I remember one time we went up on the Arbuckle Mts. in Southern Oklahoma, and when lunch time came around, Trader wanted me to pick out some sort of picturesque spot because he had his wife along on this trip. I took the group to a spring fed waterfall I used to visit as a boy. We spread out our lunch there--a sumptuous feast prepared and catered by his restaurant manager. When we returned to Dallas that night, Trader personally cooked our supper at his Trader Vic's Restaurant. It was Indonesian lamb, his favorite. Other than myself and my son, Stephen, I've never known anyone who enjoyed fossil collecting more than Trader Vic.

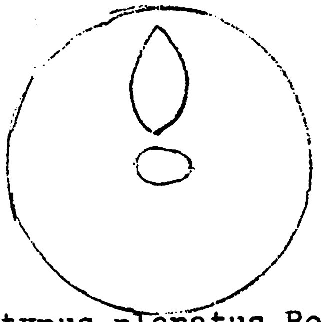
I have, of course, made dozens of friends all over the world with my hobby, but the five persons listed above stand out in my memory as something special. But so much for the human connection, and now for a little semi-technical stuff. Many people, particularly those not very familiar with the various forms of Texas echinoids, often find it somewhat difficult to identify the various genera and species, particularly those that look alike, at least at first glance. I have found it useful to use three criteria:

1. First, the general shape and then the particular characteristics such as perforate or imperforate tubercles; whether the tubercles are fine or coarse; whether, as in "heart urchins" the sulcus is long, short, wide, or narrow; whether the slit pores on the paired ambulacra are transverse or in chevron; the size and location of the periproct, etc.

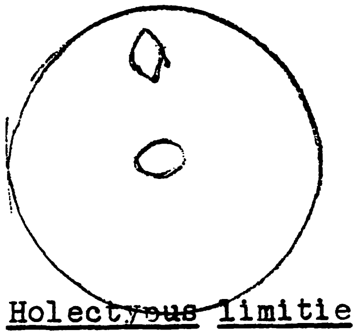
2. Second, it is always helpful to know the horizon, including formation, group, and series. For example - Glen Rose fm., Trinity gp., Comanche series, Cretaceous. It is also helpful to know whether the specimen came from the lower, middle, or upper part of the formation. A good example is the rather uncommon and beautiful Comanchean echinoid Pseudananchys completus (Cragin) and its companion species P. supernus (Cragin). These two species of Pseudananchys are found nowhere but in the basal Grayson formation, and are therefore referred to as "zone fossils". To the uninitiated, Pseudananchys are often mistaken for obsese Holaster.

3. The third criteria I use is geography inasmuch as some echinoids are restricted to certain geographical areas. That is not to say they are never found in other areas, but some are certainly more abundant in one area. A case in point is the genus Globator from the Washita group of the Comanchean. In all my 60-odd years of collecting echinoids, I have found only four--2 in the Weno of North Texas, and 2 in the upper Ft. Worth of South Oklahoma--whereas in far West Texas, however, I find them by the dozen.

The point I make is that, in my opinion, all three criteria should be used when making identification of a specimen for no single criteria is infallible. I list below simple drawings of two species of Holectypus and of two regular echinoids--Phymosoma and Tetragramma--with illustrations as to how to tell them apart easily.

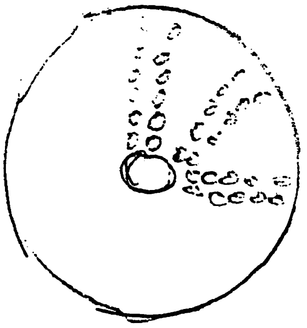


Holectypus planatus Roemer,
a Fredericksburg form

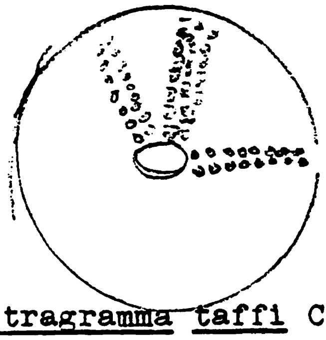


Holectypus limitie Bose,
a Washita form.

You will note that the principal difference between these two species is the size and location of the periproct. The periproct of H. planatus is relatively large and stretches from near the margin nearly all the way to the peristome, whereas on H. limitis it is much smaller and is located near the margin of the test.



Phymosoma texanum Roemer



Tetragramma taffi Cragin

The main differences between these two genera and species is that in Phymosoma the tubercles are imperforate, are much coarser, and there are alternating rows of two, as illustrated in the drawing. On the otherhand Tetragrama has more abundant and finer tubercles, the tubercles are perforate, and they alternate in lines of 2, then 3, then 2 again, as shown in the drawing. At first glance, these two genera and species are confused by some collectors, primarily I feel because they both occur in the same formations--the Goodland, Comanche Peak, and Walnut formations of the Fredericksburg group--and because they look somewhat alike. At fossil shows I have bought Phymosoma labeled as Tetragramma and vice versa.

I publicly acknowledge that God has been good to me, because He has blessed me with a son who shares my interest in and love of fossils, particularly echinoids. At the drop of a hat, he and I enjoy catching a plan as soon as he can shut down his dental practice for the week, and flying to S.W. Texas, W. Texas, Florida, or anywhere else to explore new echinoid localities. There's nothing like it. We have in our collection about 15 new genera and species of echinoids which need description by an expert, and one of these days Dr. Steve will get that done. When he does, we feel that both of us will have made our own small contribution to science.

THE PREPARATION OF ECHINOID FOSSILS IN LIMESTONE

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We all enjoy the discovery of a fossil in the field--but what happens to it then? Is it properly prepared for display, or does it end up in a box or a drawer. Other articles have appeared here in the past discussing fossil preparation, usually from a shale matrix. This article discusses the extraction of fossils from limestone matrices. Specifically, these are the Eocene limestones of North and South Carolina, the Castle Hayne and Santee Limestones, respectively.

As with most preparation techniques, a thorough knowledge of the morphology of the fossil is necessary. Further requirements include patience and "knowing when to stop". There are also several mechanical and chemical tools which may be employed, as discussed below.

These two formations vary in texture and hardness from soft, losse particles to extremely hard material. Roughing out the fossil may be done by several methods, depending on the matrix. The softer matrix may be removed from a fossil by "nibbling" around the edges with a pair of needle-nosed pliers. Harder materials may require the use of a bench grinder. In both cases, work can't be done too close to the fossil. For work of a finer degree I use a Moto-tool with carbide tipped grinding wheels. After this I resort to hand tools such as a set of machinist's files and dental tools. A particularly handy tool is a small file-like scraper obtained from a set of antique dental tools which has a roughened, square surface at the business end.

By this time a lot of matrix has been removed, but the fine detail such as ambulacral grooves, pores, and spine attachments may still remain obscured. Now is the time to use a chemical tool--acid. Limestone is a base and may be dissolved by an acid. I use a 20% solution of acetic acid, though others will work as well. Vinegar is a dilute solution of acetic acid and will also work, though it removes matrix more slowly. The fossil itself will also be attached by the acid, though not as fast as the matrix. I like to expose the echinoid to acid, rinse it with water and again use by scraper, as additional grains of limestone matrix will now be removable. This process of acid treatment followed by scraping may be repeated over a dozen times until all the detail is revealed. I usually have four to six echinoids in the acid at any one time, while I rotate them through the process.

Following the final dip in acid I soak the fossil in a basic solution to neutralize excess acid. I use sodium bicarbonate, or baking soda. This is a quick dip followed by twenty-four hours soaking in water. Sometimes upon drying the fossils develop salt crystals on the exterior as the water inside them evaporates (most are partially hollow). Additional rinses in water may be required to remove these crystals.

This process may be slow and meticulous, but it does produce beautiful specimens. There are twenty-seven echinoid species known from these Eocene limestones. Only three are found elsewhere. The species we have collected are discussed below. An excellent text on these echinoids and their localities is by Porter Kier and is found in Number 39 of Smithsonian Contributions to Paleobiology "The Echinoids of the Middle Eocene Warley Hill Formation, Santee Limestone, and Castle Hayne Limestone of North and South Carolina". A further site guide may be found in "Fossil Locations in South Carolina", by Jerry Howe and Andrew Howard, published by the South Carolina Museum Commission.

The most common species are the flat sand dollars, *Protoscutella conradi* and *Periarchus lyelli*. Next most common are the oval echinoids such as *Eurhodia rugosa rugosa* and *Eurhodia holmesi*. The distinguishing feature between these species is that *E. holmesi* is more rounded and less elongated. In the Castle Hayne formation, *Ryncholampas carolinensis* and *Echinolampas appendiculata* are both common. Specimens more difficult to find include *Linthia hanoverensis*, which has an ornate pattern of spine attachments on its test, and *Santeelampas oviformis*, which possesses a vertically elongated anal opening. The most beautiful echinoids to me are the urchins. These include *Coelopleurus infulatus* and *Cidaris pratti*. I have only found one complete specimen of the latter in three years of collecting.

Perhaps the techniques I have described will be useful with other fossils in other matrices. If not, I would encourage you to experiment until you do find the right combination of tools and materials. Its a shame not to display them properly, considering the effort by nature to produce these creatures, and by us to find them.

ECHINOIDS FROM LAKE TEXOMA AREA

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Lake Texoma was formed by Denison Dam, about five miles north of Denison, Texas, by an earthen dam approximately three miles long across the Red River. The Red River has cut a channel roughly through the axis of the Preston Anticline. Because of this anticline, one can travel north from the Grayson College campus, and cross fourteen formations (about 12 miles). Fossils found in the rubble of the beaches cannot always be pin-pointed when describing the formation. Usually local collectors are familiar with the collecting sites, and have little difficulty identifying them. Echinoids are not found here in the Upper Cretaceous (the first three) formations. Therefore, echinoid collecting is in the Comanche Series of the Lower Cretaceous. The most prolific collecting, by formation, is as follows:

Grayson formation

Enallaster adkinsi, bohmi, inflatus, mexicanus, texanus, wenoensis
Hemiaster calvini
Holectypus castilloi, charltoni (rare)
Pseudananchys completus, supernus (rare)

Main Street -- Denton (rare)

Ft. Worth and Duck Creek formation

Goniophorus scotti (rare)
Heteraster adkinsi, bohmi
Holaster comanchesi, simplex (tall phase - rare)
Lambertiaster ficheuri
Macraster aguilerae, denisonensis, elegans, kentensis (rare), nodopyga, pseudoelegans, roberti, solitariensis, texanus (rare), washitae, wenoensis
Palhemiaster bexari, comanchei
Pliotoxaster inflatus, whitei

Kiamichi -- Walnut formations

Hemiaster bexari, comanchei
Heteraster adkinsi, mexicanus, obliquatus, texanus
Holectypus planatus
Washitaster riovistae (rare)

Collecting areas around Lake Texoma are best when the lake is at low elevation. Some places are accessible only by boat.

Neogene Chromostratic Scale and Correlation

A GEOLOGIC TIME SCALE (after Harland, W. B., et al) Cambridge University Press--1982

Cretaceous Period						CRETACEOUS SYSTEM				
Period	Epoch		Age	Biostratigraphic correlation	Ma	EUROPE FRANCE N//S	EUROPE ENGLAND	CANADA SCOTIAN SHELF	USA GULF COAST	
Pg	Paleocene		Danian			MEUDON		BANQUEREAU	MIDWAY	
Cretaceous (K)	K$_2$	Senonian (Sen)	Maastrichtian (Maa)	*Pachydiscus neubergicus* *Acanthoscaphites tridens*	65·0				NAVARRO	GULF
			Campanian (Cmp)	*Bostrychoceras polyplocum* *Placenticeras bidorsatum*	73·0	CRAIE BLANCHE À SILEX		WYANDOT	TAYLOR	
			Santonian (San)	*Placenticeras syrtale* *Texanites texanus*	83·0		UPPER CHALK	DAWSON CANYON	AUSTIN	
			Coniacian (Con)	*Parabevalites emscheri* *Barroisiceras haberfellneri*	87·5					
			Turonian (Tur)	*Romaniceras deveriai* *Mammites nodosoides*	88·5	CRAIE DE TOURAINE	MIDDLE CHALK MELBOURNE ROCK		EAGLE FORD	
			Cenomanian (Cen)	*Calycoceras naviculare* *Mantelliceras mantelli*	91·0	CRAIE DE ROUEN	PLENUS MARLS GREY CHALK CHALK MARL		WOODBINE	
	K$_1$		Albian (Alb)	*Stolickzkaia dispar* *Leymeriella tardefurcata*	97·5	GRÈS GLAUCONIEUX	UP.GR.SAND GAULT	LOGAN CANYON	WASHITA FREDERIKSBERG	COMANCHE
			Aptian (Apt)	*Diodochoceras nodosocostatum* *Deshayesites deshayesi*	113	CALCARE URGONIENS	FOLKSTONE BEDS SANDGATE BEDS HYTHE BEDS ATHERFIELD CLAY		TRINITY	
			Barremian (Brm)	*Silesites seranonis* *"Nicklesia" pulchella*	119		WEALDEN BEDS WEALD CLAY	MISSISAUGA	NUEVO LEON	COAHUILA
		Neocomian (Neo)	Hauterivian (Hau)	*Pseudothurmannia angulicostata* *Acanthodiscus radiatus*	125	MARNES À SPATANGUES			DURANGO	
			Valanginian (Vlg)	*Neocomites callidiscus* *Kilianella pertransiens*	131	CALCAIRE DE FONTANIL MARNES DE DIOIS	HASTINGS BEDS			
			Berriasian (Ber)	*Berriasella boissieri* *Berriasella grandis*	138	CALCAIRE MARNEUX DE BERRIAS	PURBECK DURLSTON BEDS			
J	J$_3$	Malm	Tithonian	*Subcraspedites lamplughi*	144	CALCAIRE TITHONIQUE	LULWORTH BEDS			

OF CLUBS, SPEARS, AND WALKING STICKS
or
THE LIFE AND TIMES OF ECHINOID SPINES

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The Greek philosopher Aristotle applied the name ECHINOS to the common Mediterranean sea urchin. ECHINOS, Greek for hedgehog (itself a spiny creature) was an apt descriptive term for spine covered sea urchins. Spines are a prominent and ubiquitous feature of echinoids. Throughout echinoid evolution, spines have been adapted for a variety of functions. Study of spines and the tubercles to which they are attached can provide some insight into the life and times of a fossil echinoid.

Echinoid spines are generally shaped as tapering rods with a concave base for attachment to a tubercle to form a ball and socket joint. The base of the spine is attached to the tubercle mamelon by two concentric layers of tissue (Fig. 1). The outer layer is composed of quick acting muscle fibers that by contracting can point the spine in the direction of a stimulus. The inner layer forms a catch apparatus. This slow acting musculature contracts to hold a spine rigidly in place for extended periods of time. The outer muscle layer attaches to the areole of the tubercle while the catch apparatus inserts on the boss. In some echinoids, those with perforate tubercles, a ligament also extends from the mamelon into a pit in the spine base. Tubercle crenulation is matched by crenulation in the spine base. When the spine is tilted, the crenulations interdigitate and help to hold the spine firmly in place.

Spines, like the plates of the echinoid test, are composed of calcium carbonate intermingled with an organic matrix. Most echinoid spines are covered by a layer of epithelium, as is the sea urchin test. Cidaroid spines differ from those of most other echinoids in having an extra outer dense mineral layer forming a hard cortex that carries external ornamentation and are not protected by a layer of epithelium. Since their spines lack an epithelial covering, cidaroids are prone to have debris and small organisms attach to their spines. Cidaroids and echinacean echinoids have solid spines. Hollow spines are found on irregular echinoids, diadematoids, echinothuroids, and many Paleozoic echinoids.

Spines vary greatly in size and shape (Fig. 2 a. *Mellita*, b. *Heterocentrotus* 2° spine, c. *Lovenia*, d. *Tylocidaris*, e. *Balanocidaris*, f. *Salenia*, g. *Paracidaris*, h. *Hemicidaris*, i. *Rhabdocidaris*, j. *Heterocentrotus* 1° spine, k. *Diadema*). There is good correlation of spine size with tubercle size. Large primary tubercles have large spines while secondary and miliary tubercles have smaller ones. Echinoids with relatively uniform tubercle size (*Echinus*, *Tripneustes*, *Strongylocentrotus*, etc.) have spines that are very similar to each other. Where there is a great variation in tubercle size, as in cidaroids and echinaceans, a corresponding variation is found in the size of the spines. Oral and aboral spines are usually shorter than those located on the sides. The interambulacra usually have more and longer spines than the ambulacral areas.

Fig. 1

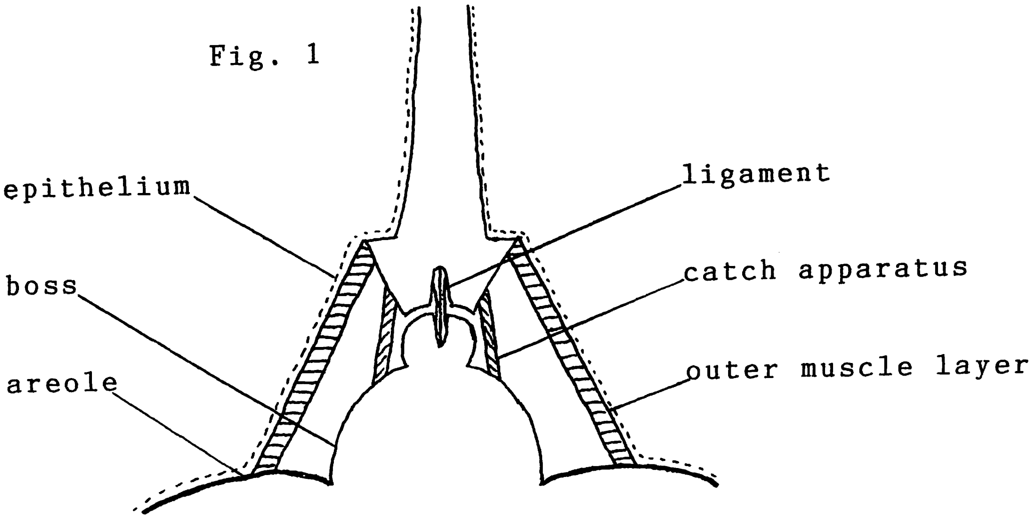
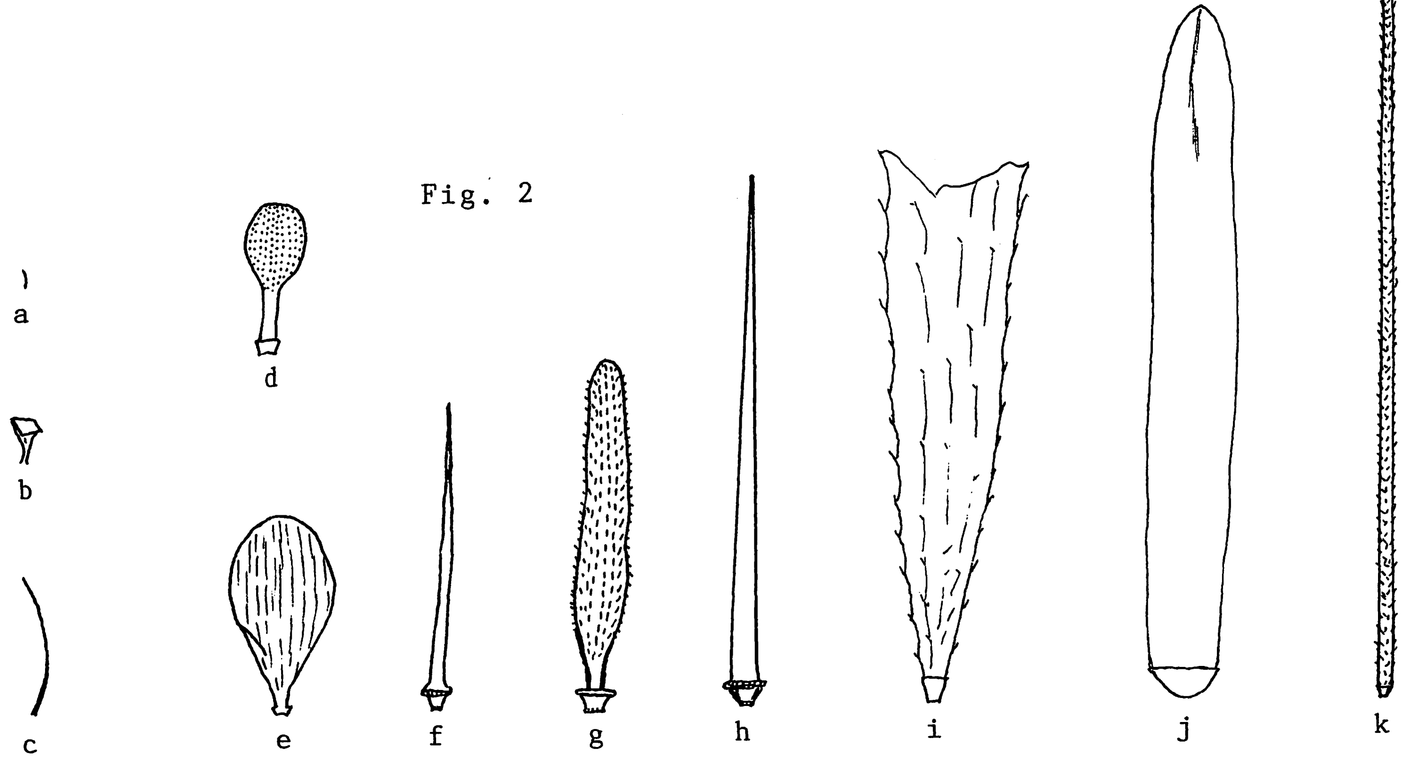


Fig. 2



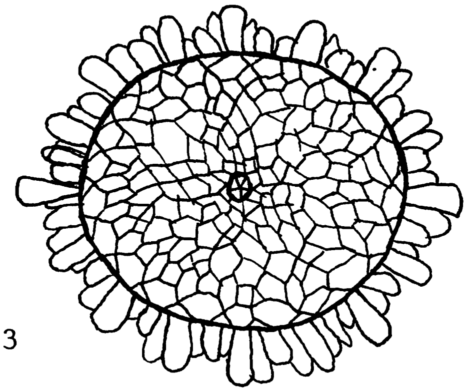


Fig. 3

Colobocentrotus

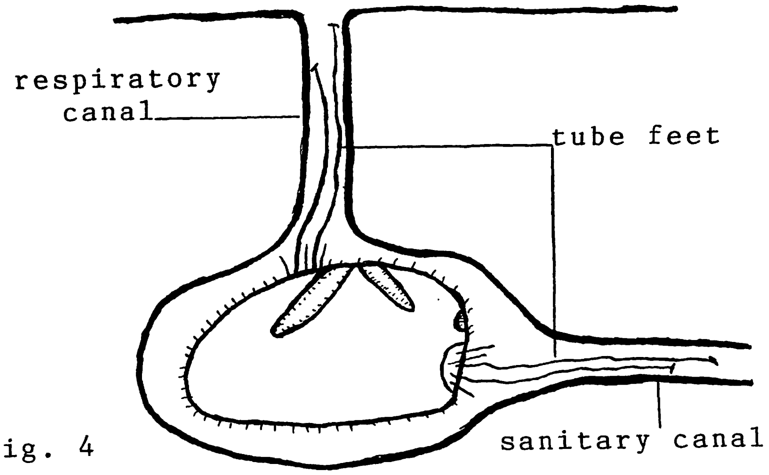


Fig. 4

There is less size variation in irregular echinoid spines which tend to be small and uniform in size. The clypeasteroids (sand dollars) are covered by tiny hair-like spines (Fig. 2a). Spatangoids (heart urchins) have spines that are of small to moderate length. Some of the longer spines (Fig. 2c) are curved and parallel the surface of the test as if combed back. Spatangoids also have narrow bands of tiny closely set ciliated spines called clavules. The clavules are used to maintain water currents around the echinoid in its burrow. The narrow bands on the test where the clavules attach are called fascioles. The fascioles are named according to their location on the test: anal, internal, lateral, marginal, peripetalous, and subanal. No single spatangoid species has every type of fasciole. The most commonly found are subanal and peripetalous.

Regular echinoids like the echinometrids have markedly contrasting primary and secondary spines. In Heterocentrotus mammillatus (pencil urchin) the primary spines (Fig. 2j) are long and thick with a somewhat triangular cross section while the secondary spines (Fig. 2b) are short and flat-topped covering the remainder of the test like a mosaic. The aboral spines of Colobocentrotus, another echinometrid, all have the short flat-topped shape while the spines around the ambitus are broad and flattened (Fig. 3). The unusual spination of Colobocentrotus is considered an adaptaion for surf-beaten rocky shore life. Cidaroids have very large, solid, and stout spines that come in a variety of shapes (Fig. 2d, 2e, 2g, 2i). The secondary spine of cidaroids are much smaller and cover the remainder of the test as well as encircling the base of each primary spine. Diadematids have slender, fragile, hollow spines which are often very long. In Diadema (Fig. 2k) the spines increase in length from the oral to the aboral surface where they may reach one foot in length. The spines of the family Echinothuridae are hollow with thin perforated walls connecting the surface grooves with the interior of the spine. Poison spines are best developed in this family of echinoids.

Spines and podia (tube feet) are both used by sea urchins for locomotion. All echinoids, with the exception of a few rock boring species that never leave their burrows, move about in search of food.

Regular echinoids live epifaunally and move over the sea floor, coral reefs, or in and about sea plants and algae. They can move in any direction with equal ease. Over sediment regular echinoids use their oral spines to move. On hard surfaces they also employ podia which end in suckered discs. This allows them to adhere to surfaces to climb up rocky corals or plants and algae. In addition, tube feet enable the echinoid to clamp its lantern more firmly against the substrate for more efficient rasping. Strong tube feet are also used by echinoids that live in turbulent shallow water habitats where they must adhere firmly to the surface to avoid being dislodged by waves crashing onto them.

Irregular echinoids usually live infaunally and use only their spines for locomotion. Infaunal living has resulted in various adaptations. The oral surface of irregular echinoids has become flattened bringing more spines in contact with the bottom. The low test profile also helps maintain stability in currents. Suckered tube feet are not useful in unconsolidated sediment where little adhesion can be developed as compared to that by regular echinoids on firm sufaces. Irregular echinoids tend to move in one direction, with ambulacrum III pointed forward. Unidirectional motion has allowed for the development of a power stroke directed posteriorly. Fossil echinoids that moved unidirectionally can be identified by noting the asymmetry of oral tubercles with posterior enlargement of the areole to accommodate a larger muscle attachment. There has also been specialization of oral spines so that only some are involved with locomotion. In holasteroids and spatangoids the plastron spines provide the thrust for movement. In clypeasteroids the oral interambulacral spines are used for locomotion. Spines used by spatangoids and holasteroids for locomotion end in expanded flattened tips increasing their efficiency in moving against sediment.

Echinoids are preyed upon by a wide variety of animals including fish, crustaceans, starfish, birds, otters, etc. Spines play a major role in an echinoid's defense against predators. Some echinoids use their spines for camouflage. The cidaroids have non-epithelial covered spines that easily become encrusted by algae and epizoans forming an effective camouflage. Some cidaroids have even evolved broad fan shaped spines which further facilitate the settlement of organisms enhancing the camouflage effect. The echinothuroids have thin-walled hollow spines which have a poison sac on the tips to discourage potential predators. The diadematids have very long needle sharp spines to deter predators. These echinoids also enhance their defense by aggregating in large numbers. When disturbed their long spines are pointed in the direction on the disturbance. In spite of this technique, some fish are able to snap off the thin spines and effectively prey upon diadematids. Cidaroids and echinaceans have given up some of the mobility of light hollow spines in favor of large solid heavy spines which are difficult to break. Such spines (Fig. 2d-2j) are often massive making the echinoid too awkward and difficult to handle by potential predators.

Irregular echinoids avoid many predators because they live buried in sediment. The eognathostomates (holectypoids and pygasteroids) use oral spines to dig vertically into sediment by pushing material out radially. Cassiduloids and clypeasteroids burrow by moving forward through sediment. The aboral spines and tube feet transport the accumulated sediment posteriorly over the test. The oral spines only provide the forward thrust to move the echinoid and do not excavate sediment. The atelosomates (holasteroids adn spatangoids) as well as a few cassiduloids and clypeasteroids have developed two lateral zones of oral spines to burrow into sediment.

Once buried in sediment the echinoid must maintain a flow of oxygenated water about itself and prevent sediment from accumulating on the test surface. In coarse sediment a canopy of closely set aboral spines can effectively keep sediment from settling onto the test. Finer grained sediments such as silt or mud cannot be effectively screened out using only a spine canopy. The spatangoids have successfully adapted to these habitats. The spines of the dorsal fasciole of spatangoids secrete a mucus film that is held above the echinoid on the tips of the aboral spines. This provides an effective barrier for even very fine grained sediments. In addition, spatangoids living in very fine sediment construct mucus coated shafts to the surface using specialized tube feet and spines along the anterior dorsal aspect of the test (Fig. 4). Through this shaft (respiratory canal) water is actively drawn in by the ciliated spines of the fascioles. Some spatangoids also construct a posterior tunnel (sanitary canal) using specialized subanal tube feet and spines. This posterior tunnel aids in maintaining the flow of water around the echinoid by providing a drainage site. A fasciole and a tuft of spines near the anus help pump water backward to carry waste products away from the echinoid.

It is rare that fossil echinoids are found with their spines still attached. After death spines quickly become disarticulated from the echinoid test. As organic tissue decays the spines begin falling from the test. Irregular echinoids with their small spines and little connective tissue may lose their spines within hours of death. Regular echinoids have more tissue holding their spines in place. If undisturbed, regular echinoid spines may remain attached for a week or so after the echinoid dies.

Finding a complete fossil echinoid with its spines still attached indicates that death occurred as a result of the echinoid being buried alive by fine sediment from which it could not escape. The sediment then holds the spines in place after the organic connective tissue has decayed. Such preservation is more common for Paleozoic echinoids and is much more rarely encountered in Mesozoic and Cenozoic deposits. If an echinoid lays undisturbed after death it may be preserved with its disarticulated spines in close association. This type of preservation is not uncommon in some Jurassic beds and later deposits. Most often, echinoids are found without their spines in close association, although spines may be found in the same deposits if one searches carefully.

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AN UNUSUAL LOWER MIOCENE ECHINOID FROM SOUTHERN CALIFORNIA

SCUTASTER VAQUEROSENSIS

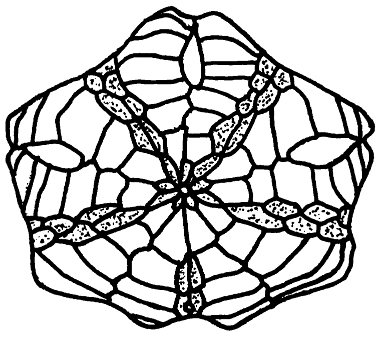
by Boris Savic Jr.

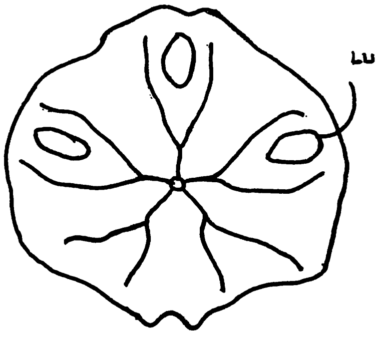
Irregular Echinoids of the West Coast of North America, have been of interest to Paleontologists and Collectors for many years. One genus of interest, that has never been discussed recently, will be the topic of this paper.

J. Wyatt Durham's statement about this echinoid was that, "no other echinoid has evolved in this direction". The evolutionary direction of Scutaster is exhibited by its unusual genetic morphology, having three anterior lunules and no posterior ambulacral lunules. After examining several specimens collected in the Vasqueros Formation from the Santa Susana Mountains. Nowhere in literature, does it disclose, the unusual bifurcation of the exterior shape near the posterior region of the sub-marginal periproct. The two lobes, give it a wing shape appearance.

The medium shape and low profile shows affinitive association to the genus Amphiope, L. Agassiz 1840, Miocene of Europe and the genus Abertella Durham 1953 - Miocene of North America. Scutaster's development of the lunules whow similarities to Astriclypcus, Verrill 1867 and Echinodiscus, Leske 1778; both ranging from Miocene to recent. Scutaster has no living descendants, today, off the California Coast.

At two collecting localities, miles apart, in the Vasqueros another echinoid is found in abundance, Scutella fairbanksi. The possibility of competitive strife for food supplies and environs may have caused the extinction of this genus, Scutaster. Somehow the symbiotic relationship, may have been its downfall. These types of associations exist today, in our oceans. For example, Encope competing in the same food chain with Dendraster and Mellitella. Scutella during the Miocene was Worldwide and dominant that niche.



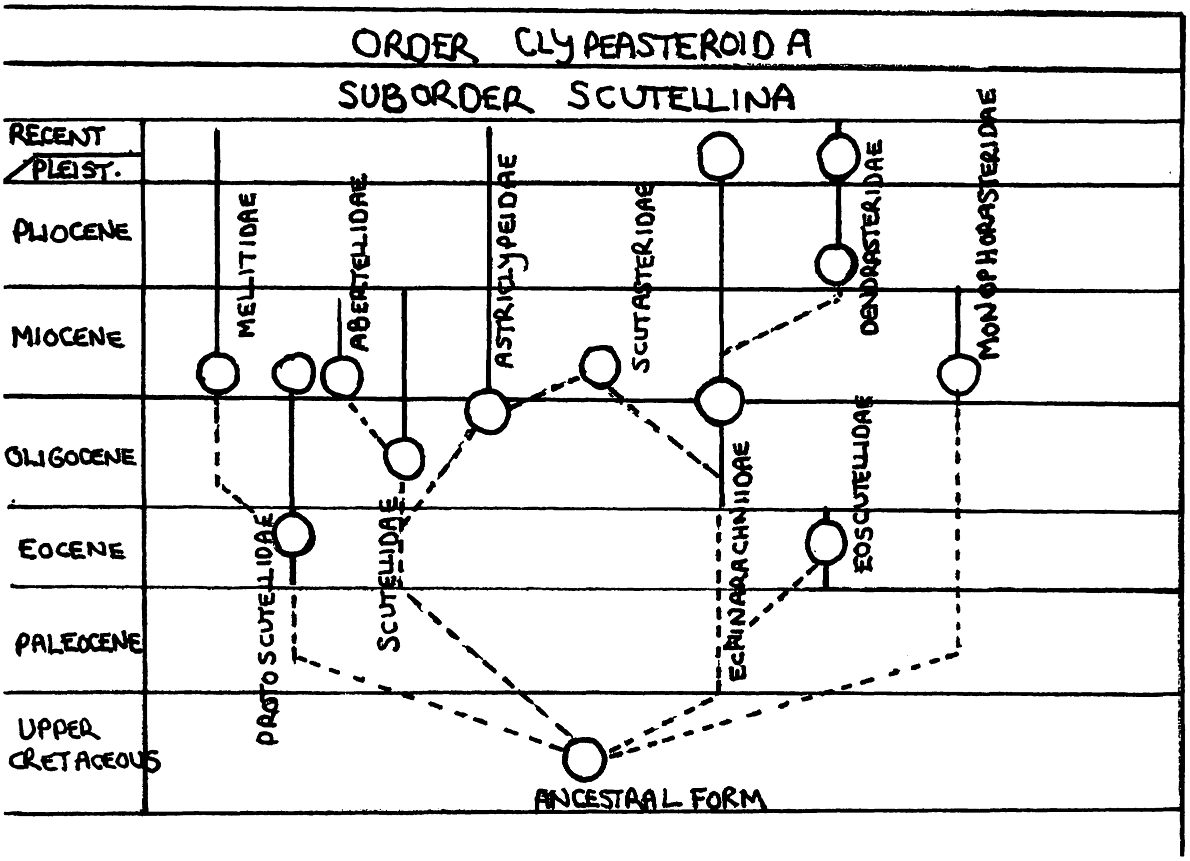


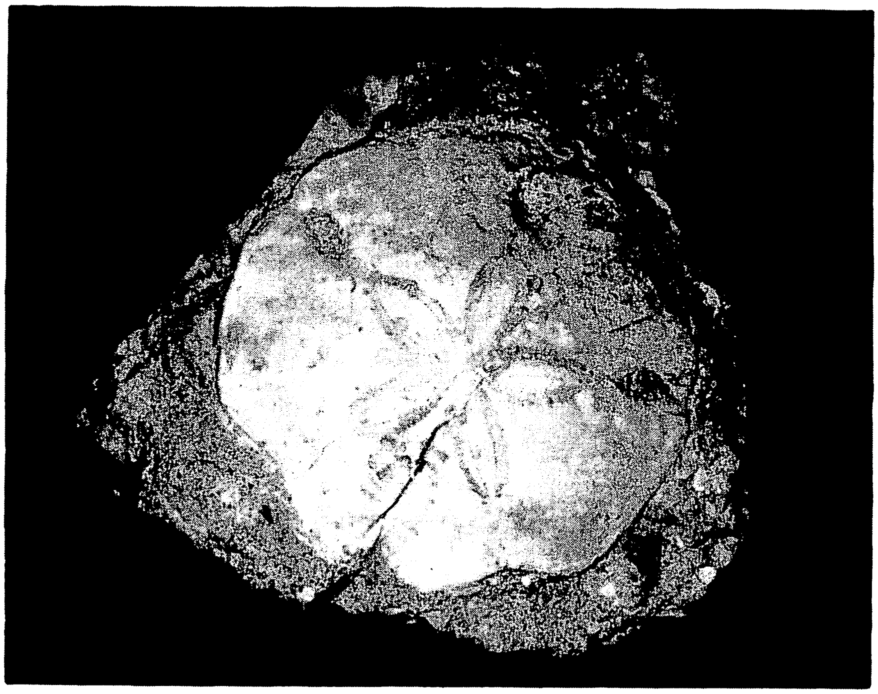
The geological records on Scutaster, show its finds are are restricted to the Coast Ranges. The two other species identified and collected, came from San Emigidio Mountains (Kew, Anderson and Hanna) and East of Muir, Contra Costa Co. (Pack, W.B. Clark and Twitchell). Additional specimens of Scutaster andersoni would be needed for positive identification and comparison with S. vasquerosensis. None were available at the time of this paper. Grant and Hertlein state that Scutaster being confined to Lower and Lower Middle Miocene of California. Such a narrow niche in geological time, Scutaster must have evolved and perished rapidly.

One analogy, may be due to its restricted oceanic lagoonal environ, demanded a certain temperature and salinity. This may have been a contributory factor to its short term.

The study of its food grooves on the oral surface, periproct positionery and inter ambulacral region postulates its past race (Durham 1955) closely affiliated to the family Echinarachniidae. But again these are speculations and all of the genera mentioned above affinitive ties.

The chart below illustrates the ancestral links for Scutaster. These have been compiled and modified from Durham, 1955, charts.





Synopsis: Scutaster shows close ties to various genus that still live in waters today. Scutaster's morphology indicates radical changes in appearance and reflects it, by its short lived Miocene time. My own view is that more samples of the oral and aboral should be studied to determine these complexities for positive conclusions.

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ASTRODAPSIS:

Genus of a Thousand Faces

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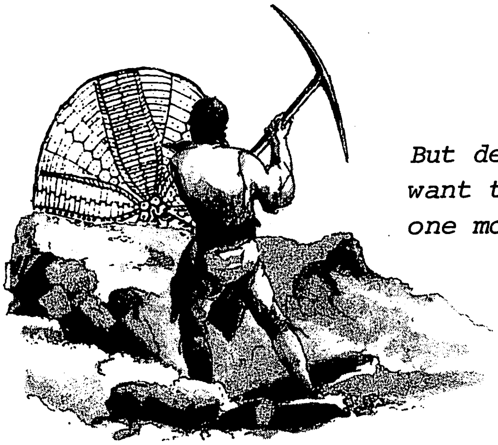

But dear! I just want to "pick up" one more!

Somewhere back near the dawn of my fossil collecting career, I discovered the fascinating echinoid genus *Astrodapsis*. Many pleasant days were spent hunting these cookie-shaped echinoids with my friend Boris Savic, Jr. The best trips were those we made in the spring months, when the new grass was emerging on the normally brown California hillsides, and the stately oaks were washed clean by the winter rains. The outcrops of Miocene sediments appeared a fresh white in contrast to the colors of spring.

Since *Astrodapsis* were gregarious creatures when alive, collecting their remains was a pleasure. We could be a bit selective as we roamed along the weathered ledges. I don't want to leave the impression that all locations produced unlimited numbers of good specimens; the matrix can be unmercifully tough at times and many a specimen sitting weathering in my yard looks as it did many years ago. But over all, it is possible to collect varied assortments of specimens with relative ease in a number of locations.

Part of the excitement of these forays was seeing how many different species we could find at a location. We would get home, clean and prepare all our finds, then compare the specimens to all the publications available to see which species we had been able to wrest from their tombs. Tray after tray was added to the drawers marked *Astrodapsis,* each with its specimens and notes on locations -- species after species after species!

Then in 1962 a paper appeared which literally destroyed years of labeling. "Evolution of the Echinoid Genus *Astrodapsis*" by Clarence A. Hall, Jr. (University of California Publications in Geological Sciences, Volume 40, No. 2, pp. 47-180) cut the described list of species from 61 to 12, and took only 179 pages, including plates, in doing it. It was traumatic, reducing our collections by 49 species!

This was the beginning of the era of "lumpers." The sound principles of morphology, racial variation, and environment were being applied to the tangle of endless descriptions of each slight variation. The "splitter's" day was coming to a close. New rules were applied to the game, or maybe some old rules were being applied in the light of modern evidence. The effect has been very good. We now look at individuals as members of a race, rather than endless species evolving from "parent X." We consider the evolution of radiation of these races and are able to gain a better view of the environment where the creatures lived.

Clarence Hall's paper on the *Astrodapsis* has to be the best work done on this genus. It develops strong statistical evidence to support its conclusions, using morphological evidence -- the position of the periproct, relative heights of the petals, notched or unnotched petals -- to develop a strong case, if not always for speciation, at least for parental lineage. Hall looks at the evolution of the genus, and in my opinion his conclusions are very sound. Anyone interested in the genus *Astrodapsis* should try to get this paper.

OK, if I like the paper so much, why am I doing this article? There are two reasons. Firstly, in the last two years I have attended shows where specimens of *Astrodapsis* have been displayed with an incredible array of names, some also incredibly misspelled. I saw one specimen labeled as from the Eocene, yet *Astrodapsis* is found only from the Middle Miocene to the Late Pliocene. (Those among us who disdain labels, please don't snicker; at least these people tried.)

Secondly, through the years of collecting I have had the opportunity to look closely at a number of the major *Astrodapsis* locations in California. To my knowledge the genus is restricted to this state. Many of my specimens have been taken *in situ,* racial units have been checked for variation, and in some cases hundreds of specimens have been looked at. In a few cases my own work has led me to disagree with Clarence Hall's conclusions, and I feel there are some valid species existing which he discarded.

The following list is my interpretation of the species of the genus *Astrodapsis*. The starred (*) names are those I feel should be included in a list of valid species, even though they are not included by Hall. A brief summary of each follows the list. The unstarred species are the 12 used by Hall in the 1962 work. I will not include descriptions, as they are readily available in several publications. I hope in this way to acquaint fellow collectors with the species most probably valid and to show the synonomy of named specimens under the species where they most probably fall.

Astrodapsis brewerianus (Remond 1864)	*A. Hootsi* Grant & Eaton 1941 (Hereafter G & E)
Astrodapsis diabloensis Kew 1920	*A. altus antiquus* G & E 1941 *A. armstrongi* G & E 1941 *A. auguri* G & E 1941 *A. brewerianus bitterensis* G & E 1941 *A. brewerianus emergens* G & E 1941 *A. brewerianus junior* G & E 1941 *A. brewerianus ovalis* G & E 1941 *A. diabloensis superior* G & E 1941 *A. reedi* G & E 1941 *A. schucherti* G & E 1941 *A. schuscherti affinis* G & E 1941
**Astrodapsis cierboensis branchensis* G & E 1941	
**Astrodapsis galei* G & E 1941	

Astrodapsis pabloensis (Kew 1915)	*A. cutleri* G & E 1941
	A. elevatus G & E 1941
Astrodapsis cierboensis Kew 1915	
Astrodapsis davisi G & E 1941	*A. blakei* G & E 1941
	A. englishi G & E 1941
	A. clarki G & E 1941
	A. desaixi G & E 1941
	A. goudkoffi G & E 1941
	A. isabellae G & E 1941
	A. major parens G & E 1941
	A. quaylei G & E 1941
**Astrodapsis gregerseni* G & E 1941	*A. gregerseni fragilis* G & E 1941
	A. gregerseni varians G & E 1941
	A. johnsoni G & E 1941
	A. johnsoni simile G & E 1941
**Astrodapsis tumidus* (Remond 1864)	
Astrodapsis antiselli Conrad 1856 (Genotype)	*A. altus* Kew 1915
	A. ornatus Kew 1920
	A. margaritanus Kew 1920
Astrodapsis whitneyi Remond 1864	*A. coalingaensis* Kew 1920
	A. cuyamanus Kew 1920
	A. californicus Kew 1920
	A. grandis Kew 1920
	A. hertleini G & E 1941
	A. laimingi G & E 1941
	A. perrini G & E 1941
	A. woodringi G & E 1941
Astrodapsis spatiosus Kew 1920	*A. scutelliformis* Kew 1920
	A. salinasensis Richards 1935
Astrodapsis fernandoensis Pack 1909	
Astrodapsis arnoldi Pack 1909	*A. arnoldi crassus* Kew 1920
	A. arnoldi depressus Kew 1920
	A. arnoldi fresnoensis Kew 1920
	A. major Kew 1920
Astrodapsis peltoides Anderson & Martin 1914	
Astrodapsis jacalitosensis Arnold 1909	*A. schenki* Grant & Hertlein 1938
	A. schenki mirandaensis G & E 1941

Astrodapsis cierboensis branchensis weathers from a zone in the Upper Cierbo of Grant & Eaton 1941. These authors claim a broad stratigraphic horizon for the species, but I have not been able to confirm their observation. It would appear to be from a zone less than 10 meters thick, which also produces large quantities of *A. diabloensis* and another possible species, *A. galei*. Hundreds of specimens weather from this zone, tumbling or washing down until there is a mix of specimens that may not represent any shallow horizon in the zone, but the zone in its entirety. The only way to check the racial constituancy would be to excavate narrow zones. *A. cierboensis branchensis,* a broad petaled, thick margined species, may in fact be more closely related to *A. brewerianus* than to *A. cierboensis*. Another factor that might help explain several species in such close proximity would be non-competing breeding cycles. More work is needed to finally put the questions to rest.

Astrodapsis galei is easily distinguished by its consistently narrow petals and narrow margins. It is very close to *A. diabloensis* but does not seem to grade into that species. I have looked at many hundreds of specimens from this horizon and cannot conclude that there is a complete series of gradation.

Astrodapsis gregerseni and its varieties appear to be restricted to a single horizon at the type location. Both Boris Savic, Jr., and myself have worked along this horizon and have found it free of other species. The problem has arisen at this location, as it has at others in the area, that specimens weathering out of one horizon eventually work their way down slope and intermix with other species. In this case they are found with weathered out *A. davisi*. In the *A. davisi* zone, excavation shows no *in situ* mixing with *A. gregerseni*.

Astrodapsis tumidus in the location I have worked would stand well as a species. It may be the ancestor of *A. antiselli,* but is easily recognizable as distinct from that species in consistency of size and unique ornamentation. Larry Oliveria of Milpitas, California, was kind enough to collect a group of specimens for me showing almost perfect surface ornamentation. Large indented spine bases, far apart, would be the easiest way to define the surface. *A. antiselli* also has moderately large spine bases which are raised, but even on the young specimens they are much more closely spaced.

Of the four species listed above, only *A. galei* falls perilously near being included with *A. diabloensis,* with which it appears related. There are many other reasons for selecting the above as species, but time and space suggest this would be more appropriate for another article.

I have found several specimens of a race evolved from *A. diabloensis* in the Lower Neroly as used by Grant & Eaton 1941. It is a high crowned, large variety that may eventually warrent description. At the present time only badly weathered specimens have been found.

I wish to thank my friends Boris Savic, Jr., of Los Angeles, California, and Larry Oliveria, of Milpitas, California, for donating specimens or information on field work; also, Marty, my generous wife, who always comes to my aid when I inevitably collect too many specimens to carry, or need a knowledgeable editor/typist.

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A REEXAMINATION OF DENDRASTER VIZCAINOENSIS SIMILARIS, A PLEISTOCENE ECHINOID

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An interesting scarce local echinoid, a kind of "sand dollar", was described in 1938. It was called _Dendraster vizcainoensis similaris_*by U. S. Grant IV and L. Hertlein. They named it after _Dendraster vizcainoensis_ Grant and Hertlein, 1938. There is a possibility that the little known _similaris_ should be a new Southern California species.

It is believed that Grant and Hertlein did not have many of the subspecies _similaris_ to look at when they named it. They found a few common characteristics with _Dendraster vizcainoensis_ and noted that it seemed larger than the _vizcainoensis_. It was mentioned that further studies might be advisable.

The type locality of the subspecies is near Signal Hill in the Long Beach area. The holotype is #7432 U. C. L. A. and is now in the Los Angeles County Museum of Natural History collection. The specimen is not of the best quality. The same subspecies was found to the north of Long Beach in the Playa del Rey district. There may be a range extension of _similaris_. A fossil was dredged from the Pleistocene in San Diego 1985 that resembles the _similaris_. Working the Playa del Rey site for several years I collected enough examples of this sand dollar to reveal some new distinguishing details to add to the original accounting.

The genus _Dendraster_ has been found only in the North Eastern Pacific coastlands and shores. Currently _Dendraster_ lives from Alaska to Mexico. They range from Pliocene to the present time. They may have evolved from the echinarachnids proposed by Durham (1955) or the mellitids (Jensen 1981). Possibly as many as 25 species and subspecies of _Dendraster_ have been cited in the literature. But recently a few species have been put in synonymy reducing their numbers. Though many appear alike, there are some definite clues to their classification. To understand the problem presented by _Dendraster vizcainoensis similaris_ we need to consider its anatomy in detail and something of its habitat.

The salient feature of _Dendraster_ are the excentric placement of the petal configuration and the oral and inframarginal position of the periproct. The food grooves bifurcating, branching and often extending to the dorsal side are diagnostic. The plate shapes are important too (Fig. 1).

Three miles inland, in the Upper Pleistocene of Playa del Rey the _Dendraster vizcainoensis similaris_ were plentiful. They occurred in a compact layer 6" to 10" thick which now is 4' to 5' below the present surface. Beneath the sand dollars is an assemblege of warm water marine fauna that contains very deep water mollusks (15-35 fathoms). Above the echinoids is a covering of Pleistocene sand with few fossils (Fig. 2) and some Indian artifacts. The formation the sand dollars were in was Palos Verdes Sand sensu lato.

Since the echinoids were very abundant and rather separate from the other marine life this may indicate a short geological time that they were there (100 years plus or minus). Dendraster excentricus lives generally 9 years (Birkland and Chia 1971). Perhaps the temperature became cooler preceding a glaciation. It became an optimum time for the sand dollars.

The sand at the Playa del Rey locality around the fossils was somewhat coarse, light-brown and unconsolidated. When excavated it tended to cave-in. These very fragile sand dollars often break during collecting especially when wet. It was therefore very difficult to extract whole specimens. Many were found in a vertical position as are the recent Dendraster excentricus. This indicates that they were buried in situ, often a rarity in echinoid sites.

These echinoids varied in size from small juveniles to large ones over 90 mm in width. The echini dug out whole and those observed were in very good condition. There were almost no signs of predation. The solid layer of Dendraster had been infiltered with fine sand and minute mollusks. The lanterns (jaws) were no longer there. A few of the spines were found (Fig. 3). The Dendraster have very short spines used for locomotion and feeding.

In an allometric study of excentricity in Dendraster excentricus Raup (1965) concluded that Dendraster in sheltered bays tend to be less excentric in the petal placement than those in open seas. Also he noted that the tests have a higher camber (summit) in protected areas than those in the exposed seas. This may relate to the Playa del Rey fossils where there once may have been a deep bay. The deposit may have been lenticular. Other ecological or individual differences in the Dendraster are probably: shape (circumference or outline of test), petal width and length, bulging center of petals, angle of the two short petals (bivium) and dome or summit shape from a lateral view.

The Dendraster vizcainoensis are from Baja California in the southern section. In the Pleistocne times they may have been found as far north as Newport Bay, California. It is not known if both the D. vizcainoensis and D. vizcainoensis similaris lived at the same time in the Upper Pleistocene. The similaris are now extinct. Emerson (1980) reported some D. vizcainoesis extant in Turtle Bay, Baja California. Verification is needed. There has been no exact dating of the sites either species has been found in. The material below the Playa del Rey echinoids was dated at 125,000 years approximately. This area is near an extinct fault and may have been subject to tilting and unconformities.

According to the classification of Durham and Melville (1957) on the systematics of Dendraster, the order is Clypeasteroida A. Agassiz, 1872, suborder Scutellina Haeckel, 1896, family Dendrasteridae Lambert, 1889 (which includes four major genera, among them the Dendraster L. Agassiz, 1847). The type species is the living Dendraster excentricus Eschscholtz, 1847.

In a chart using 20 mature specimens of Dendraster vizcainoensis similaris, several of the Dendraster vizcainoensis and 20 of the Dendraster excentricus a comparison was made (Table 1). Using a matching method to study their morphology, the differences if any were noted. This helped decide upon their validity as species. Dendraster excentricus was used as a control species because of its importance and its availability.

Since *Dendraster* are most variable both in individuality and in preservation many specimens are necessary to classify a population. Often confused with *similaris* is *Dendraster sp*. Pliocene from central Baja California. The spines and apical area are different and layering of the plates not the same. The California Pliocene *Dendraster diegoensis venturaensis* Kew might also be mistaken for a *similaris*. This fossil differs in that the food grooves branch more like *excentricus* and it is generally more similar to *Dendraster diegoensis* Kew.

Repeating the dissimilarity between *Dendraster vizcainoensis similaris* and *Dendraster vizcainoenis* the significant points of disparity are: the peristomal plates definition, the food grooves continuing to the dorsal side or not, the presence of small tubercles lining the food grooves or not, the profile single or double summit (in 90% of the time), the elevation of the apical system, the size of pores on the madreporite, the single long petal flatness (85% of the time), and the structure of the apophyses. These differences of *Dendraster vizcainoensis similaris* may be enough to consider it a separate species from *Dendraster vizcainoensis*. **

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* *Dendraster mexicanus* Clark a recent species living in Baja California may be the *Dendraster vizcainoensis* of Grant and Hertlein. They are very much alike in many features.

** In recent correspondence with Dr. J. Wyatt Durham, Echinoid Specialist, Professor Paleontological Museum, Emeritus, University of California, Berkeley, he took the position that *Dendraster vizcaineonsis similaris* was *Dendraster vizcaineonsis*. This is largely based on work by Dr. Carol W. Allison. She used size and distribution of tubercles for identification. Her paper was not completed.

TABLE I

SPECIES	*Dendraster vizcainoensis similaris*	*Dendraster vizcainoensis*	*Dendraster excentricus*
EPOCH	Pleistocene	Pleistocene ?	Plio.? Pliestocene to recent
LOCATION	Southern California	Mexico (Baja Ca.)	Alaska to Mexico
SIZE OF ECHINOID	Large to 95 mm	Medium to 88 mm	Medium to 75 mm
TEST SHAPE MARGINAL	Subcircular	Subcircular	Subcircular to chevron like
EDGE OF TEST	Medium to 5 mm flat	Small to Medium to 4 mm rounded	Medium to 7 mm rounded
SPINES (MILIARY)	Fig. 3 Pointed	No data	
ORAL (ACTINAL AREA)	Flat	Flat slight incurvature	Flat
PERISTOME (MOUTH	Rounded Large Sunken	Rounded Large	Rounded Large
PERISTOMAL PLATES	Fig. 4	Not defined	Smaller less defined pattern
PERIPROCT (ANUS)	Circular Small	Circular Small	Circular Small
FOOD GROOVES (ACTINAL FURROWS)	Deep Wide Simple Fig. 5	Extending to Dorsal side Branched	Extending to Dorsal side very branched
TUBERCLES ORAL SIDE	Many large in depressed scrobicules scattered. Small bordering food groves All imperforate.	Many the same size large Fewer small size and sparcer	In Scrobicules abundant, large same size. Very many smaller at outer edge.
PLATES ORAL SIDE	Fig. 1	No data	Similar to Fig. 1
TEST PROFILE VIEWED FROM ANT.-POST. LINE	Fig. 6 Duel Summit in 90% High to Low	Single Summit High to Low	Aver. Lower

APICAL SYSTEM (MONOBASAL) STELLATE EXCENTRICITY	Small Depressed Fig. 7 pores large Near center	Small elongate Raised pores very small Near center	Larger Even With Test pores small Off Center
OCULAR PORES (5)	Small Fig. 7	Very Small	Small
GENITAL PORES (4)	Medium Away from Madreporite	Medium Between petals not touching	Medium Touching Madreporite
PETALS	Open Fig. 8	Open	Tend to Close
CENTER OF PETALS	Raised Singular long petal usually flat	Raised	More often Flat
BIVIUM	Petals Straight	Petals Straight	Petals often Flexous
BIVIUM ANGLE AVER.	85° Aver.	90° Aver.	Very wide Aver.
TUBERCLES ABACTINAL SURFACE	Scattered Sparce All sizes & close on ambulacra in rows	Scattered Large & small smaller on ambulacra	Very dense Similar Sizes & on on ambulacra
APOPHYSES (INTERNAL)	Wide Squarish Near peristome Fig. 9	Pointed Back from Peristome	Wide Squarish Back from Peristome

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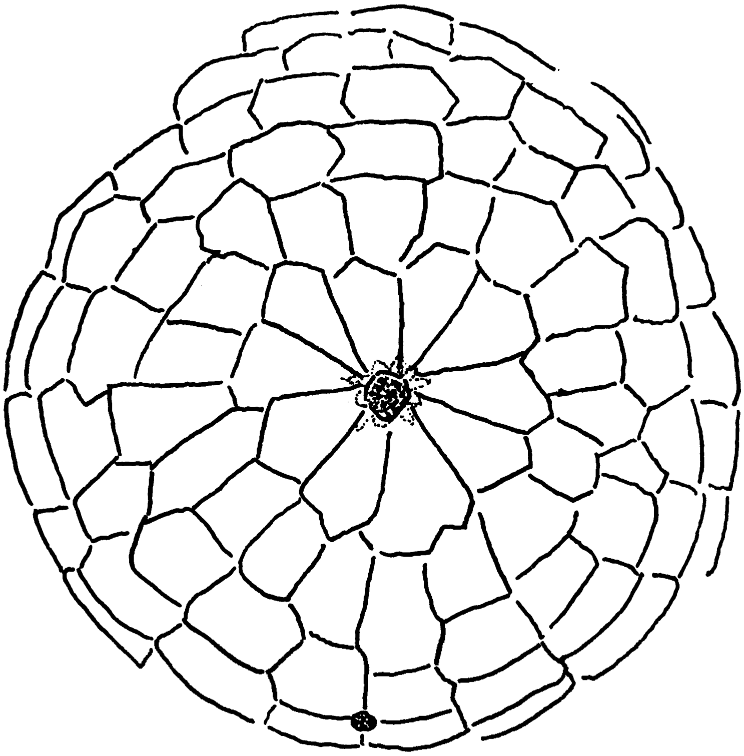


Fig. 1
Etched oral plates
Omitting food grooves
Life size
Dendraster vizcainoensis similaris

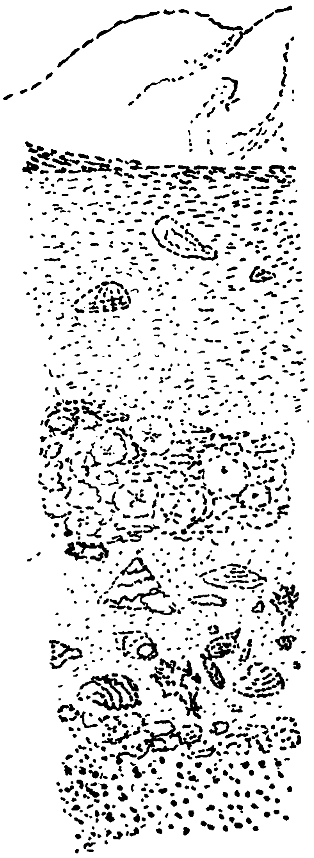


Fig. 2

Fig. 3
Miliary spines
D. vizcainoensis similaris
3.00 mm
2.90 mm
2.96 mm

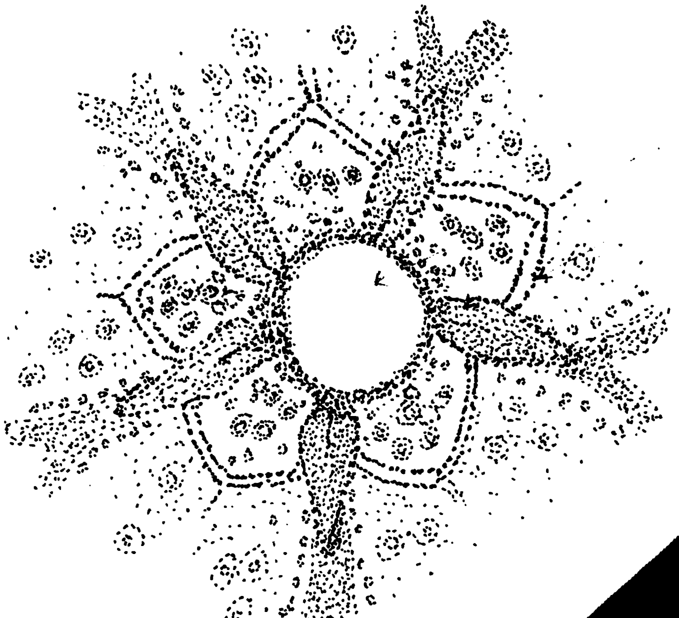


Fig. 4
Peristome
Bifurcating food grooves
Peristomal plates
D. vizcainoensis
similaris
15 mm

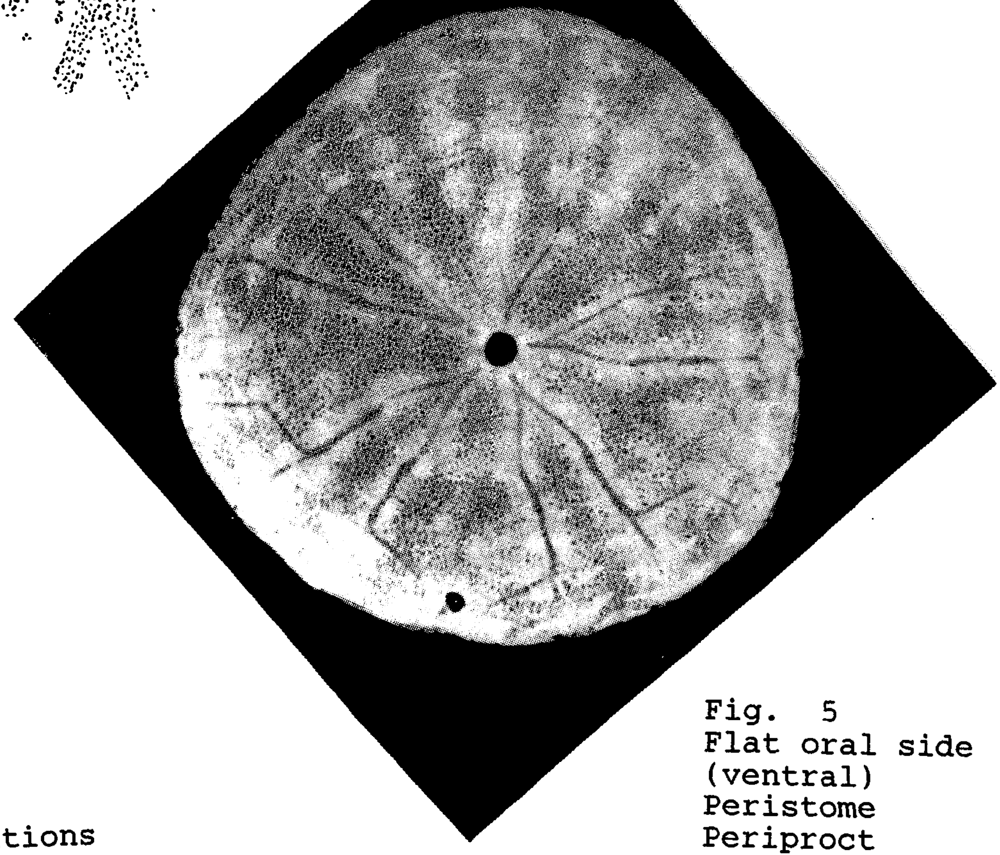


Fig. 5
Flat oral side
(ventral)
Peristome
Periproct
Food grooves
D. vizcainoensis
similaris

Illustrations
Yvonne Albi
Photography
Bert Draper

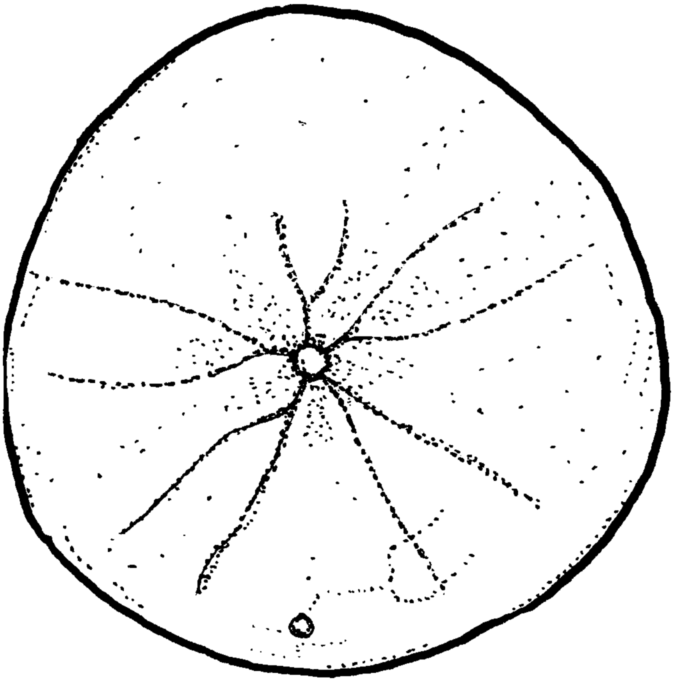
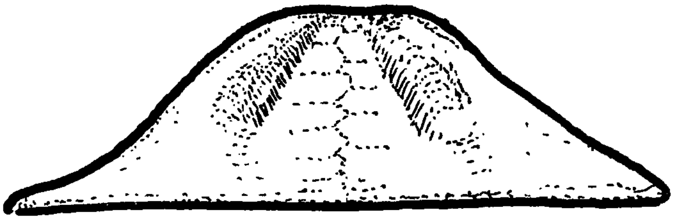


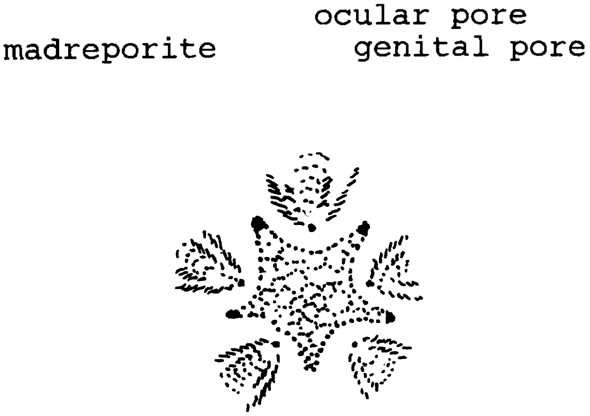
Fig. 6
Dendraster vizcainoensis
similaris
Life size
Oral side

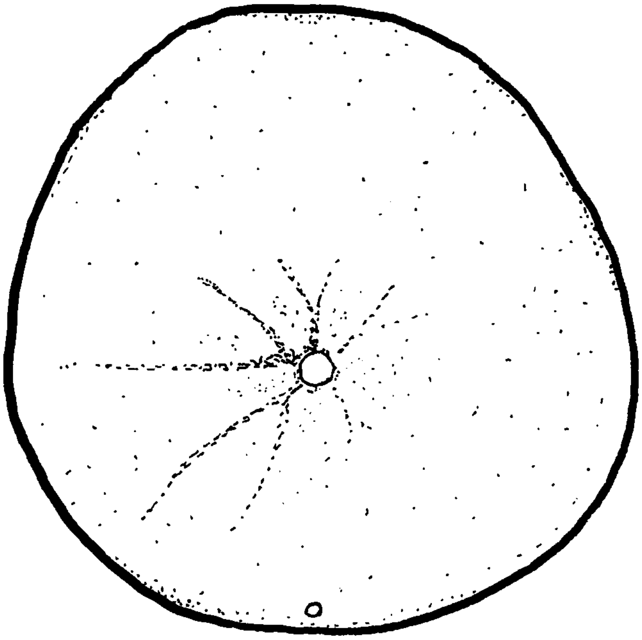
89 mm W
86 mm L



25 mm H

Posterior
Profile





82.3 mm W

80 mm L

Fig. 7
Apical system
Depressed
Monobasal Madreporite
Genital pores 4
Ocular pores 5

D. vizcainoensis
similaris

16 mm H
Variation in height

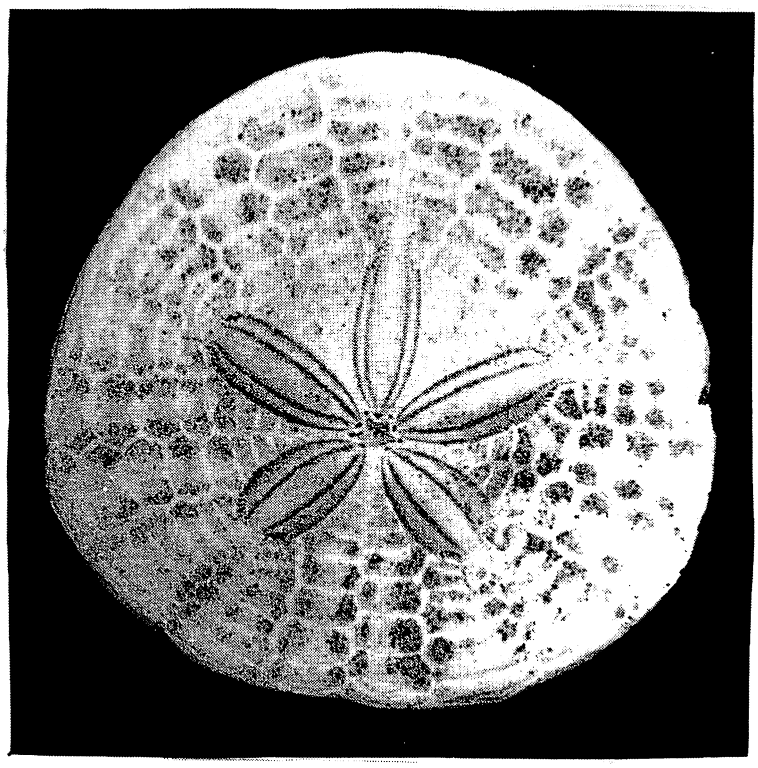


Fig. 8
Dorsal surface
Genital pores
Plates (etched)
Petals
Apical area
Life size

<u>Dendraster</u> <u>vizcainoensis</u>
<u>similaris</u>

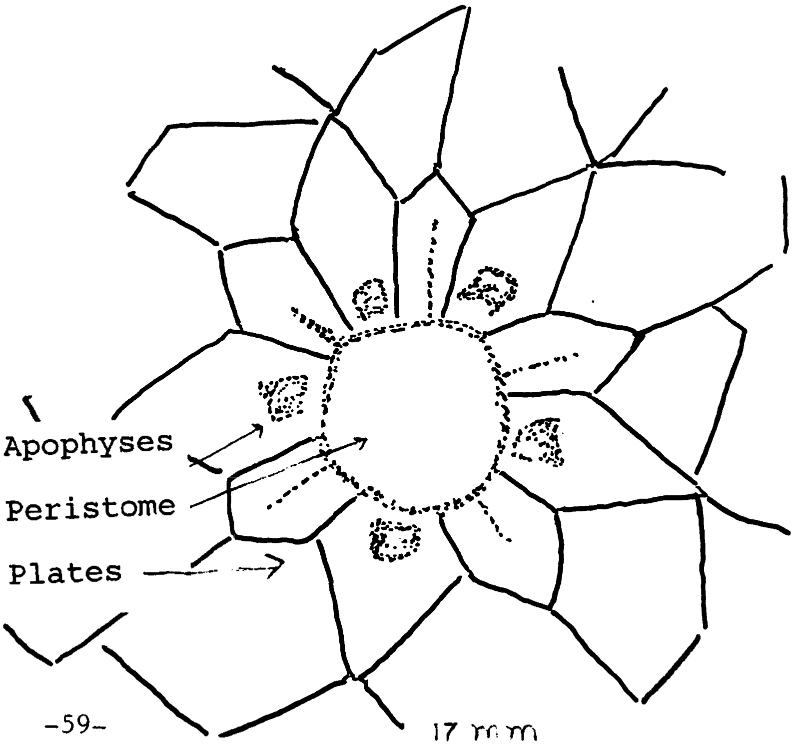


Fig. 9
Interambulacral
basicoronal plate
arrangement.
Apophyses, internal
supports for the jaws.

<u>Dendraster</u> <u>vizcainoensis</u>
<u>similaris</u>

SUMMARY NOTE ON THE DISTRIBUTION AND COLLECTING CONDITIONS FOR JURASSIC ECHINOIDS IN FRANCE

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I. INTRODUCTION

Many hobby palaeontologists specializing in Echinoids come to France in search of fossil sea urchins, and a substantial number are swapping specimens with French and foreign collectors. When looking at their lists of species available for exchange, we have, however, found numerous debatable entries regarding names of species (which is unavoidable) but also erroneous indications of localities and geological formation (which is much more serious).

Since we have mainly studied the sea urchins of Jurassic age, the present article shall be limited to this geological period, and we leave it to others to go into the subject of the Echinoids from the Cretaceous or Tertiary periods. As a general remark let us first point out that regular sea urchins are much rarer than irregular ones and that sea urchins from the Jurassic are much rarer than those from the Cretaceous, not to mention those from the Tertiary period.

II. GEOLOGICAL FORMATIONS

American fossil collectors are well acquainted with the fossiliferous rocks of the Palaeozoic era, which provide fertile hunting grounds in the United States, but not so well with those of the Jurassic period. Therefore, we shall start with an outline of the geological formations.

The Jurassic period lasted about 60 million years (from 195 to 135 million years ago), but for all practical purposes you can expect to find fossil sea urchins in France and its neighboring countries only at the end of the Lower Jurassic (or Lias) and in greater numbers from the Middle Jurassic (or Dogger) onwards.

The Lower Jurassic, lasting for 20 million years, comprises the following stages: Hettangian, Sinemurian (or Lotharingian), Pliensbachian (or Charmoutian = Domerian + Carixian) and the Toarcian.

The Middle Jurassic lasted 25 million years (from 175 to 150 million years ago) and comprises the following stages: Aalenian (formerly placed in the Lower Jurassic), Bathonian, Bajocian and Callovian.

The Upper Jurassic (or Malm) covers only 15 million years and is subdivided into: Oxfordian, Kimmeridgian and Portlandian (the latter one in Southern France is called the Tithonian).

What is now defined as Oxfordian comprises 3 stages, which you still find named as Oxfordian, Rauracian and Sequanian.

The top part of the Portlandian is constituted by a facies of emergence named Purbeckian.

III. THE ECHINOIDS OF THE JURASSIC PERIOD

1. The Lower Jurassic (or Lias)

In the Lower Jurassic, fossil sea urchins are very rare and restricted to localized occurence only. We have never collected in these strata, but in old and recent collections we have mainly seen only fragments of "Cidaris" and some primitive regular sea urchins belonging to the genus Diademopsis.

2. The Middle Jurassic (or Dogger)

This period brings an abrupt change with the development of a rich variety of sea urchins in the fossil-bearing formations.

The main rock outcrops of this age are presently found along the cliffs of the Normandy beaches (Langrune, Luc-sur-Mer, ...) and further inland in the Normandy, as well as in the Boulonnais, the Ardennes and the Lorraine regions of France. They also occur in the French and Swiss Jura Mountains.

a. Collecting sites in the **Aalenian** are rare today and provide only a few species. In very restricted localities in Normandy and the Swiss Jura, Galeropygus agariciformis can be found.

b. The **Bajocian** is fossiliferous mainly in the cliffs north of Bayeux and in the Swiss Jura near Basle.

The outcrops in the Normandy cliffs are strictly protected sites today, as a result of unscrupulous exploitation by profit-seeking individuals. This is all the more regrettable since once they yielded Stomechinus bigranularis, "Cidaris" honorinae or bajocensis and Pygorhytis ringens.

In Switzerland you mostly find Pygorhytis ringens.

c. The **Bathonian** is mainly fossiliferous in the Boulonnais region (around Boulogne-sur-Mer), in Normandy (around Caen), in the Ardennes (near Hirson) and in Lorraine (around Nancy), as well as in the Swiss and French Jura Mountains (near Basle and Belfort).

This is the great era of Acrosalenia and Hemicidaris. Today you find Hemicidaris mainly in the Normandy cliffs, near Luc-sur-Mer and Langrune, and very rarely in the other regions. The main species are: Hemicidaris luciensis (the larger one with fewer granules) and langrunensis (the smaller one with more granules). There are other species of Hemicidaris indicated (like grimaultensis, icaunensis, ...) which we consider to be just varieties.

The Acrosalenia on the other hand are almost exlusively found in the Boulonnais area (and in the Swiss Jura). They represent a large variety of species and sub-species. We have recently revised this group and considerably reduced the number of species. According to this study, the Boulonnais region offers Acrosalenia spinosa and hemicidaroides (with the varieties pustulata, lamarcki = wiltoni, bradfordensis and marioni).

In the Swiss Jura you can find Acrosalenia spinosa and hemicidaroides sensu stricto.

Any reader interested in more detail may order this Revision of the Acrosalenia (in French) from the author.

Along with Acrosalenia and Hemicidaris, but much rarer, other regular sea urchins can be found in Normandy, the Boulonnais area and the Swiss Jura, such as: Gymnocidaris pustulata, koechlini, Acrocidaris striata, Stomechinus serratus, Polycyphus normannus, Polydiadema depressum, Diplopodia pentagonum, Cidaropsis minor and the occasional fragment of "Cidaris" babeaui.

The irregular sea urchins become abundant in the Bathonian, and everyone knows the famous Clypeus ploti, which today is mainly found in Lorraine, since almost all other localities have disappeared. The genus Clypeus comprises numerous other species, most of which are probably only varieties. As bona fide species Clypeus hugi and agassizi would remain.

In all Bathonian localities, however, Holectypus depressus, different species of Nucleolites (woodwardi, griesbachi, amplus, clunicularis, triangularis, elongatus, orbicularis) and more rarely Pygaster laganoides and Pygurus depressus can be found.

Specific sites have yielded Hyboclypus gibberulus and (or) Pygomalus (ex Collyrites) ovalis and analis.

d. **The Callovian** formations are rich in fossils in the Sarthe region (south of Alençon on the accompanying map). Here you find mainly irregular sea urchins with Collyrites elliptica as the most common species, followed by Holectypus depressus, Pygurus depressus and orbicularis and other representatives of Collyrites (dorsalis, bicordata) and different species of Nucleolites (goldfussi, pulvinatus).

Among the much rarer regular ones, the small Polydiadema inaequale is undoubtedly the most frequent, while Pedina gervilii and davousti, Stomechinus serratus and pyramidatus, Acrosalenia (?) radians, Hemicidaris langrunensis and rare specimens of "Cidaris" (difficult to identify: microstoma or desnoyeri) and spines of Rhabdocidaris copeoides may also be encountered.

Switzerland provides us with a beautiful small regular one: Hemipedina granulata.

3. The Upper Jurassic (or Malm)

a. The **Oxfordian** offers the best chances for the Echinoid collector in Normandy (near Honfleur on the map), in all of the eastern outcrops in France (from Auxerre to St. Mihiel) and in the Jura Mountains (from Belley to Montbéliard) as well as in the Ardèche region (near Crussol).

Among the regular Echinoids, the most common ones, depending on the particular locality, are Hemicidaris intermedius or Glypticus hieroglyphus. They are accompanied by a well-diversified fauna of sea urchins which increases in variety the more you go towards the South, that is towards the ancient tropical ocean named "Thetys Sea".

Different species of Cidaris were prominent here, and are in high demand by today's collectors from around the world. They are rightfully highly prized since they are so hard to come by. In association with corals (that is, in deposits formed at low depth) you find: Paracidaris florigemma, blumenbachi and Plegiocidaris cervicalis. In deposits without corals (that meant living at greater depths): Paracidaris laeviscula, alpina, filograna.

In these formations are also encountered: Rhabdocidaris princeps, Diplocidaris gigantea and etaloni, Acrosalenia angularis, Hemicidaris crenularis, Gymnocidaris agassizi and lestocquii, Hessotiara florescens, Hemitiaris stramonium, Pseudosalenia aspera, Pseudodiadema pseudodiadema and orbignyanum, Acrocidaris nobilis, Polydiadema mammilanum (and other species), Diplopodia versipora, Phymosoma supracorallinum, Phymechinus mirabilis, Stomechinus perlatus and gyratus, Pedina sublaevis.

Irregular sea urchins are rare in the coral reef deposits: you might, however, find Pygaster umbrella and gresslyi, Pygurus icaunensis and Nucleolites scutatus.

In environments without corals the irregular ones occur more frequently, and along with those just cited you also meet Pygomalus bicordata, acuta and conica.

b. The **Kimmeridgian** offers best hunting grounds in the area of La Rochelle (Le Chay), in Normandy (Le Hâvre) and in the Swiss Jura (near Neufchâtel). In other areas fossil sea urchins are much rarer.

For once the most frequent Echinoid is a Cidaris (!): Plegiocidaris marginata (which also occurs in Southern Germany). The coronas have frequently fallen apart or are deformed, but with good luck you can also come across a perfect one. In Switzerland this species is absent and is replaced langrunensis and rare specimens of "Cidaris" (difficult to identify: microstoma or desnoyeri) and spines of Rhabdocidaris copeoides may also be encountered.

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The members of the Cidaris family are accompanied by one of the most diversified Echinoid faunas, consisting mostly of regular sea urchins: Paracidaris florigemma, blumenbachi and poucheti, Diplocidaris giganteus, Pedina sublaevis, Phalacropedina guerangueri, Orthopsis saemani, Acrosalenia angularis, Pseudosalenia aspera, Hemicidaris intermedius, Hessotiara florescens, Pseudocidaris mammosa and pulchella, Gymnocidaris agassizi, Acrocidaris nobilis, Pseudodiadema orbignyanum, Polydiadema mammilanum and ariovense, Diplopodia planissimum, Cyphosoma supracorallinum, Phymechinus mirabilis, Stomechinus perlatus, Polycyphus distinctus, Magnosia decorata, Acropeltis aequituberculata, Goniopygus pilleti... Some of these are extremely rare, others occur more frequently.

In association with these the following irregular ones have been found: Holectypus coralinus, Pygaster gresslyi and umbrella, Pygaster macrocyphus, Pygurus jurensis and blumenbachi, Nucleolites cf. scutatus and Dysaster granulosus.

Once again, the irregular ones are more abundant in deposits without corals.

c. The only fossiliferous sites in the **Portlandian** (from the point of view of the Echinoid collector) are in the Boulonnais area.

Here you find first of all Hemicidaris purbeckensis (accompanied by numerous varieties or sub-species, some of which are extremely rare: glasvillei, pellati, equihensis, morinicum) and "Acrosalenia" koenigi, which in our opinion is only a very peculiar Hemicidaris. Much rarer are Polydiadema thirriai, Diplopodia planissimum, Polycidaris legayi, Cyphosoma legayi, Nucleolites haimii and brodiei.

IV. COLLECTING CONDITIONS, PREPARATION AND CONSERVATION OF JURASSIC ECHINOIDS

In France, fossil sea urchins can be found in four different types of collecting sites: Cliffs along the sea shore (where you go on fossil hunts in winter time, when there is no cover of algae), abandoned quarries or those still in operation (which require prior authorisation by owners or operators), plowed fields in winter (provided the farmer lets you walk across his property, which is not always the case) and finally, sediments of rivers or brooks.

The bedrock of fossil-bearing strata is normally too hard and the frequency in which you could expect to find a fossil sea urchin is too low to permit digging or amateur mining operations with reasonable chances of success. Therefore, most of the time you have to content yourself with surface collecting.

In most cases the fossil sea urchins are embedded in a matrix consisting of a mix of calcite ($CaCO_3$) and argilaceous components. To begin with, the specimen must be roughly worked out of the matrix with small chisels and steel needles. Then you place small dry pellets of Potassium hydroxide (KOH) on the wetted sea urchin. This extremely hygroscopic and aggressive chemical dissolves the argilaceous components of the matrix but does not attack the calcite of the tests. After this treatment you have to water the cleaned specimens for several weeks to remove all traces of the KOH. Then you soak the specimen in mineral oil to give it back its luster. This method gives excellent results in appropriate cases (ideally a marlstone matrix), but it may take several months to complete, because of the long rincing and watering periods.

The accompanying maps of France and its neighboring countries are taken from: J.C. Fischer, 1980, "Fossiles de France et des régions limitrophes", Published by Masson, Paris. We heartily recommend the purchase of this book (in French) to all those interested in a global summary of the fossils in France and by extension in Western Europe.

The photographs show some fossil sea urchins from the Bathonian of the Boulonnais region and the collection of the Museum of Boulogne-sur-Mer.

Clypeus ploti, seen from above to show the petals and the anal groove. Diameter of the specimen: 10 cm.

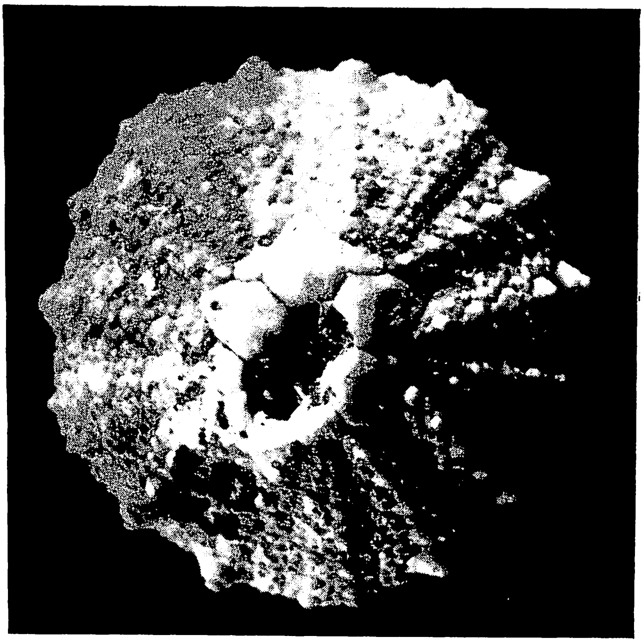
Acrosalenia spinosa, seen from above. Note the numerous interambulacral tubercles and the large apical system in which the central suranal plate is missing. Diameter of the specimen: 12,5 mm.

Acrosalenia hemicidaroides with its apical system. Note the sparse granulation. Diameter: 33 mm.

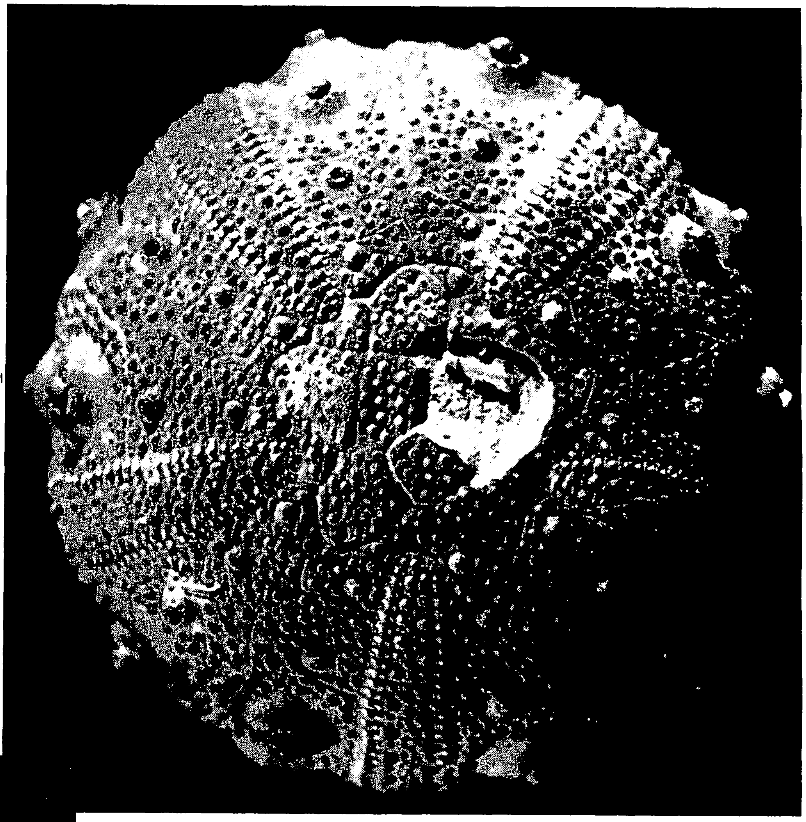
Acrosalenia hemicidaroides var. pustulata, note the rich granulation. Diameter: 22,5 mm. (This specimen was figured by Cotteau in the "Paléontologie Française").

Acrosalenia hemicidaroides var. wiltoni=lamarcki, seen in profile to show the minute ambulacral tubercles. Diameter: 23,5 mm.

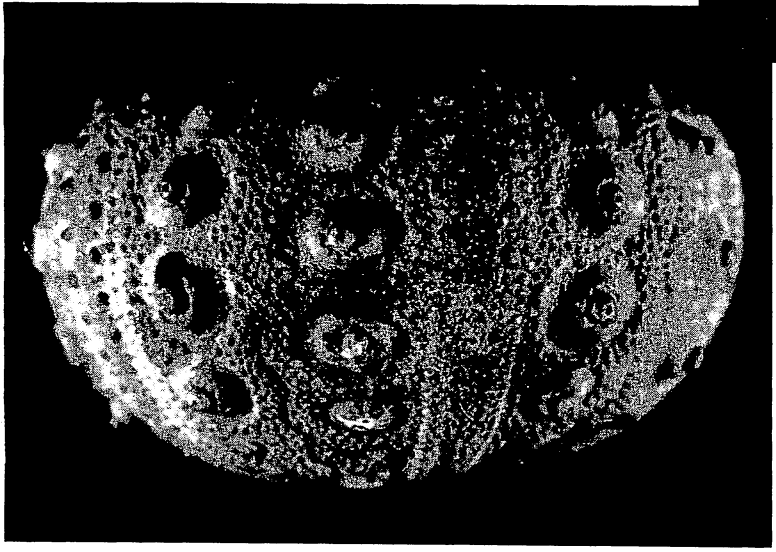
For those who read German there is a magnificent modern book on fossil sea urchins, star fishes and crinoides from the Swiss Jura Mountains: Hans Hess, "Die fossilen Echinodermen des Schweizer Juras", published by Natural History Museum of Basle, Augustinerstraße 2, CH-4051 Basle, Switzerland.



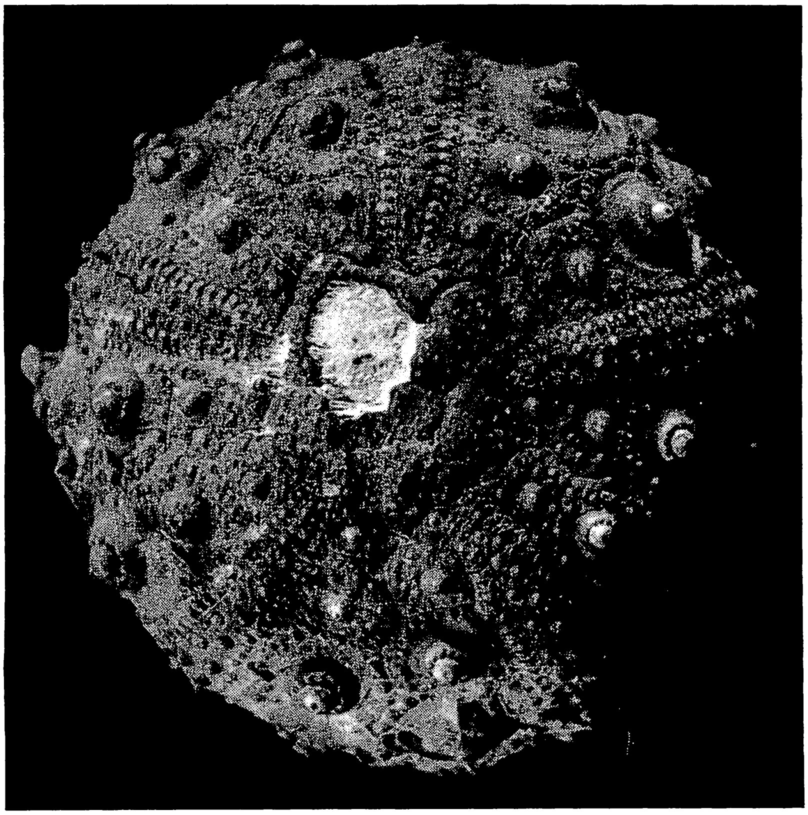
Acrosalenia spinosa



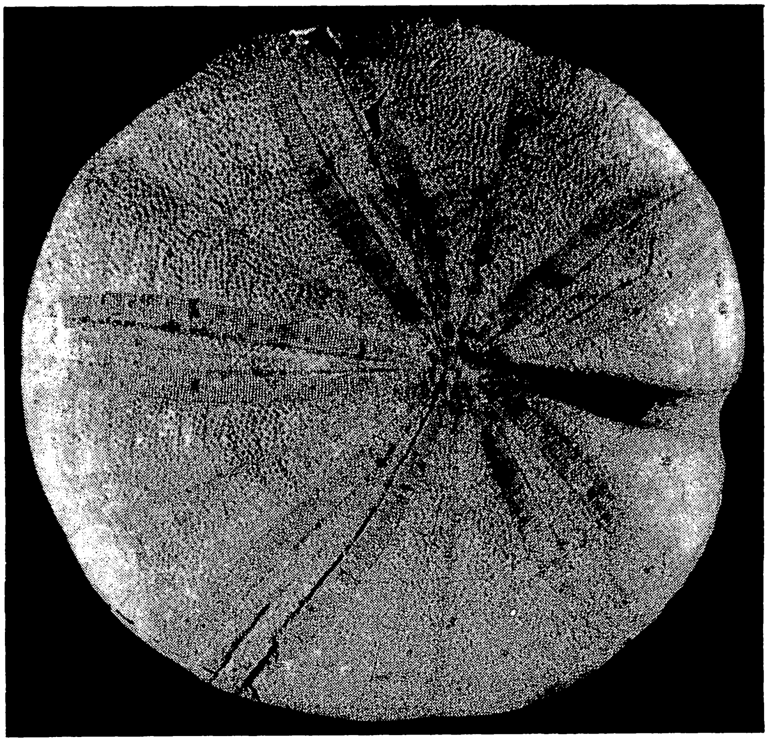
Acrosalenia hemicidaroides var. pustulata



Acrosalenia hemicidaroides var. wiltoni=lamarcki



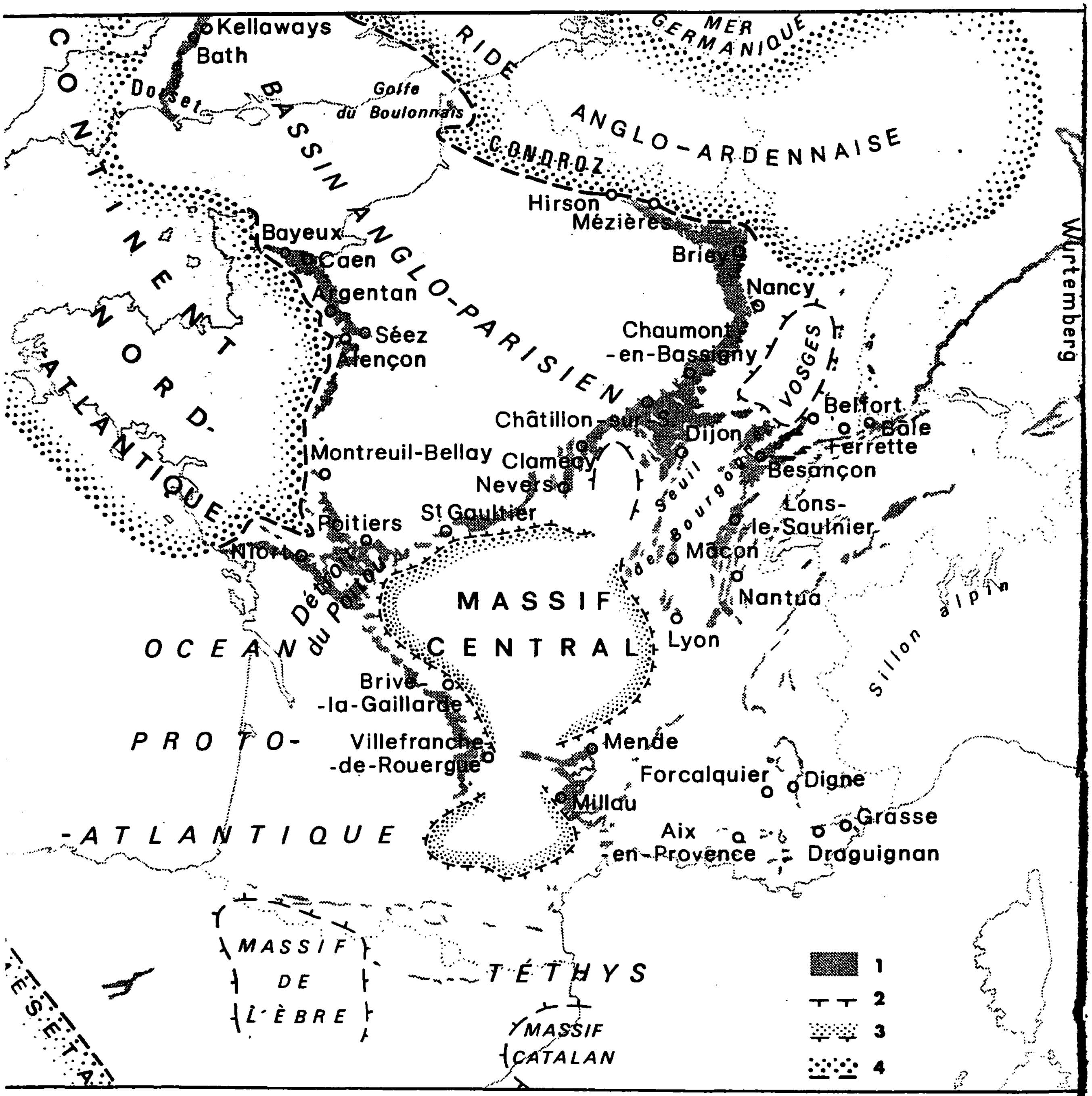
A. lamarcki



Clypeus ploti

Middle Jurassic

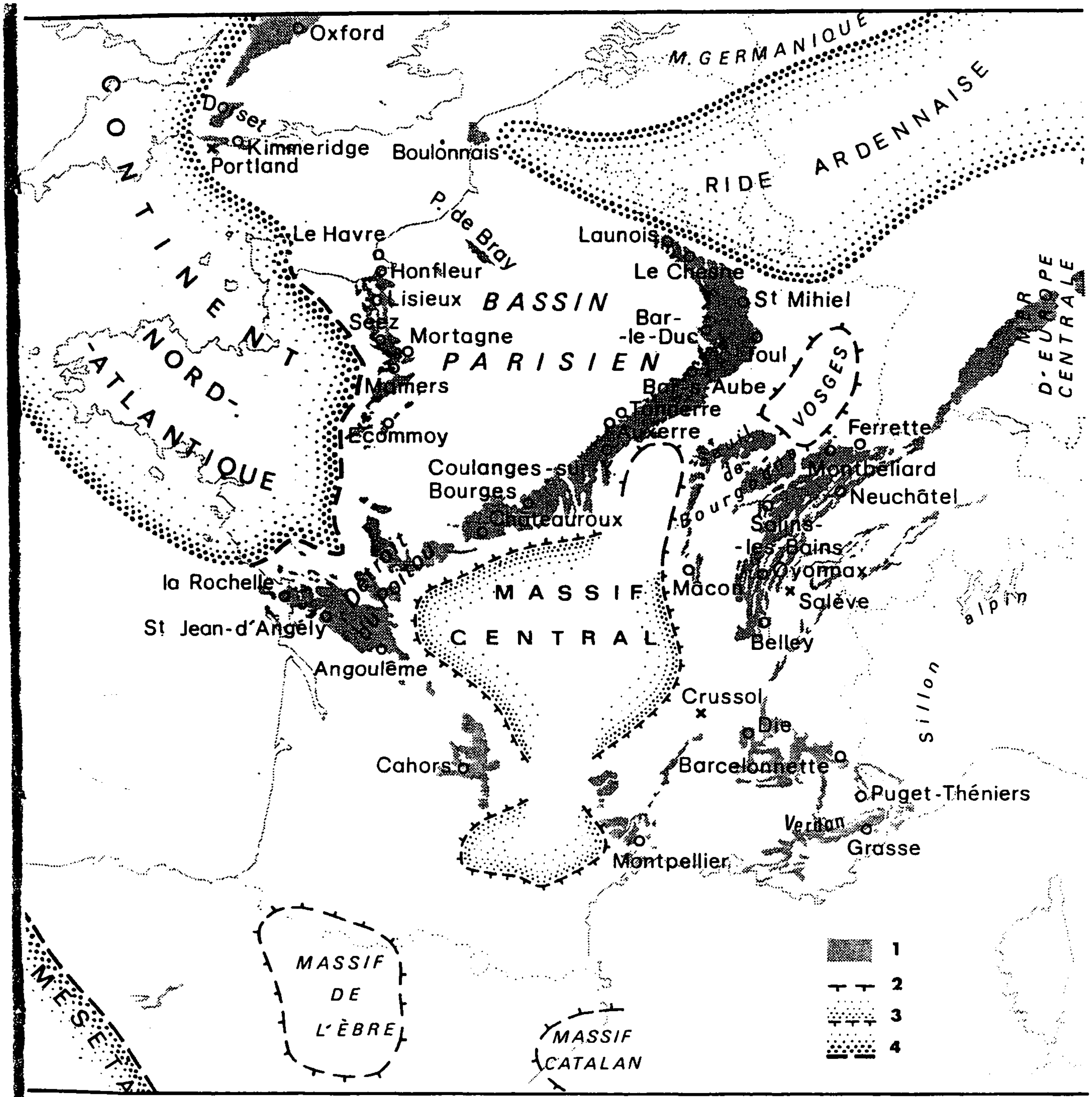
1. Main outcrops 2. Zones of high grounds 3. Mountain massifs which were temporarily somewhat emerged 4. Probable limits of the seas during the Bathonian age.



Jurassique moyen
1. Principaux affleurements – 2. Zones de hauts fonds – 3. Massifs pouvant avoir été temporairement et faiblement émergés – 4. Limites probables de l'extension des mers au Bathonien.

Upper Jurassic

1. Main outcrops 2. Zones of high grounds 3. Mountain massifs which were temporarily somewhat everged 4. Probable limits of the maximum extension of the seas during the Upper Jurassic period.



Jurassique supérieur

1. Principaux affleurements – 2. Zones de hauts fonds – 3. Massifs pouvant avoir été temporairement émergés – 4. Limites probables de l'extension maximum des mers au Jurassique supérieur.

A CRETACEOUS ECHINOID WITH FALSE TEETH

Porter M. Kier

(The following article is printed in this issue of MAPS DIGEST with gracious permission of Dr. Michael Bassett, National Museum of Wales.)

[Palaeontology, Vol. 12, Part 3, 1969, pp. 488-493, pls. 93,94.]

Abstract. The teeth described in 1911 in a specimen of **Conulus subrotundus** Mantell from the Turonian Middle Chalk are from a Recent echinoid. No lantern was present in adults in **Conulus** or probably in other members of the families Conulidae Lambert or Galeritidae Gray. The structures previously thought to be lantern support structures (auricles) are considered to be related in function to the large buccal plates. Instead of being degenerating structures as previously thought, they increase in size in later species.

Although echinoid workers generally have not become very aroused in their controversies, two subjects have caused considerable heat: the question whether **Bothriocidaris** was an echinoid (now resolved in the affirmative), and wheter or not **Conulus** had teeth. **Conulus** is one of the better-known and more 'popular' echinoid genera in Europe because of its abundant occurrence in the Chalk. It was assumed that it was toothed because it is an holectypoid, and most holectypoids have teeth. Forbes (1850 p. 3) described and figured what he considered to be teeth and jaws in **Conulus** and subsequent authors (see Hawkins, 1911, p. 70 for a complete history) accepted his opinion until Duncan (1884, p. 11) in a paper considered to be dogmatic by those opposed to his views, disagreed with the previous workers and contended that the objects they thought to be jaws were imaginary, or merely grooves made by a tool in the soft matrix within the peristome. After this strong rebuttal the proponents for a lantern retreated and most subsequent workers until 1911 accepted that it was lanternless. However, Hawkins (1911, p. 71) found a specimen of **Conulus subrotundus** Mantell, in the British Museum with four teeth protruding from its peristome. He was unable to find any jaws. Since this time it has been assumed by all echinoid workers that **Conulus** and the rest of the genera of the families Conulidae Lambert and Galeritidae Gray had jaws and teeth when adults.

As part of a study of the lantern in echinoids, I was particularly anxious to see a lantern in **Conulus** and dissected hundreds of specimens of **C. albogalerus** Leske. This is a relatively easy task with an air abrasive machine because of the soft chalk matrix. However, no fragments of a lantern or teeth were found in any of them. Inasmuch as the peristome is very small in diameter, bits of the lantern would have been expected to have been retained in the test. Furthermore, I dissected a specimen of **C. albogalerus** in which all the buccal plates were still preserved in place but there were no fragments of a lantern. These plates have been found on only a handful of the thousands of specimens of this species that have been collected. Obviously the slightest movement of the specimen after death caused these plates to become separated, and if a lantern had been present in this specimen it would be expected that parts of it would still be there. Hawkins also dissected hundreds of **C. albogalerus** and never found any lantern fragments. But the teeth in the specimen of **C. subrotundus** described by Hawkins were positive evidence that could not be ignored. It could not be assumed that four teeth were washed into a specimen all with their tips extending outward. But if it had teeth, why were no pyramids preserved? Hawkins noted that it would not be possible for the pyramids to slip out through the small peristome and have the teeth remain. He suggested that perhaps the pyramids were noncalcified--a conclusion with which he was not satisfied but could suggest no other alternative. Restudy of this specimen has revealed the solution to this dilemma--the teeth do not belong to the specimen. Some person excavated a cavity inside the peristome and inserted four Recent teeth mixed with some cement into the cavity.

The following evidence indicates that the teeth did not belong to the echinoid:

1. The matrix around the teeth is much softer than the matrix in the rest of the test. This difference was readily apparent when the air abrasive machine was used. The machine had very little effect on the area away from the peristome but one blast of abrasive in the area around the teeth removed considerable matrix. As is well known to anyone who has worked with chalk fossils, the matrix in Middle Chalk specimens is commonly quite hard as opposed to Upper Chalk specimens. The matrix in this specimen is typical of the Middle Chalk except in the cavity where the teeth lie. Here it is not only very soft and crumbly but also much coarser (Pl. 93, fig. 5) in texture. Dr. Maurice Black, an authority on chalk, examined this material and concluded that it was not chalk. Only a few coccoliths were visible and he suggested that these had probably come from the adjacent chalk matrix. He surmised that this material around the teeth was probably some type of cement (perhaps dental). A.G. Brighton, curator of the Sedgwick Museum, Cambridge, reports (personal communication, 1968) that there have been many chalk 'fossils' faked by individuals anxious to sell specimens to museums, or interested collectors. Commonly, the hoaxer mixes up a matrix of crushed chalk or lime, and some type of cement and inserts into it a Recent specimen and then offers it for sale as a 'perfectly preserved Cretaceous fossil with color markings.'.

After hearing about this forgery in **Conulus**, Peter J. Moulds of Queen Mary College, London, examined some specimens of Chalk echinoids which had been puzzling him and discovered that at least two of them are forgeries. According to his letter to me (1968): 'one block of chalk with several spines enclosed had an entirely different test added later. This test had been sawed in half in order to fit to the block! I suppose the main reason for these forgeries was to increase the interest and thus the value (financial that is--many of the museum specimens have their original price on them).'

2. The quality of the preservation of the teeth indicates that they are from a Recent echinoid and not fossil. All the teeth have a glistening, porcellanous sheed (Pl. 94, fig. 1) which I have never seen to this extent in a

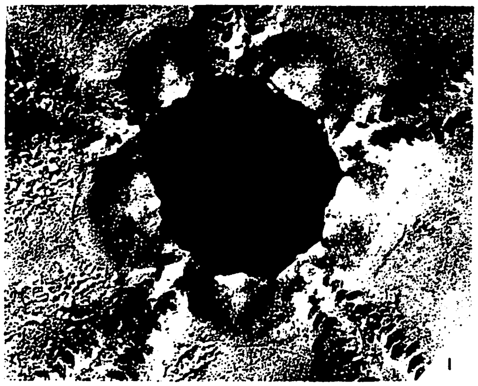
fossil tooth. Although a slight sheen may rarely be preserved on an extremely well-preserved fossil tooth, it is never as pronounced as on these teeth. Furthermore, the open meshwork of the microstructure of the tooth is not permineralized as it would be in a fossil (pl. 93, fig. 4). The open interstices in the tooth are normally filled with secondary calcite in a fossil tooth but in this specimen they are not. Furthermore, the upper part of the teeth are soft and fibrous with the asbestos-like structure found in a Recent tooth but never in a fossil.

The teeth are too small for a carbon-14 analysis, but Dr. Kenneth Towe pointed out that Weber and Raup (1968, p. 42) have shown that skeletal magnesium is lost early in diagenesis and that Recent echinoids therefore have a higher magnesium carbonate content than fossil ones. Dr. Towe suggested that if these teeth were Recent, they should contain a larger amount of $MgCO_3$ than the rest of the fossil. He analyzed (using X-ray diffraction) a portion of one of the teeth, part of the test of a **Conulus subrotundus**, and for comparison purposes a Recent tooth, and a tooth known for certain to have come from a Chalk species, **Phymosoma koenigi** (Mantell). The fragment of the test of **C. subrotundus** and the tooth from **P. konigi** contained no $MgCO_3$, whereas the tooth of the Recent echinoid contained 6-8 mol per cent $MgCO_3$ and the tooth from the **Conulus** contained 3-4 mol per cent. The fact that the **Conulus** tooth contained $MgCO_3$ and the specimen from which it was supposed to have come contained none indicates that the tooth is not from the **Conulus**.

3. The fact that all the teeth are broken and that all these broken ends are on the ends of the tooth in the matrix must arouse considerable suspicion as to their authenticity. It is very doubtful that any natural forces could break the inner ends of all four teeth and still permit their outer ends to protrude unbroken from the echinoid test. Echinoid teeth are quite strong and any force which broke all of them would surely disassociate them enough so they would not all remain with their tips still protruding out the peristome. Probably the hoaxer, in order to avoid drilling a much deeper hole into the test, simply broke part of each tooth and inserted the broken ends into the hole.

4. The teeth themselves are unlike any found before in an irregular echinoid. Their keels are far too narrow and sharp. Hawkins (1911, p. 72) stated that the teeth were very like those found in **Camerogalerus cylindricus** (Lamarck), but the tooth of **Cam. cylindrisus** has a much broader keel, tapering from the edge of the keel to the sides of the tooth, whereas the teeth in the **Conulus** have the sides of the keel parallel to each other. Although, Durham and Melville (1957, text-fig. 1B) show a narrow sharp keel in **Holectypus depressus** (Leske) I have made further preparations of the specimen they figured and have found that the tooth has a broad keel very much like that in **Pygaster** as described by Melville (1961). I know of no irregular echinoid tooth resembling the teeth attributed to **Conulus**.

Palaeontology, Vol. 12 PLATE 93



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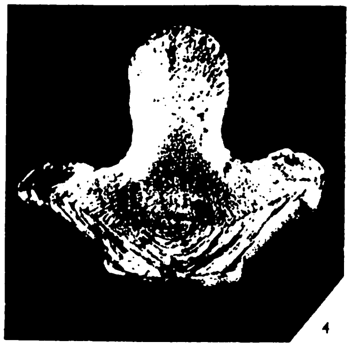

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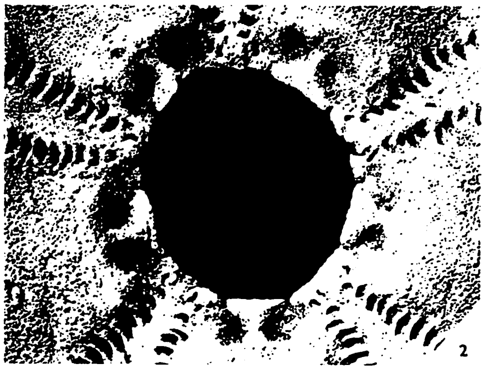

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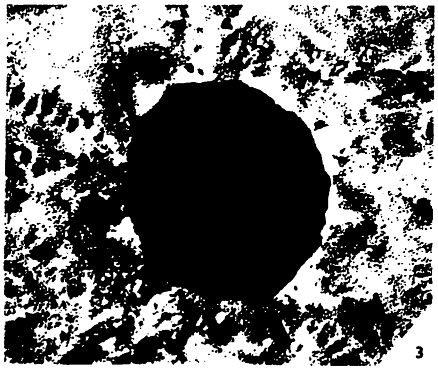


3

6

KIER, Cretaceous echinoid with false teeth

EXPLANATION OF PLATE 93

Figs. 1–3. View of the interior region around the peristome in three species of *Conulus* showing the thickened basicoronal plates which have been considered to be auricles. The pictures are arranged stratigraphically with the earliest species, *Conulus castanea* (Brongniart) from the Cenomanian at the base (fig. 3), the Turonian *C. subrotundus* Mantell in the middle (fig. 2) and the latest, the Senonian *C. albogalerus*, at the top (fig. 1). Note that the structures formerly considered to be auricles are more pronounced in *C. albogalerus* than in the older species contradicting the assumption that these structures are degenerating lantern supports. 1, *Conulus albogalerus* Leske, Upper Chalk, Gravesend, Sedgwick Museum B. 3623, Kent, × 8. 2, *Conulus subrotundus* Mantell, Middle Chalk, *Orbirhynchia cuvieri* zone, Hitchin, Herts., Sedgwick Museum B. 408, × 10. 3, *Conulus castanea* (Brongniart), Bed 13 Meyer, Beer Head, Devon, Sedgwick Museum B. 7577, × 13.

Fig. 4. Section through tooth considered to be Recent but found in specimen of *Conulus subrotundus* figured in fig. 6. Note the microstructure which is normally visible on a Recent tooth but not on a fossil, × 37.

Figs. 5, 6. *Conulus subrotundus* Mantell. Specimen which H. L. Hawkins found in the British Museum (Natural History) with four teeth protruding from the peristome. He cut the specimen in half and excavated the area around the peristome but found no fragments of a lantern. Note the coarser matrix around the teeth. Label for specimen, B.M. E 10743, only states Upper Chalk which is presumably an error because this species is known only in the Middle Chalk. Fig. 5, × 6·5; fig. 6, × 2.

5. When Hawkins first saw the specimen he noted that someone had enlarged the peristome by cutting. Presumably, he thought that this enlarging was done in an effort to expose the teeth, but probably the hoaxer was unable to fit all the teeth in the small peristome and just widened it enough to accommodate them--which might also explain why he inserted only four teeth.

6. The presence of teeth but absence of any of the numerous parts of the jaws is nearly impossible to explain. The peristome of **Conulus** is so small in diameter that the jaws could hardly have slipped out around the teeth without the teeth slipping out also. Commonly, the teeth are the first to slip out of the test after the echinoid dies. They are connected to the jaws by far less tissue (they must be able to move down the dental slide as the echinoid grows) than the pyramids are to each other. I have found very few teeth in comparison to the number of jaws during my excavations of fossil echinoids, and I have never found teeth without there also being part of the jaws.

The only direct evidence of a lantern in **Conulus** was the presence of the teeth described above. Now that they are shown to be fraudulent we must examine again the problem as to whether **Conulus**, and for that matter any of the members of the Conulidae or Galeritidae, had a lantern. Recent workers (Hawkins 1911, 1917, 1934, Mortensen 1948, p. 43, Wagner and Durham 1966, p. 455) have considered that the thickened structures (Pl. 93, figs. 1-3) in the interambulacra at the edge of the peristome were auricles (lantern support structures). Although Hawkins's illustration (1917, pl. 28, fig. 1, reproduced in the Treatise, Wagner and Durham 1966, fig. 331, 4c) does depict a structure strongly resembling auricles, this figure is highly stylized and gives a misleading impression of the structure. In this figure the auricle-like features are exaggerated.

Although the thickened basicoronal plates do resemble auricles or apophyses, they differ from them in an important character. Auricles or apophyses consist of processes which rise upward from the basicoronal ambulacral or interambulacral plates. These tabs may be thick or thin but invariably they rise far above the general level of the basicoronal plates. No such tabs are present in **Conulus**. Although minute knobs are present on the edge of the thickened basicoronal plates in large specimens of some species of **Conulus**, they are absent from most species and are far too small to be considered as auricles.

Many workers including Hawkins (1911, p. 72) have considered that the 'auricles' in **Conulus** were degenerate structures and that their lack of strong development resulted from the fact that the lantern and its supporting structures were gradually being lost through time. If this were the case it would be expected that these 'auricles' would be less pronounced in succeeding species, but just the opposite is the case. This thickening of the basicoronal plates becomes more pronounced in later species. The earliest **Conulus** in which I have been able to expose the interior is **C. castanea** (Brongniart) from the Cenomanian. The basicoronal plates are slightly thickened (Pl. 93, fig. 3) and two slight depressions are present in each of these thickened interambulacra. In the Turonian **C. subrotundus** Mantell the interambulacral plates are more thickened (Pl. 93, fig. 2) the paired depressions deeper and the angle of their faces greater. Finally in the Senonian **C. albogalerus** Leske all these features (Pl. 93, fig. 1) are even more pronouced. Therefore, this thickening cannot be considered a degenerating character.

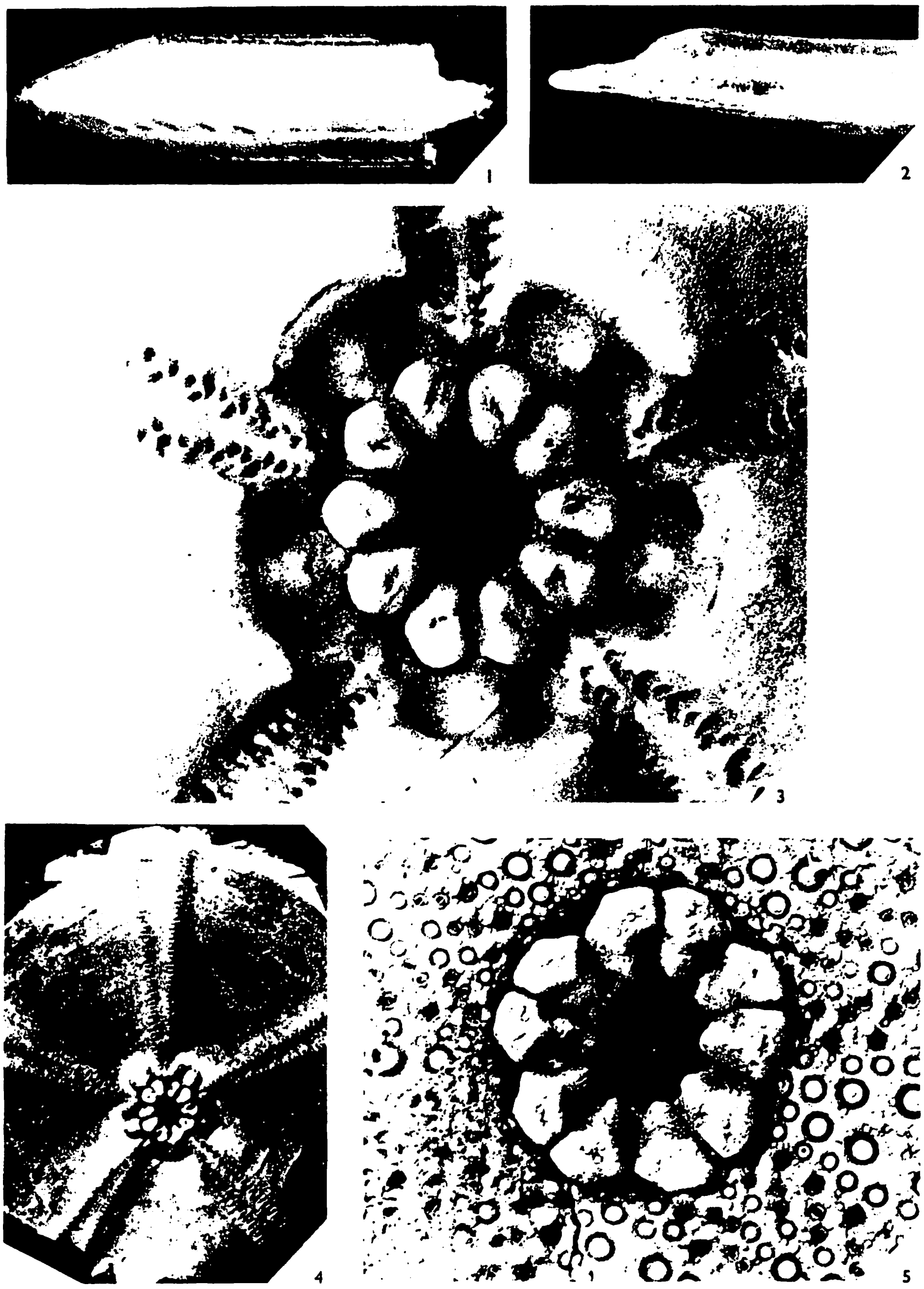
The position and character of these structures suggest that they are related to the function of the ten plates around the peristome which are considered to be buccal plates. These plates are interpreted as buccal plates rather than basicoronal plates because they are not attached to the rest of the test by normal sutural tissue as is indicated by their absence in most specimens (they have only been found in **C. albogalerus** but presumably were present in the other species of **Conulus**) and their loose connection of those few specimens where they are found. Furthermore, the plates which precede them have the arrangement and number characteristic of basicoronal plates, with a single plate in each interambulacrum, and the ambulacral plates and their pores arranged according to Loven's law. Finally, these basicoronal plates have their edges curved inward with their tubercles facing the peristomial opening.

The plates are very thick and large in **C. albogalerus** (Pl. 94, figs. 3-5) and could have their origin in the large buccal plates normally found in a regular echinoid or be derived from the secondary buccal plates found in irregulars. The primary buccal plates of regular echinoids have large buccal tubefeet whereas tubefeet are absent from the secondary buccal plates of irregular echinoids. The absence of pores in the **Conulus** buccal plates indicates that they probably are derived from these secondary plates. Although some authors (Mortensen 1948, p. 38) thought pores were present in these plates because of the presence of pits on the interior of the plates. These pits (Pl. 94, fig. 3) are shallow and do not penetrate to the exterior.

Hawkins suggested that the 'auricles' may have been slots into which the buccal plates were retracted. However, the exterior of the buccal plates has tubercles, presumably for spines or pedicellariae, which probably would have prohibited the sliding of these plates back into the peristomial opening. Furthermore, the buccal plates curve interiorly over the edge of the peristome almost in a joint which would make impossible their sliding back over the edge of the peristome.

It is apparent, however, that there is some relation between the 'auricles' and the buccal plates. The ten depressions in the thickened interambulacral plates are directly behind the ten buccal plates. I agree with Hawkins that the pits on the interior of the buccal plates are for the insertion of muscles and suspect that the deep depressions of the 'auricles' were where these muscles were attached to the test. Perhaps the buccal plates functioned as teeth, pushing food into the gut. The thickening of the basicoronal plates would be necessary not only to provide a properly angled face for attachment of these muscles, but also would strengthen these plates so that a large stress could be exerted on them when the muscles contracted.

Palaeontology, Vol. 12 PLATE 94



KIER, Cretaceous echinoid with false teeth

EXPLANATION OF PLATE 94

Figs. 1–2. Views of two of the teeth, believed to be Recent, from specimen of *Conulus subrotundus* Mantell figured on Plate 93, figs. 5, 6. Note the glistening porcellanous sheen and the fibrous microstructure which are typical of a Recent tooth but never so well preserved on a fossil, ×16.

Figs. 3–5. *Conulus albogalerus* Leske. 3, Interior view of area around peristome showing the buccal plates and the deep depressions in the thickened basicoronal interambulacral plates which may have served for the attachment of muscles leading to buccal plates. The small pits on the buccal plates do not pass through the plates and were probably for the insertion of these muscles, ×10. 4, View of same specimen less enlarged, ×2. 5, Exterior view of same specimen showing buccal plates and the small tubercles for the attachment of spines or pedicellariae, ×10. BM E 33079, Senonian, *Micraster coranguinum* zone, Northfleet, England.

SUMMARY

There is no direct evidence that **Conulus** or any member of the Conulidae or Galeritidae had a lantern when adult. Excavation of hundreds of specimens of **Conulus** has revealed no fragments of a lantern. The teeth described by Hawkins are shown to be Recent and the Fragment that he considered to be part of a pyramid, he later suggested was a piece of a pelecypod. The structures considered to be auricles were probably related functionally to the large massive buccal plates which occur immediately oral to them. The obliquity of the peristomial opening in many species of **Conulus** and its relatives is further evidence that no lantern was present in the adult. All echinoids having a lantern have a symmetrically shaped peristome.

Acknowledgements. This study was carried out under a Guggenheim Fellowship at the Sedgwick Museum, Cambridge. I thank Professor H. B. Whittington for making the facilities of the Museum available to me, and A.G. Brighton and Maurice Black for their advice. Dr. R.P.S. Jefferies, Curator of Fossil Echinoderms at the British Museum (Natural History), very kindly lent me specimens of **Conulus**. J. Wyatt Durham and Richard E. Grant reviewed the manuscript and made several very useful suggestions. Kenneth Towe not only pointed out the value of making a magnesium carbonate analyses of the tooth, but also made the analyses.

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AUSTRALIAN TERTIARY ECHINOIDS

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A BRIEF REVIEW OF AUSTRALIAN TERTIARY ECHINOIDS

by Frank Holmes, Secretary, Fossil Collectors' Assoc.of Australasia.

The history of fossil echinoids in Australia extends back at least to the early Devonian, although few species have been recorded from the Mesozoic or Paleozoic formations. In fact the only truly Mesozoic irregular echinoid described to date, *Hemiaster sweeti* (Etheridge) of Cretaceous (Aptian) age, was found nearly a century ago in a quarry at Maryborough, Queensland (Fig.1, Loc.1), over 900 miles north-east of the main Tertiary echinoid deposits of southern Australia.

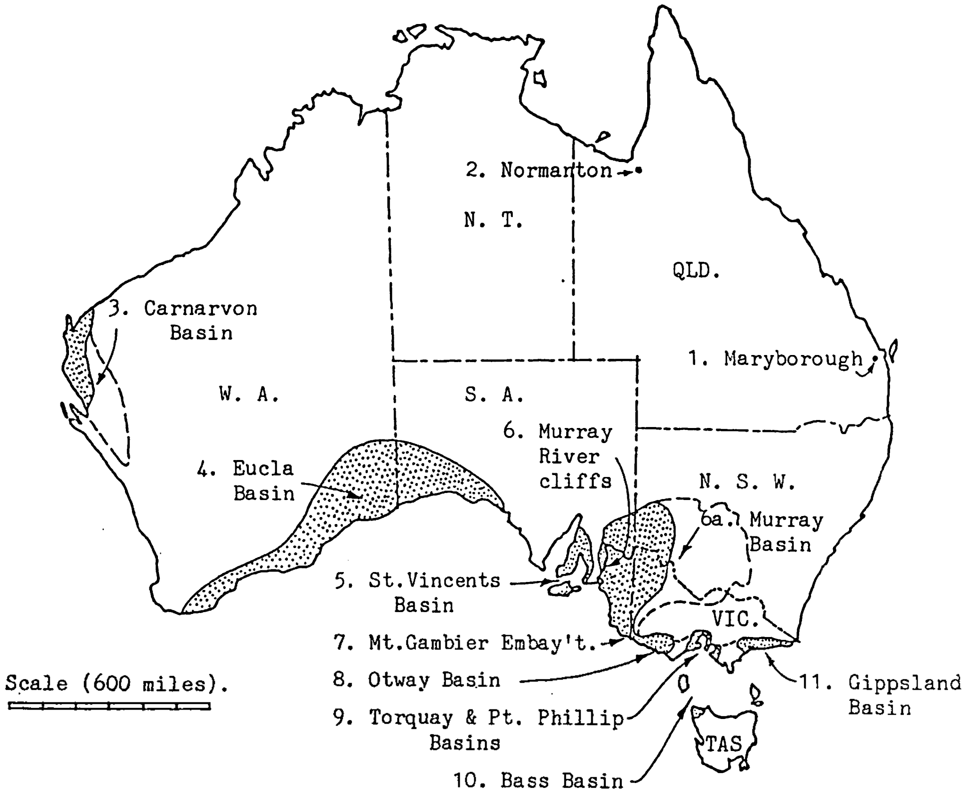

Fig. 1. Distribution of the main marine Tertiary sedimentary basins in Australia in which fossil Echinoids are known.

While considerable areas of the Australian continent were inundated by the sea during the Cretaceous, particularly in Western Australia and central and northern Queensland, it is quite surprising that other irregular echinoids do not appear to have been found, or if found, recorded and described.

It is not as if these marine Cretaceous deposits are devoid of fossils, as there are many known localities where ammonites, belemnites and other molluscs are quite common.

For the above reason, this article is limited to a generalised review of the Australian Tertiary fossil echinoids, with the emphasis on irregular species, the fauna with which the author is more familiar.

Although the explorer Captain Charles Sturt included drawings of three echinoids from the calciferous sandstone of the River Murray cliffs (Fig.1, Loc 6) in his book "Two Expeditions into the Interior of

A BRIEF REVIEW OF AUSTRALIAN TERTIARY ECHINOIDS (Cont.)

southern Australia", published in 1834; the first major paper on Australian Tertiary echinoids was written by Dr. G.C. Laube in 1869. In this paper, "Ueber einige fossile Echiniden von den Murray Cliffs in Süd Australien", Laube described the clypeasteroid genus Monostychia (Fig.2), which is unique to the Oligocene/Miocene of southern Australia.

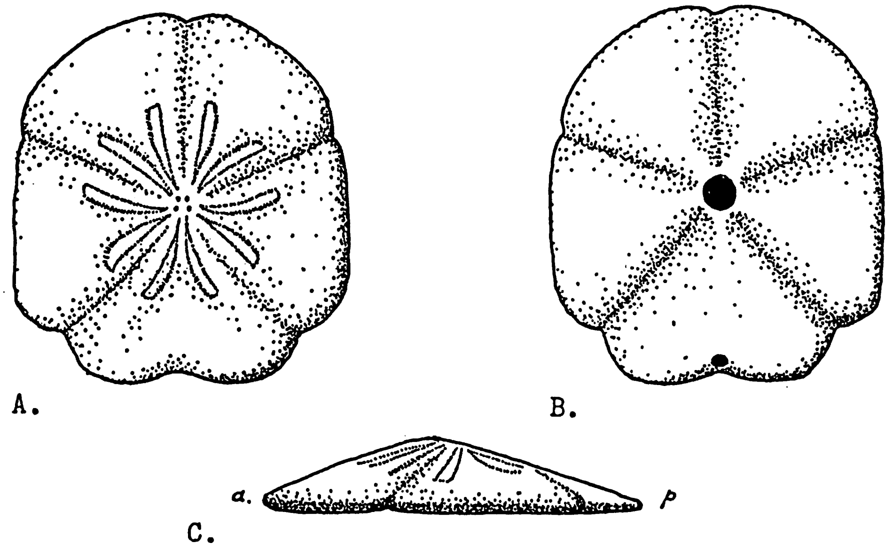

Fig. 2. Monostychia australis Laube. A, adapical view, B, Adoral view, C, lateral view, all x 1. Specimen from Mannum Fm. (Lower Miocene), Murray River cliffs, north of Swan Reach, Sth. Aust.

Between the 1870's and the turn of the century, a large volume of literature was published on Australian palaeontology including many papers on the echinoid fauna by such men as Duncan, McCoy, Etheridge, Tate, Gregory and Bittner. While much of the original nomenclature given to these early discoveries has been changed over the years, often because of the poor preservation of detail in many of the originally described specimens, the work of these men forms an invaluable basis for the current revision of most major families and genera found in Australia.

Between 1910 and the early 1960's, work on Tertiary echinoids was virtually non existent. Even H.L. Clark's 1946 "The echinoderm fauna of Australia; its composition and its origin", relies almost entirely on pre 1900 literature for its information on fossil species. It is only in the last twenty years or so that palaeontologists such as Foster, Kruse, McNamara and Philip have begun to systematically update the literature. Recent papers cover the revision of Australian Tertiary species of Echinolampas, Eupatagus Pericosmus, Protenaster and brissid echinoids amongst others. In addition between 1963 and 1969 G.M. Philip recorded 53 species of regular echinoids in a series of four papers on the "Tertiary echinoids of south-eastern Australia".

Although the section of the "Treatise of Invertebrate Paleontology" that deals with echinoids (Part U, Echinodermata 3) was written over 20 years ago, before most of the work mentioned above was published; a review of the listed genera of irregular echinoids excluding neolampadoids (see later note), shows a strong predominance of clypeastorid and spatangoid species within Australian Tertiary deposits, as can be seen from the following figures :-

A BRIEF REVIEW OF AUSTRALIAN TERTIARY ECHINOIDS (Cont.)

HOLECTYPOIDS	Genera listed in Treatise	30,	known from Australia	2	(6.6%)
CLYPEASTEROIDS	" " "	73,	" " "	11	(15%)
CASSIDULOIDS	" " "	69,	" " "	6	(8.6%)
HOLASTEROIDS	" " "	81,	" " "	3	(3.7%)
SPATANGOIDS	" " "	147,	" " "	18	(12.2%)
NEOLAMPADOIDS	" " "	7,	" " "	2	(28.6%)

As there has been no relevant bibliography published in this Country since 1946, let alone a comprehensive list of known species, the above figures must be subject to some degree of error.

However, even with changes in classification and description of new species, the overall picture remains basically the same. The percentage shown for Neolampadoids gives a very false picture in terms of the fossil record, as the two known Australian genera listed in the 1966 Treatise, namely *Notolampas* and *Pisolampas*, were at that time the only recorded fossil genera of this group in the world.

FIGURE 1, shows the distribution of the main marine Tertiary sedimentary basins in Australia from which fossil echinoids are known. These deposits are generally marginal to the southern coast of the continent, unlike their Cretaceous equivalents which covered vast areas of inland Australia. While these Tertiary sequences are discontinuous and somewhat fragmentary; there is, with the exception of the western Carnarvon Basin (Loc.3), a considerable amount of overlap in faunal occurrences between the basins (Loc's.4 to 11).

The most important echinoid deposits are associated with the marine transgressions that reached a maximum in the Oligocene and early Miocene and are generally attributable to the gradual subsidence of the southern edge of the continent after the final separation of Australia from Antarctica in the late Paleocene/early Eocene - about 55 million years ago.

In the following pages, each of the major Tertiary basins containing such deposits are listed together with a brief account of their general location, age and significance in the overall fossil record with which we are concerned.

CARNARVON BASIN

Deposits in the Carnarvon Basin in Western Australia (Loc.3) are predominantly older than those along the southern coast and contain surface outcrops of late Cretaceous age. In 1978 Foster and Philip erected a new genus of holasterid echinoids from the Giralia Range of this basin, one species of which, *Giraliaster jubileensis*, while being abundant in the middle and late Paleocene has its earliest occurrence in the Maastrichtian Miria Marl. Previously the four species in this genus had been placed in the genus *Cardiaster*.

Other genera recorded from the Carnarvon Basin include *Cardabia*(related to *Corystus*),*Echinocorys* and *Schizaster*.

EUCLA BASIN

The Eucla Basin (Loc.4), which extends for approximately 1,000 miles along the western part of the southern continent, contains an important echinoid fauna varying in age between the middle/late Eocene and early Miocene.

A BRIEF REVIEW OF AUSTRALIAN TERTIARY ECHINOIDS (Cont.)

Eucla Basin cont.

Because of the isolation of this semi-arid part of the continent from major towns and the problems of access once off the major east-west highway; detailed information on the distribution of echinoid species is difficult to obtain, although many species found in this Basin are recorded from other localities in southeastern Australia, in particular the St. Vincent Basin (Loc.5), which also contains distinctive late Eocene echinoids.

Species found in the middle to late Eocene, Wilson Bluff Limestone of the Eucla Basin, include *Australanthus longianus*, *Corystus dysasteroides* (Fig.3), *Echinolampas posterocrassa*, *Gillechinus cudmorei* (formerly *Brissopatagus*), *Protenaster preaustralis* and the salenioid *Salenida tertiaria* amongst others. Most of the genera from the early Miocene Abrakurriel Limestone of this Basin can be found elsewhere in sediments of equivalent age and lithology, particularly the Murray and Otway Basins, (Loc's 6 & 8). Forms such as *Lovenia forbesi*; *Eupatagus murrayensis*, *Scutellinoides patella* and the regular echinoid *Ortholophus woodsi* being amongst the most common.

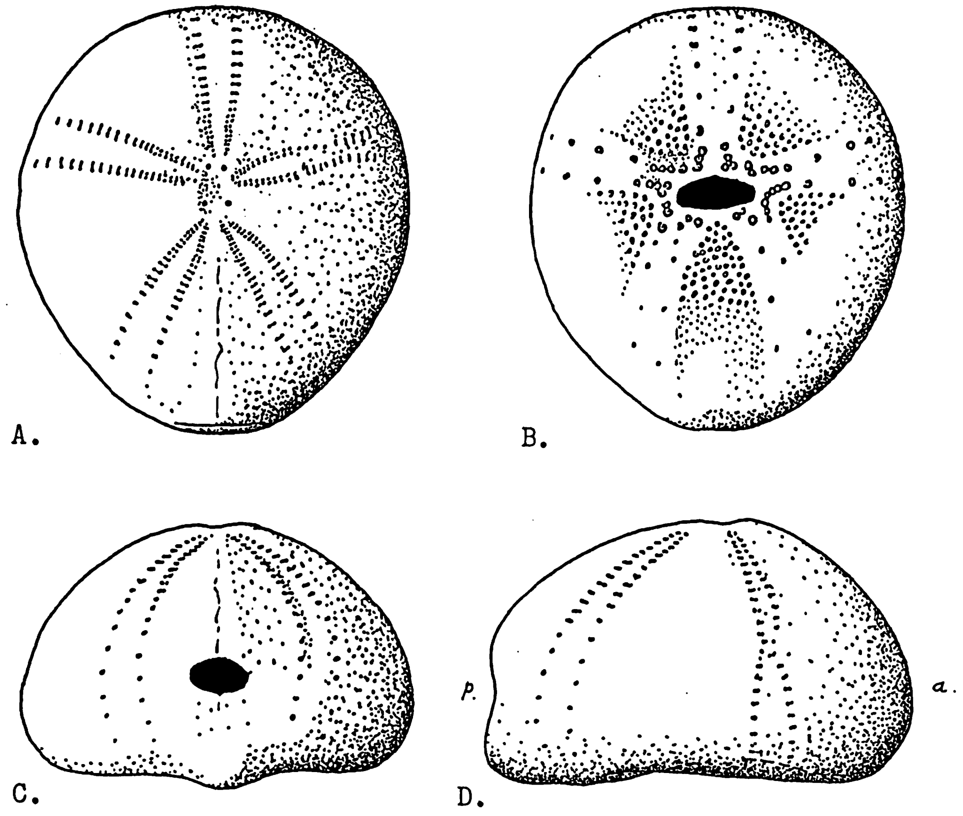

Fig. 3. *Corystus dysasteroides* (Duncan). A, adapical view, B, adoral view, C, posterior view, D, lateral view, all x 1. Specimen from Point Addis Limestone (Upper Oligocene), Aireys Inlet, Victoria.

A BRIEF REVIEW OF AUSTRALIAN TERTIARY ECHINOIDS (Cont.)

ST. VINCENT BASIN

Unlike the Eucla Basin, the St. Vincent Basin contains a continuous sequence of marine deposition from the beginning of the late Eocene through to the middle Miocene. A wide range of echinoids can be found within this sequence which outcrops along the coast of St.Vincent Gulf between 20 and 25 miles south-east of the South Australian State Capital of Adelaide. Other important, but less frequented outcrops occur on the coast of Yorke Peninsula, just over two hours drive from the City, and at Kingscote on Kangaroo Island. The echinoid fauna in this latter deposit is late Eocene in age, and contains large specimens of Australanthus longianus up to 8 cms (3" +) long and Fibularia gregata up to 1.5 cms (½" +) long. Unfortunately the Kingscote Limestone in which the specimens are found is almost impossible to remove without serious damage to the fossils. Like so many Australian localities, unless the specimens have been weathered out of the rock by natural means, they are extremely difficult to prepare.

MURRAY BASIN

Forty miles due east of Adelaide lies the town of Mannum. Situated on the Murray River, it is ideally located as a base for excursions along the cliffs and gullys that border much of the lower section of the river (Loc.6). The Murray Basin itself (Loc.6a) is over 450 miles wide in an east-west direction and extends way into the centre of New South Wales and Victoria. However, exposure of its vast echinoid beds is virtually restricted to the river cliffs and adjacent areas in South Australia. Although, like the other southern basins the initial marine deposition began in the middle to late Eocene, outcropping of the echinoid rich beds is confined almost entirely to two formations; the Mannum Formation and the Morgan Limestone. These range from the earliest Miocene through to an unconformity at the end of the early middle Miocene when the sea made its first regression from the Basin. A list based only on material cited in recent literature shows that at least 41 species (including 11 regular forms) from 28 genera have been recorded from these two formations. Of these, 7 species appear to be confined purely to the more recent Morgan Formation with another 8 common to both.

By far the most abundant echinoid found in the Mannum area is the spatangoid Lovenia forbesi (Fig.4). Other commond forms are Eupatagus murrayensis - one of six species of this genus recorded in the Murray Basin; Fibularia gregata - usually fairly small; Monostychia australis - specimens over 4 cms (1½") rarely found whole (Fig.2); Scutellinoides patella; and the regular Ortholophus woodsi. Forms not previously mentioned in this article which are not uncommon in the Mannum Formation are Cyclaster archeri - a large brissid; Echinolampas ovulum; Studeria elegans - a cassiduloid; and the regular Paradoxechinus novus.

MOUNT GAMBIER EMBAYMENT AND OTWAY BASIN

During part of the Tertiary the S.W. corner of the Murray Basin was linked to the Mt. Gâmbier Embayment of the Otway Basin (Loc's 7 & 8). With the exception of areas around Mt. Gambier, a town near the border between South Australia and Victoria, most of the accessible outcrops containing echinoids are restricted to the coastal cliffs, large areas of the Otway Basin in western Victoria being covered by Pliocene to Recent volcanics.

A BRIEF REVIEW OF AUSTRALIAN TERTIARY ECHINOIDS (Cont.)

MOUNT GAMBIER EMBAYMENT & OTWAY BASIN (Cont.)

Unlike the Mannum Formation, outcrops within the Mt. Gambier Embayment ranges from late Eocene right through the Oligocene to the early Miocene and consequently contains a number of species not found along the Murray River cliffs such as Granobrissoides australia.

At Portland in the Victorian section of the Otway Basin large numbers of Lovenia are found well preserved in a friable limestone believed to be of early Pliocene age. These are currently assigned to Lovenia woodsi but are now considered to be sufficiently different to justify the erection of a new species (McNamara, pers.comm.).

TORQUAY & PORT PHILLIP BASINS

The accessible outcrops of the Torquay & Port Phillip Basins (Loc.9) occur primarily along the coastal cliffs to the south-east of Melbourne, the Victorian State Capital, and on the eastern side of Port Phillip Bay, a large inland expanse of water linked to the ocean by a narrow channel less than 2 miles wide. Although three of the main lithologies that make up the Torquay Basin (the Point Addis Limestone, Waurn Ponds Limestone and the main Jan Juc Formation), are of the same Oligocene age, each support quite a different echinoid fauna. Cassidulus florescens, a species quite common in the Point Addis Limestone is very rare if not entirely absent from the other beds. On the other hand Corystus dysasteroides (Fig.3), and Willungaster spp., although not abundant, are found throughout the Oligocene of the Torquay Basin irrespective of lithology. From this it would appear they were not too particular about the sediment in which they lived. Other interesting species that occur in these two basins are the spatangoids Pericosmus maccoyi and Waunia nelsoni (Torquay Basin) and Victoriaster gigas (Pt. Phillip Basin). One specimen of the latter early middle Miocene species housed in the Museum of Victoria measures a staggering 21 cms (8¼") in length.

The Port Phillip Basin is probably best known among echinoid collectors for the abundance of the echinoid Lovenia woodsi that occur in the cliffs at Beaumaris, a suburb 12 miles south of the centre of Melbourne. This species is of latest Miocene age and differs in several ways (see Fig.4) from L. forbesi, the common species of the Murray Basin.

BASS BASIN

Between mainland Australia and Tasmania lies the predominantly offshore Bass Basin (Loc.10). Outcrops which are restricted to the N.W. corner of Tasmania and the islands of Bass Strait are of little importance as far as echinoids are concerned although a rich molluscan fauna is recorded from the late Oligocene-early Miocene sequence.

GIPPSLAND BASIN

The last of the main marine Tertiary sedimentary basins, the Gippsland Basin in eastern Victoria (Loc.11), is renowned for the occurrence of the large clypeasteroid Clypeaster gippslandicus which can be found in the cliffs and banks of the rivers and other waterways that surround the Gippsland Lakes just over 150 miles from Melbourne.

A BRIEF REVIEW OF AUSTRALIAN TERTIARY ECHINOIDS (Cont.)

GIPPSLAND BASIN (Cont.)

This middle Miocene echinoid is not confined to the Gippsland Basin, being recorded from both the Murray and Otway Basins, although it is quite rare in these latter areas.

The final regression phase in the early Pliocene of the Gippsland Basin is marked by the occurrence of *Fellaster incisa* a species of the Arachnoididae family.

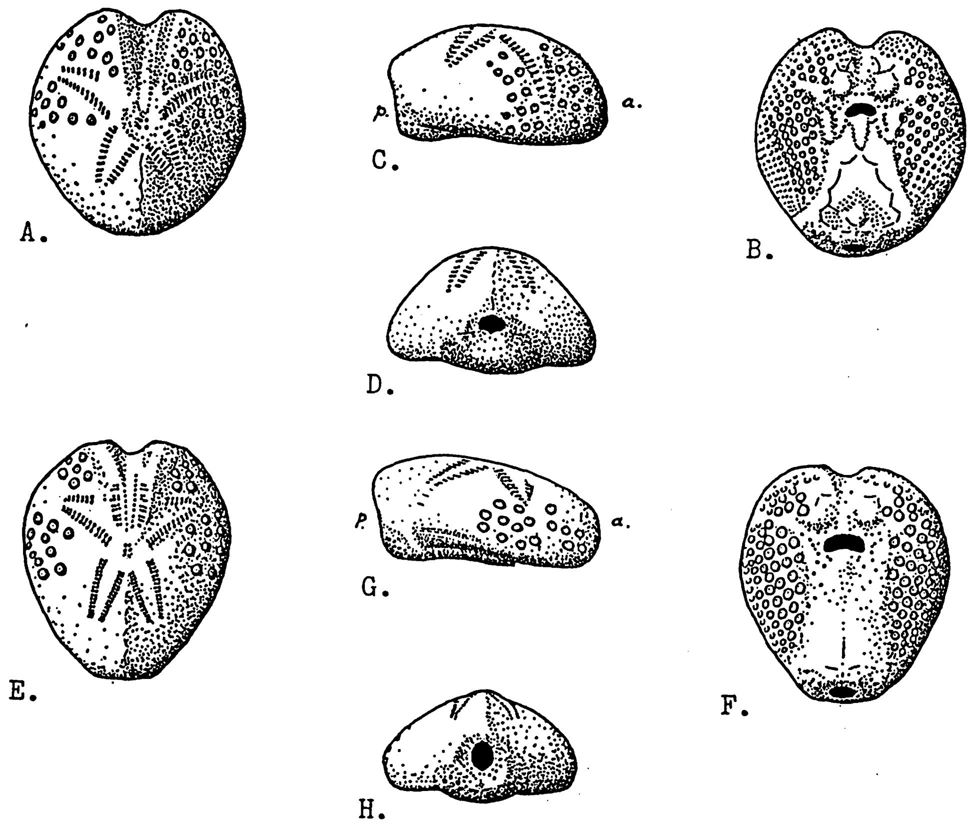

Fig. 4. *Lovenia woodsi* (Etheridge). A, adapical view, B, adoral view, C, lateral view, D, posterior view, all x 1. Drawing based on specimens from Black Rock Sandstone (Upper Miocene), Beaumaris, Victoria.
Lovenia forbesi (Woods & Duncan). E, adapical view, F, adoral view, G, lateral view, H, posterior view, all x 1. Drawing based on specimens from Mannum Fm. (Lower Miocene), Mannum, South Australia.

In conclusion, it is not possible in an article such as this to list all the recorded species of echinoids from the Tertiary of Australia, even if such information was readily available. A rough calculation indicates in excess of 140 species of both regular and irregular forms have been described to date. Nevertheless, even if distance between deposits and general inaccessibility of many localities are ignored; it would be difficult for the average collector to find and identify more than about 40 species.

In addition for the sake of brevity, details of the various lithologies, geological formations, exact localities, and reference literature could not be included.

A BRIEF REVIEW OF AUSTRALIAN TERTIARY ECHINOIDS (Cont.)

Finally, a brief comment on the origin of Australian Tertiary echinoids:

Early researchers such as Clark (1946), Mortensen (1951), and Fell (1952), generally believed in an Indo-Pacific origin, with migration via the Indo-Malayan archipelago or its Tertiary equivalents. However, these hypotheses do not appear to have taken into account what we now know was the global position of this continent during the late Cretaceous and early Tertiary; a fact which must favour a Gondwanaland origin for at least the earlier forms found in the S.W. of the continent with the possibility of later Indo-Pacific migrations during and after the Miocene.

NOTE: For the purpose of this article, the term Tertiary is deemed to exclude the Quaternary.

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HEMIASTER

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Hemiaster is a member of the phylum Echinodermata, order Spatangoida. Its age ranges from lower Cretaceous to Recent and is found widespread in North America.

Hemiaster is a heart-shaped urchin longer than wide (approximately 1½ inches long and 1 3/8-inches wide), highly domed with flat base and posterior margin truncated. The upper surface has four small petal-shaped ambulacra of unequal size; posterior petals small and close together; anterior petals longer and diverging forward. The fifth area is not petal-like, but is expanded to fill a shallow groove extending from center of upper surface of the skeleton to the mouth on lower surface. Two rows of tiny pores border each ambulacra and the fifth area. A narrow band of small bumps circles the ambulacra and crosses the fifth area. Other areas, except for ambulacra and their extensions, are covered with larger bumps. The area where the ambulacra come together is not directly opposite the kidney-shaped mouth, which is located on the base near the anterior margin.

Hemiaster is an irregular echinoid (Irregularia); the apical system is divided. The anus and periproct are located off center and to the rear, giving the crown right and left sides. The oculogenital ring remains at or near the center of the upper surface. It has one genital plate that is a sievelike madreporite through which water is taken into canals leading to the tube feet. The tube feet are used for sensing, feeding, locomotion, and respiration. The foot starts out as two sacs which send tubes through a pair of pores. The tubes then join and form a single organ. Tubercles served as attachments for delicate and silky spines that were held in place by ligaments and moved by cordlike muscles. These spines appeared on the ambulacral plates.

Hemiaster inhabited muddy or sandy bottoms where they crawled or burrowed.

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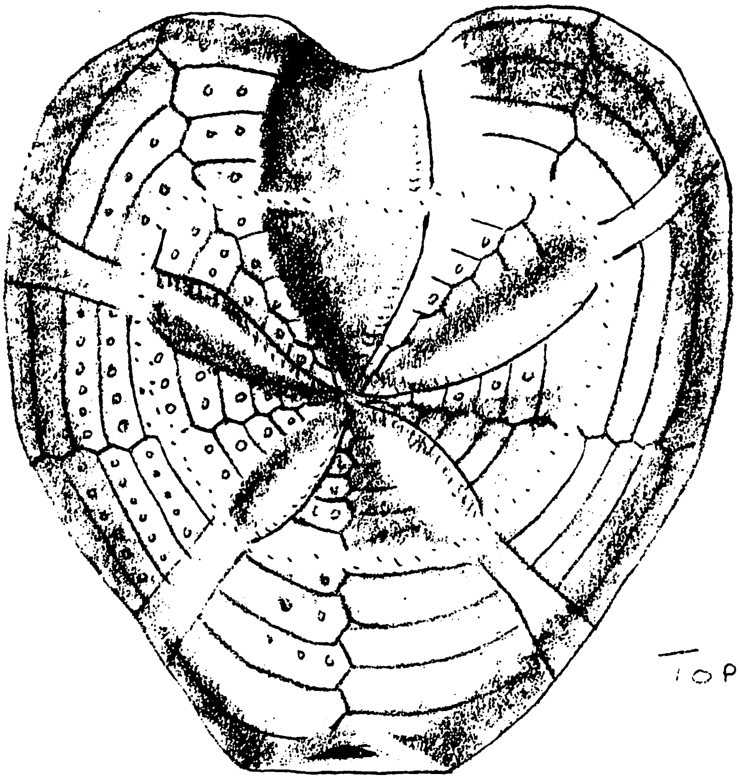
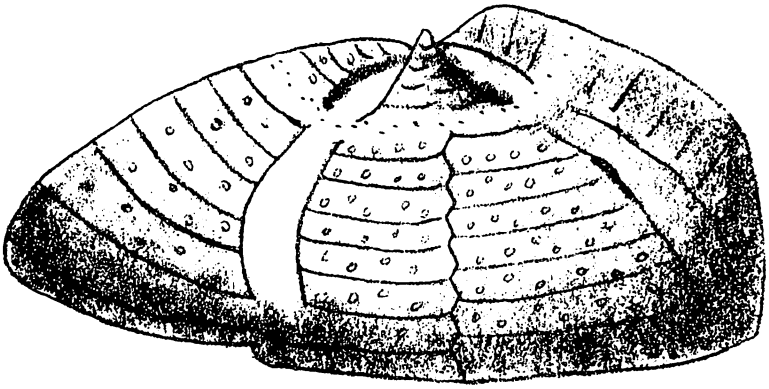
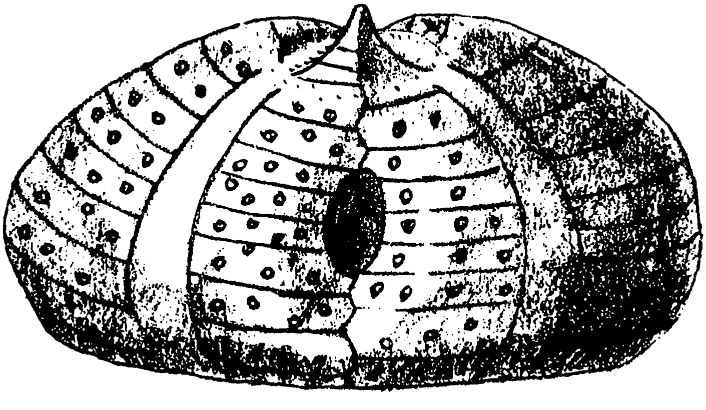


Top View



Side View



Posterior

Hemiaster texanus Roemer

A NEW ECHINODERMATA FROM NEW ZEALAND

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NATURE Vol 321 26 June 1986
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These days, there are not many places left where undiscovered species can stay hidden. During examination of echinoderms from a small crevice in a soggy piece of sunken wood collected from depths between 1,057 and 1,208 m off the New Zealand coast, (the authors) discovered nine specimens of a small flattened discoidal invertebrate. These animals, briefly described here, superficially resemble a cnidarian medusa, but their pentamerous morphology is distinctly echinoderm-like.

The authors consider that the features of these newly discovered echinoderms warrant the recognition of a new class. *Xyloplax medusiformis* n. gen. and n. sp, informally known as the sea daisy, represents a radical departure in morphology from any other known extant echinoderm. Its obvious tube feet, clearly pentamerous body pattern, and calcite skeleton leave no doubt that the animal is an echinoderm. However, its concentrically arranged skeletal structures and single series of tube feet arranged in a ring are novel. The water vascular system of *Xyloplax* consists of a double ring of canals which service the tube feet in inter-radial positions; in all other living echinoderms the vascular ring is single, and the tube feet are serviced from it in radial positions. These specimens represent the first new class of living echinoderms to be described since 1821.

Class Concentricycloidea nov.

Diagnosis: A free-living echinoderm characterized by a weakly inflated disk-shaped body, without mouth, anus or radiating arms. Its water vascular system, including tube feet, and supporting skeletal structures are arranged concentrically on the ventral surface. The water vascular canals form a double ring with inter-radial connections to the tube feet; the ventral surface is covered by a complete velum.

Etymology: *concentricua* and *cyclus* are Latin for 'concentric' and 'ring', respectively, alluding to the double water vascular ring and the concentric skeletal structures.

Order Peripodida nov.

Family Xyloplacidae nov.

Diagnosis: The same as for class.

Etymology: *peri* and *podos* are Greek for 'around' and 'foot', erferring to the nearly circumferential arrangement of tube feet.

Xyloplax n. gen.

Type species: *Xyloplax medusiformis* n. sp.

Diagnosis: Body medusiform, dorsally plated with peripheral, excavate spines and uniserial, nearly circumferential tube feet.

Xyloplax medusiformis n. sp.

Etymology: Xylos and plax are Greek for 'wood' and 'plate' and allude to the habitat and plating of this animal; Medusa and form are Latin and allude to the animal's superficial resemblance to a cnidarian medusa.

Another interesting feature of the new species is that it broods its young. This is not uncommon in starfish, but in the sea daisy, the five pairs of gonads contained embryos at all stages of development--up to small versions of the adult.

Thanks to:
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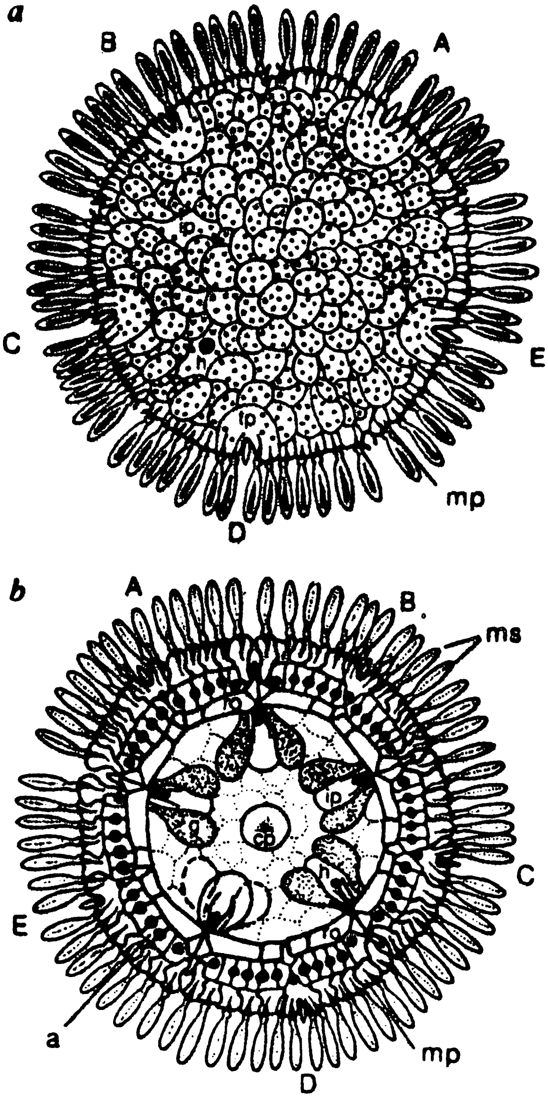
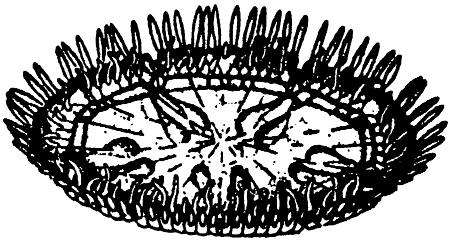
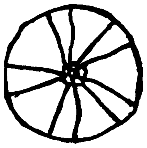
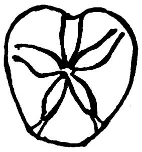
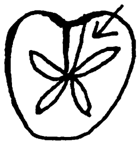
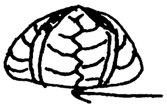
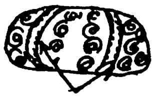
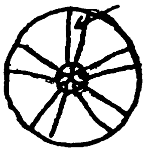
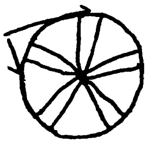
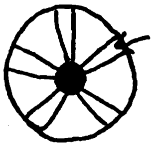
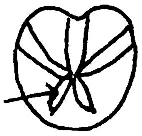
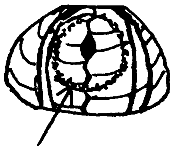
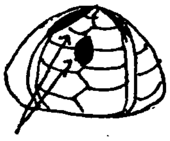
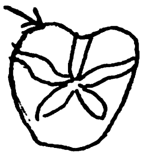
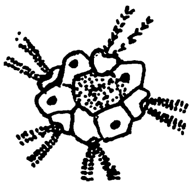
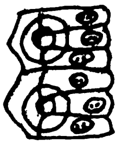
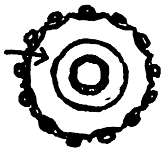
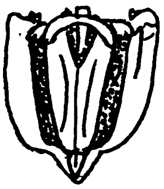
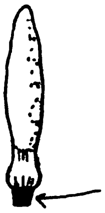
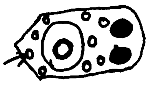
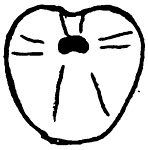
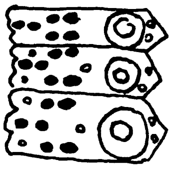
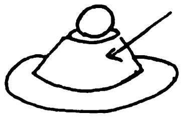
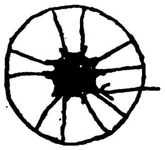
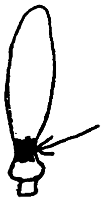
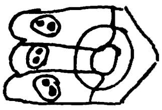
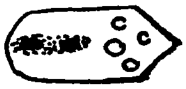
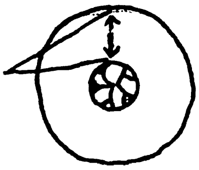


Fig. 2 Semi-diagrammatic representation of paratype NMNZ 4241 of *Xyloplax medusiformis* n.g. and n.sp. Dorsal (*a*) and ventral (*b*) views. Diameter 6.2 mm. A-E, radii; ip, Primary inter-radial plate; mp, marginal plate; tp, terminal plate; h, hydropore; ms, marginal spines; g, gonad; ro, ring ossicle; a, adambulacral plates. cp, central dorsal plate.

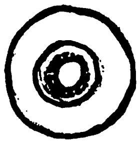


GLOSSARY OF TERMS

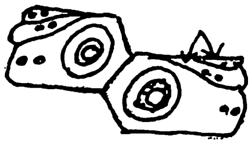
above (top)	-	Area of test encompassing the apical system.	 
aboral	-	Side opposite the mouth.	
adapical	-	Toward the apical system	
adoral	-	Toward the mouth.	
adradial	-	Boundry between amb and interamb.	
amb	-	Abbreviated for ambulacra.	
ambitus	-	Margin of test with greatest diameter.	
ambuclacra	-	Five parts of test extending from apical system to peristome alternating with interambuclacra. This segment of test and its pores are part of the water radial system.	 
anal fasciole	-	Groove around the periproct.	
anal plates	-	Paired interamb plates in contact with periproct of irregular echinoids.	
anterior	-	Toward amb III.	
apex	-	Highest part of the test.	
apical system	-	Area of test with ocular and genital plates.	

arbacioid compound plate	- Plate with three elements of which the adapical and adoral ones are demiplates.	
areole	- Scrobicule or depression around boss for attachment of muscles controlling movement of spines.	
Aristotle's lantern	- Similar to a lantern. Attached to inside of mouth for chewing.	
base	- Portion of spine below milled ring.	
bead	- Small tubercle.	
below (bottom)	- Surface of fossil with the peristome.	
biserial	- Two rows of pore pairs in each pore zone.	
boss	- Part of tubercle below mamelon shaped like truncated cone.	
bourrelete	- Bulging interambs near mouth.	
branchial	- Gill slits at the peristome.	
collar	- Smooth tapering portion of spine located above milled ring.	
compound plate	- Amb plate unit composed of two or more individual plates each with two pores for tube foot, bound together by single large primary tubercle.	
conjugate pores	- Pores of a pair connected by groove in the external surface of test.	
corona	- All amb and interamb.	

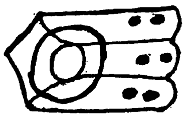
cortex - Differentiated dense outer layer of spines usually bearing ornamentation.



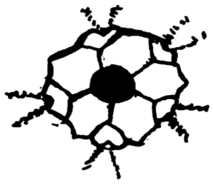
crenulate - Term to describe a tubercle or spine with ribbed edge.



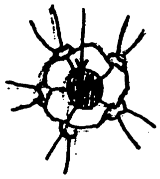
demiplate - Amb plate which touches interamb, but not inside amb suture.



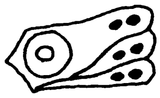
diadematoid compound plate - Amb plate with three primary parts of which the middle one is largest.



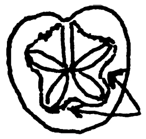
dicyclic - Apical system with ocular and genital plates in two concentric rings. Genitals in contact with the periproct.



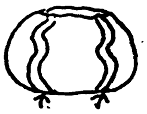
discal opening - Apical opening.



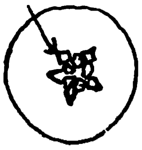
echinoid compound plate - Plate with three or more elements of which adoral and adapical ones are primaries the adoral one is largest.



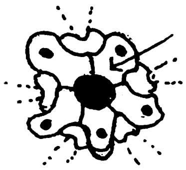
fasciole - Narrow band of small densly packed ciliated spines to create currents. On test often represented by a groove or band free of tubercles.



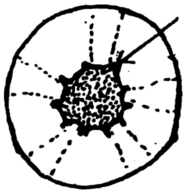
flexuous - Wavy.



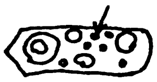
floselle - Star shaped area around peristome.



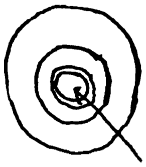
genital plates - Apical plates at the head of each interamb with zero or more pores for reproduction. Madreporite is a modified genital plate.



gill slit - Indentation of the peristome in interamb for passage of the external gill.

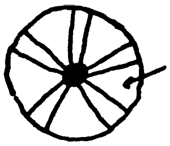


granule - Small tubercle.

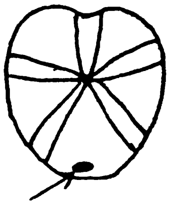


imperforate - No openning in tubercle.

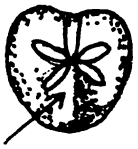
interambulacra (interamb) - Five segments of the test extending from apical system to peristome, alternating with amb.



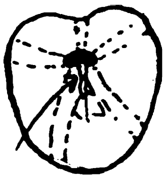
irregular echinoid - Test with periproct located outdside the oculogenital ring.



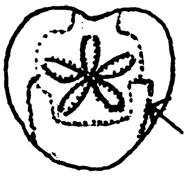
keel - Raised or ridged section of corona.



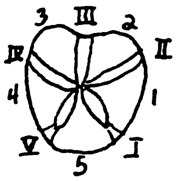
labrum - Somewhat enlarged, unpaired interamb plate at the rear end of the peristome.



lateral fasciole - Groove or band free of tubercles extending to rear from peripetalous fasciole.

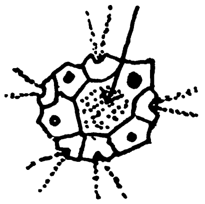


loven's law - Orientation of echinoids determined by madreporite being right of amb number III and in interamb number 2.

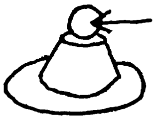


lower - Side with the peristome.

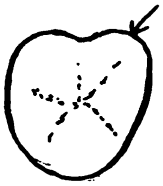
madreporite - Genital plate of apical system adapted as part of water vascular system and identifiable as different from other genital plates by larger size and more perforation.



mamelon - Raised, rounded top of tubercle on which spines articulates.

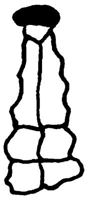


margin - Edge of the test in flattened echinoids.



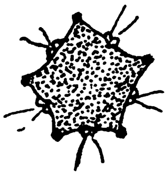
medulla - Meshlike, central core of spines.

mesamphisternous - Plates of the plastron that are close to a mirror image of each other.

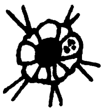


milled ring - Flange near the base of the spine for attachment of the muscles that move the spines.

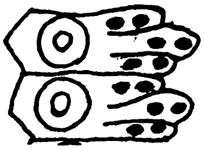
monobasal - Apical system where genital plates seem to fuse and ocular plates do not intervene.



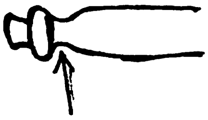
monocyclic - Apical system where genital and ocular plates form a single ring around the periproct.



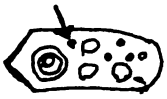
multiserial - Pore pairs arranged in more than two longitudinal series.



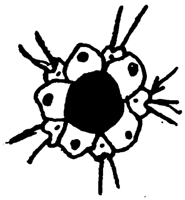
neck - Part of primary spine between the collar and the shaft.



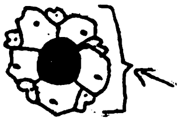
node - Small tubercle.



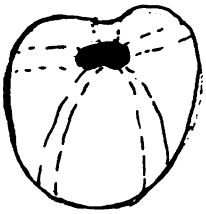
ocular plates - Plates of the apical system at the end of the amb, perforated by an ocular pore.



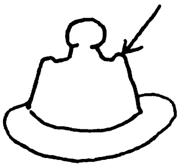
oculogenital ring - System of ocular and genital plates at apical end of amb and interamb areas surrounding periproct in regular echinoids



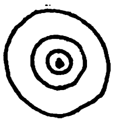
oral - Side of the test on which the peristome is located, usually facing down.



parapet - Edge of the platform where the mamelon sits.

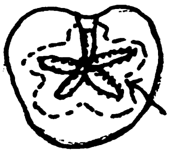


perforate tubercle - Tubercle with a small depression (also called foramen) in the top for a ligament to connect the spine with a tubercle.



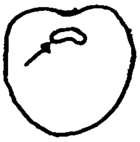
perignathic girdle - Internal structures around the peristome.

peripetalous fasciole - Groove passing around petals of the amb.

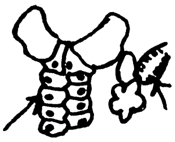
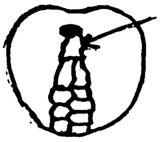
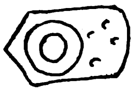
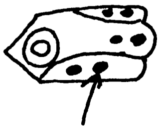
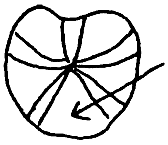
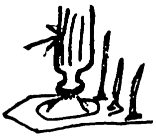
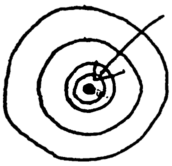
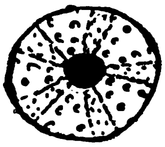
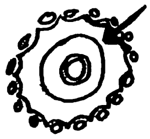
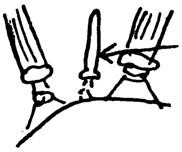
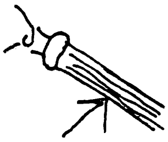
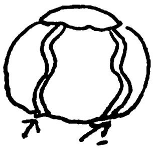
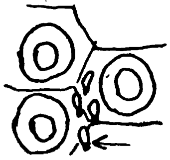


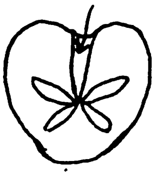
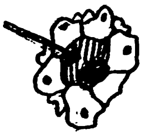
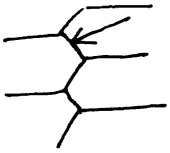
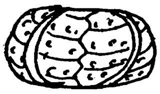
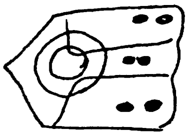
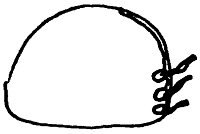
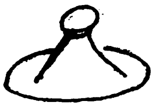
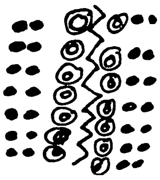
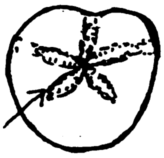
periproct - Opening in the test for the anus, covered in life by a periproctal membrane and commonly plated.

peristome - Opening in test for the mouth.



petal (petaloid) - Area of amb with pores unequal in size. Typically one long and one short.

phyllode	- Depressed area near the peristome with enlarged pores, commonly leaf shaped and part of the floscelle.	
plastron	- Bulging, expanded adoral segment of interamb number 5.	
plate	- Single, somewhat flattened segment of the test composed of a single calcite crystal.	
pore	- Perforation or hole in the test for the tube foot of the water vascular system.	
pore pair	- Double perforations in the amb through which single tube foot passes.	
posterior	- Toward interamb 5.	
primary spine	- First formed and usually largest spine of a plate, located over a growth center of the plate except on compound amb plates.	
primary tubercle	- Prominent elevation of the test for articulation of primary spine.	
punctate	- Perforated.	
regular echinoid	- Type of test having periproct within the apical system and having radial symetry.	
scrobicule	- Sunken area around the base of the tubercle for attachment of spine muscles.	
secondary spine	- Middle sized spine.	
shaft	- Main part of the spine.	
sinuous	- Wavy amb.	
spheridia	- Tiny, short spines located adorally in pits.	

spicules	- Tiny calcareous discs or rods in body tissue, often found when sifting dirt for micro fossil material.	
spine	- A calcareous shaft articulating on a tubercle.	
sternal plates	- First pair of postlabral plates in echinoids with **plastron.**	
subanal fasciole	- Curved groove or band free of tubercles below the periproct.	
sulcus	- Troth or depression in the test.	
suranal plate	- Large plate of periproctal system that pushes the anal opening away from the center of the periproct	
suture	- Contact between adjacent plates.	
test	- Hard part of the echinoid including apical, periproctal and peristome systems.	
trigeminate	- Having three pore pairs.	
truncated	- Blunted.	
tube foot	- End of branch of water vascular system serving for grasping, adhesion, locomotion, respiration or combination.	
tubercle	- Knobs or bumps.	
uniserial	- Referring to ambulacrum with pore pairs in a single, long row.	
upper	- Side of the test with the apical system.	
zygopore	- Pore pair.	

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