QUATERNARY MOLLUSCS of South Australia

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QUATERNARY MOLLUSCS OF SOUTH AUSTRALIA

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Cover: Glanville Formation with *Anadara trapezia*

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INTRODUCTION

The Quaternary is the youngest period of the Cainozoic Era. It includes both the Pleistocene and the Holocene Epochs covering geological time from the end of the Tertiary Period to the present (Table 1).

This book seeks to assist the student and collector in identifying the molluscs preserved in South Australian rocks during the Quaternary Period. A high percentage of molluscs found in South Australian Late Pleistocene deposits are living species, although some no longer inhabit South Australian waters. As a basis for identifying Quaternary fossil molluscs it is necessary to begin with the living fauna.

Identifying Fossils

As fossils were once living organisms they are classified in the same manner and under the same rules as modern plants and animals, the Rules being set out in the International Codes of Botanical and Zoological Nomenclature. A binominal system of nomenclature is used, somewhat similar to our own custom of having a family name and a given name. So that the system may be orderly and universally intelligible, names are preferably either derived from classical Latin or Greek or given Latin or Greek endings; with the proliferation of names this preference has had to be considerably relaxed, although vernacular or popular names are still not acceptable as formal scientific names. Every species belongs to a genus and has a generic name, indicated by a capital letter; the species name is shown in lower case. Thus dogs belong to the genus *Canis*; the domestic dog is *Canis familiaris*, the wolf *Canis lupus*, the dingo *Canis dingo*, the coyote *Canis latrans*, the striped jackal *Canis adustus*. Eucalypts belong to the genus *Eucalyptus*; the River Red Gum is *Eucalyptus camaldulensis*, the South Australian Blue Gum is *Eucalyptus leucoxylon* the Sugar Gum *Eucalyptus cladocalyx*, the Manna Gum *Eucalyptus viminalis* and so on.

This system was initiated by the Swedish naturalist Carolus Linnaeus, who, in the 10th Edition of his *Systema Naturae*, in 1758 set out a uniform system of binomial nomenclature for animals as he had earlier for plants. The date 1 January, 1758, is set as the starting point of zoological nomenclature.

All plants and animals whether living or fossil are classified in a hierarchical system of categories which enables one readily to narrow the limits within which an organism can be related to similar organisms. The major categories are:

KINGDOM
 PHYLUM
  CLASS
   ORDER
    FAMILY
     GENUS
      SPECIES

Our own species, living Man, *Homo sapiens*, which includes both male and female, may be taken as an example of how we can narrow down the category into which an organism is placed: Man is classified in the Kingdom Animalia—Man is an animal; Phylum Chordata of which the Vertebrata are a Subphylum—Man has a notochord and a vertebral column; Class Mammalia—Man is a mammal, suckling the young; Order Primates—Man is a primate, belonging to a group of animals including the lemurs, monkeys, manlike apes and Man; Family Hominidae, which includes fossil and living Man; Genus Homo (Latin for 'man'), which has several species; Species sapiens (Latin for 'wise'), the name living Man rather immodestly gave himself.

General Classification of the Animal Kingdom

		Stratigraphic range
1. PROTISTA	protozoans	
RHIZOPODEA		
Foraminiferida	foraminifers—mostly minute organisms with a shell or test composed of calcite, agglutinated particles or 'pseudochitin'. Important in stratigraphic correlation	Cambrian to Holocene
Radiolaria	radiolarians—minute pelagic protozoans which secrete elaborate skeletons composed mainly of silica	Ordovician to Holocene

2. PORIFERA	sponges—aquatic fixed organisms inhabiting shallow seas or freshwater environments; multicellular masses supported by a skeletal framework of calcareous, siliceous or horny spicules. They have a very long fossil record as spicules	Precambrian to Holocene
3. ARCHAEOCYATHA	coral-like, calcareous cup-shaped organisms with an outer wall separated by a space which contains radial walls	Lower to Middle Cambrian
4. COELENTERATA	include jellyfish, corals, sea pens etc.	
Hydrozoa	marine and freshwater polyps	Precambrian to Holocene
Scyphozoa	jellyfish or medusae	Precambrian to Holocene
Anthozoa		
Alcyonaria	sea pens, sea fans and sea feathers	Precambrian to Holocene
Tabulata	extinct colonial corals	Ordovician to Jurassic
Rugosa	rugose corals	Ordovician to Permian
Heterocorallia	elongate, cylindrical solitary corals	Carboniferous
Scleractinia	hexacorals, includes modern reef building corals	Permian to Holocene
Zoanthidea, Antipatharia, Ceriantharia	black corals	Holocene
5. PLATYHELMINTHES	flatworms	Holocene
6. NEMERTA	proboscis worms	Holocene
7. ANNELIDA	segmented worms	Precambrian to Holocene
Polychaetia	bristle worms	
Sedentaria	worms that build tubes	
8. BRYOZOA (also ECTOPROCTA, POLYZOA)	moss animals or lace corals	Ordovician to Holocene
9. BRACHIOPODA	lamp shells	Cambrian to Holocene
10. SIPUNCULOIDA	peanut worms	Holocene

11. MOLLUSCA	molluscs	
Monoplacophora	cap-shaped shells with paired muscle scars	Cambrian-Silurian; Holocene
Amphineura	chitons	Cambrian to Holocene
Scaphopoda	tusk shells	Silurian to Holocene
Gastropoda	snails, slugs, whelks, abalones etc	Cambrian to Holocene
Cephalopoda	Nautilus; squids, octopus, ammonites, belemnites etc., very important as fossils and unsurpassed as stratigraphic indicators in the Palaeozoic and Mesozoic	Cambrian to Holocene
Nautiloidea	nautiloids, have external shells generally divided by simple septa turned back along the siphuncle	Cambrian to Holocene
Ammonoidea	ammonites, with external shell divided by fluted septa which in early forms are turned back, in advanced forms turned forward at the siphuncle	Devonian to Cretaceous
Dibranchiata	belemnites, squids, etc with internal shells or no skeleton	Carboniferous to Holocene
12. ARTHROPODA		
Trilobitomorpha	trilobites	Cambrian to Permian
Pycnogonida	sea spiders	Cambrian to Holocene
Eurypterida	eurypterids	Ordovician to Permian
Arachnida	spiders, scorpions	Carboniferous to Holocene
Crustacea	lobsters, crabs, prawns, barnacles, ostracodes etc.	Cambrian to Holocene
Miriapoda	millepedes, centipedes	Silurian to Holocene
Insecta	insects	Carboniferous to Holocene
13. ECHINODERMATA	echinoderms	
Carpoidea	carpoids	Cambrian to Devonian

Crinoidea	sea lilies	Ordovician to Holocene
Blastoidea	blastoids	Ordovician to Permian
Echinoidea	sea urchins	Ordovician to Holocene
Asteroidea	starfish	Ordovician to Holocene
Ophiuroidea	brittle stars	Ordovician to Holocene
Holothuroidea	sea cucumbers	Devonian to Holocene
14. PROTOCHORDATA		
Ascidiacea	sea squirts	Permian to Holocene
15. CHORDATA		
Pterobranchia	pterobranchs	Ordovician; Holocene
Graptolithina	graptolites, important index fossils of the Ordovician and Silurian	Cambrian to Carboniferous
16. VERTEBRATA		
Agnatha	primitive, jawless vertebrates, including the living lampreys and hagfish	
Diplorhina	pteraspids	Ordovician to Devonian
Monorhina	cephalaspids	Ordovician to Devonian
Petromyzones	lampreys	Holocene
Myxini	hagfish	Holocene
Placodermi	plated fishes, ancient jawed fishes	Devonian
Chondrichthyes	cartilagenous fish, primitive sharks, skates and rays	Devonian to Holocene
Osteichthyes	bony fishes	Devonian to Holocene
Amphibia		
Labyrinthodontia	labyrinthodonts	Carboniferous to Triassic
Urodela	salamanders, newts	Permian to Holocene
Salientia	frogs and toads	Triassic to Holocene
Reptilia		
Anapsida	stem reptiles	Permian to Triassic

	turtles	Triassic to Holocene
Ichthyopterygia	ichthyosaurs	Triassic to Cretaceous
Sauropterygia	plesiosaurs	Triassic to Cretaceous
Placodontia	placodonts	Triassic
Proganosauria	mesosaurs	Permian
Lepidosauria	tuatara, lizards, snakes	Permian to Holocene
Archosauria	ruling reptiles	
Thecodontia	thecodonts	Permian to Triassic
Crocodilia	crocodiles	Jurassic to Holocene
Saurischia	dinosaurs (sauropods)	Triassic to Cretaceous
Ornithischia	dinosaurs (stegasaurs)	Cretaceous
Pterosauria	pterosaurs, pterodactyls	Jurassic to Cretaceous
Synapsida	primitive reptiles pelycosaurs	Carboniferous to Permian
	therapsids	Permian to Triassic
Aves	birds	
Sauriurae	*Archaeopteryx*	Jurassic
Odontoholiae	include *Hesperornis*	Cretaceous
Ornithiurae	modern birds	Cretaceous to Holocene
Mammalia	mammals	
Eotheria	decodonts	Triassic to Cretaceous
Prototheria	platypus, echidna (egg laying mammals)	?Pliocene to Holocene Holocene
Allotheria	rare early mammals	Jurassic to Cretaceous
Metatheria	(young born alive)	
Marsupialia	pouched mammals (diprotodon, dasyurids, thylacines, kangaroos etc.	Cretaceous to Holocene
Eutheria	placental mammals (includes Man)	Cretaceous to Holocene

General Classification of the Plant Kingdom

		Stratigraphic range
	PLANTAE	
1. THALLOPHYTA	non-vascular plants, primarily aquatic: algae, fungi, dinoflagellates, coccoliths, diatoms	
Calcareous algae		Precambrian to Holocene
Chlorophyceae	green algae	
Rhodophyceae	red algae	
Schizophyceae	includes stromatolites	
Bacteria		Precambrian to Holocene
Fungi		Carboniferous to Holocene
Chrysophyceae	coccoliths, discoasters	Jurassic to Holocene
Bacillariophyceae	diatoms	Cretaceous to Holocene
Dinophyceae	dinoflagellates, cysts	Cretaceous, Tertiary
Acritarcha	acritarchs	Precambrian to Holocene
2. BRYOPHYTA	liverworts and mosses	Devonian to Holocene
3. CHAROPHYTA	stoneworts	Silurian to Holocene
4. PTERIDOPHYTA	vascular plants, reproducing by means of spores:	
Psilophytopsida	vascular plants with naked stems and sporangia either terminal, grouped or scattered along branches	Silurian to Devonian
Lycopsida	club mosses, lycopods	Silurian to Holocene
Sphenopsida	horse tails	Silurian to Holocene
Pteropsida	ferns	Devonian to Holocene
5. GYMNOSPERMOPHYTA	gymnosperms. Seed-bearing plants in which the seed is not completely enclosed in an ovary—includes conifers	
Progymnospermopsida		Devonian to Carboniferous

Pteridosperm-opsida	pteridosperms, includes *Glossopteris*, *Gangamopteris*, *Taeniopteris*	Devonian to Triassic
Coniferopsida	conifers	Carboniferous to Holocene
Cycadopsida	cycads	Carboniferous to Holocene
Gnetopsida	mainly represented by *Ephedra*-like pollen; modern ivy	Triassic to Holocene
6. ANGIOSPERMAE	the flowering plants; seed completely enclosed in an ovary	Cretaceous to Holocene

1. FOSSILS

Palaeontology is the study of fossils, the word 'fossil' being derived from the Latin adjective *fossilis* (verb *fodere* past participle *fossum* to dig). Originally a fossil was an object that had been dug up.

The observant ancient scholars and travellers recognised the true nature of fossils and their origin: Herodotus (c.484-c.425 BC), for example, saw shells in the hills in Egypt and deduced that the area had formerly been a gulf of the Mediterranean Sea, and the Athenian soldier-historian Xenophon, in describing the great march into Persia and back to Greece, noticed at a fortification on the Tigris which had been inhabited by the Medes that 'the base of this fortification was made of polished stone in which there were many shells'.

But for nearly two thousand years, particularly in what we call the Dark Ages, guided by superstitious beliefs, people regarded fossils as curious objects or freaks of nature. In England ossicles of crinoids ('sea lilies') from the Carboniferous Limestone were called 'St Cuthbert's beads' and coiled ammonites were called 'snakestones' from the legend that pious maidens St Hilda and Keina had transformed living serpents into stone so that they might no longer harm mankind. Not surprisingly, the coiled stone 'serpents' were found headless and carved heads are sometimes added by stoneworkers.

The Renaissance brought with it a more open-minded approach to natural objects and in 1508 the versatile genius Leonardo da Vinci, then living in Milan, made a series of notes on natural science. He observed, like Herodotus nearly two thousand years before, that shells and other evidence of marine life were to be found in the hills, and deduced that the country had once been covered by the sea.

Other scholars such as Fracastoro and Bernard Palissy also correctly interpreted the origin of fossils.

It was not until the seventeenth century that the serious study of fossils began and the name 'fossil' was restricted to the remains of living organisms whether plant or animal. The word 'paléontologie' was introduced by de Blainville in 1825 for 'l'étude des corps organises fossiles'.

Living organisms may be converted into fossils in various forms, and the likelihood of their becoming fossilised depends on the nature of the organisms themselves and the physical environment in which they died. Those animals or plants which have skeletons, shells or tests, or other hard parts, are more likely to be preserved than those consisting only of soft organic material made up of carbohydrates and proteins. An organism living on the sea bed where it can be rapidly buried in fine sediment such as mud or inorganically precipitated calcium carbonate has a much better chance of preservation than one living on land where it is exposed to erosion. To become a true fossil an organism must become embedded in some enclosing material. Somewhat unusual but very effective media for preserving soft parts are the amber or fossil resin of the Baltic in which insects have been preserved, the La Brea tar pits of Los Angeles, California, in which sabre-toothed tigers and other prehistoric animals were entombed, and the tundras of Alaska and Siberia where numerous large elephant-like woolly mammoths were frozen in ice as long as 25000 years ago. The ice was such a good preserving agent that the flesh remained edible and the ivory tusks saleable to ivory traders.

Types of Preservation

Preservation of hard parts as original material or by chemical change

Mollusc shells, echinoderm tests, corals, calcareous algae and the microscopic tests of some foraminifers which are composed of *calcium carbonate* are commonly preserved in their original form.

The protective or supporting structures of some sponges, radiolaria and plants, such as diatoms, which are composed of *silica,* readily survive fossilisation.

Bones and teeth contain high proportions of *calcium phosphate,* which is very resistant to weathering, and many vertebrates are known only from teeth. Sharks' teeth are particularly common in early Tertiary sediments in South Australia.

Chitin or horny material which forms the exoskeletons of some arthropods and insects and graptolites, and *cutin* which occurs in the cuticles of plants and covers pollen grains and plant spores may be preserved, but more commonly it survives only as thin films of *carbon.*

Due to percolating waters or other conditions in the sediment enclosing the organism the chemical composition of the original material may be changed. Plants are commonly converted to carbon or to coal, organic material may be replaced by pyrite, and shell material may be replaced by silica, opal, gypsum or other minerals. Opalised fossils

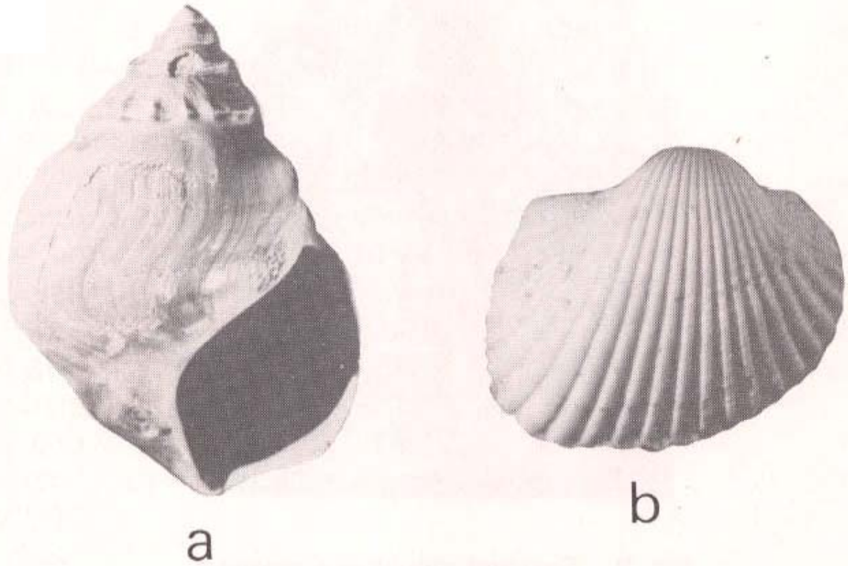


Fig. 1 Original shell: a. *Tylospira coronata marwicki* from Late Pliocene; b. *Anadara trapezia* (juvenile) from Glanville Formation, Late Pleistocene.

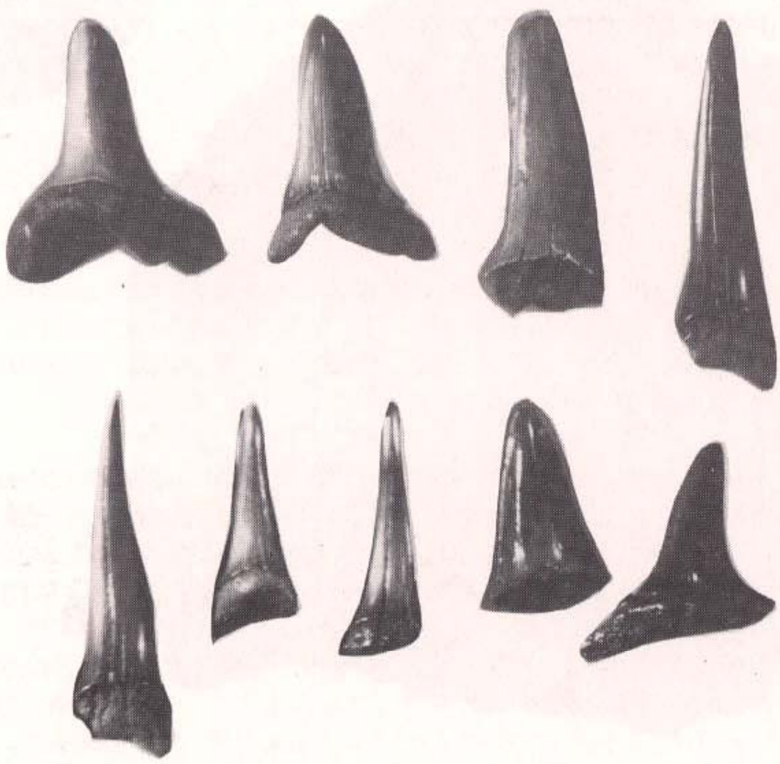


Fig. 2 Sharks' teeth from Eocene of Lower South-East, South Australia.

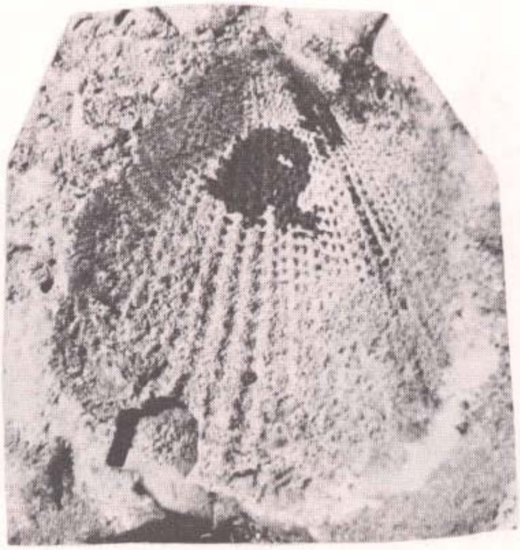


Fig. 3 External mould of *Eotrigonia*.

Fig. 4 Internal casts of: a. *Miltha* from Hallett Cove Sandstone (Late Pliocene); b. *Anadara trapezia* (juvenile) from Glanville Formation, Late Pleistocene.

are not uncommon on South Australian opalfields and gypsum replacement of mollusc shells has occurred in limestone in the cliffs of the Murray River. Fossils in which exact replicas of original material have been made in another substance are called pseudomorphs.

Preservation as indications or traces

Moulds and casts are a very common form of preservation. After its death an organism becomes buried in the enclosing sediment. If subsequently the original shell is dissolved away an external mould of the organism may be left; if the internal cavity has also been filled with the sediment or with some mineral such as calcite, silica, or glauconite, a cast of the interior may result. An interesting example of the preservation of soft-bodied animals by external moulds and impressions is found in the very old (Precambrian) fossils from Ediacara, west of Beltana, where the imprints of jellyfish, flat segmented worms and other primitive forms were preserved on the under surface of the overlying sediments.

Trace fossils in the form of footprints, tracks and trails, burrows, borings, coprolites (fossil excreta) and gastroliths (stomach stones) also give evidence of former life.

The Fossil Record and Earth History

Fossils are contained in sedimentary rocks, formed by the accumulation of sediments which have been broken down from older rocks, transported and deposited by agents such as wind, water, or ice, or precipitated after being held in solution or suspension.

The most characteristic feature of sedimentary rocks is their tendency to occur in layers or strata. The geological history of the earth is recorded in the strata of the earth's crust, and fossils are valuable tools in the study of historical geology, or *stratigraphy.* Three principles are applied in stratigraphic studies:

1. That geological processes in the past operated in the same way as they do today—the principle of uniformitarianism or 'the present is the key to the past'.

2. That a layer or rock is younger than the layer on which it rests—'the law of superposition'. This is the first of the laws of William Smith (1769-1839), earlier formulated by Nicolaus Steno (1669). The rule must be applied with caution as a sequence may be disturbed by folding or faulting.

STRATIGRAPHIC COLUMN

ERA	PERIOD	EPOCH		AGE OF BASE (in millions of years before present- Ma)
	Quaternary	Holocene		10 000 years
		Pleistocene		1.8 Ma
Cainozoic	Tertiary	Pliocene	Neogene	5
		Miocene		23.5
		Oligocene	Palaeogene	38.5
		Eocene		53.5
		Palaeocene		65
Mesozoic	Cretaceous			135
	Jurassic			190
	Triassic			225
Palaeozoic	Permian			280
	Carboniferous			345
	Devonian			395
	Silurian			430
	Ordovician			500
	Cambrian			570
Proterozoic	Adelaidean	Precambrian		uncertain; ?800-1 100
	Carpentarian			1 800
	Early Proterozoic			2 500
Archaean				

Formation of Earth's crust about 4 600 million years ago

3. That strata are identified by fossils—'the principle of faunal dissimilarity' and William Smith's second law. These principles established an entirely new concept for the study of fossils, that strata of the same age contained the same types of fossils and could be correlated over wide areas. On the framework of these principles historical geology or stratigraphy has been built. The sedimentary record of geological time has been established in a scheme called the Stratigraphic Column, rather similar to the dynastic charts of, say, ancient Egypt, Persia or China.

The scheme, established in England and Western Europe, can be applied all over the world. The largest divisions are called Eras, divided into Periods. Until fairly recently various methods were used to estimate the age of the earth and the length of time necessary for the deposition of the rocks formed during each period; one of these was based on rates at which sediments were deposited in modern environments and applying these rates to estimated thicknesses of strata. This and other methods, while providing a relative scale, were not satisfactory because complexities of rates of sedimentation and erosion could not be taken into account.

The development of radiometric dating has provided a more accurate means of graduating the geological time scale and establishing the order of magnitude of geological time. This process depends upon the fact that by the emission of rays uranium breaks down to other elements the stable end product of which is lead. The rate of decay is always constant and the uranium-lead ratio is always the same in unaltered minerals of the same age. In age determinations three transformations are now commonly used: uranium and thorium into lead and helium (U^{235}/Pb^{207} and U^{235}/Pb^{206}), potassium into argon (K^{40}/Ar^{40}) and rubidium into strontium (Rb^{87}/Sr^{87}).

Rocks younger than about 40000 years old can be dated from organic matter by determining the ratio of the radioactive isotope carbon-14 to other carbon in the material.

By radioactive dating it has been possible to relate the stratigraphic column to a time scale in millions of years (Ma) BP (before the present, taken as 1950).

Radiometric dating is not a substitute for palaeontology. It enables the radiometric age of a mineral, preferably a fresh mineral in an igneous rock, to be established, but correlation of most sedimentary rocks is still determined by the fossils they contain. The general name applied to the interpretation of strata by means of their fossil content is called *biostratigraphy*.

Despite gaps in the record due to the chance of preservation, the fossil record presents a very good account of life on earth since the Precambrian. One should be careful, however, not to use the term 'evolution' as synonymous with 'the fossil record'. The fossil record is the visible and factual record of the different fossils occurring in rocks throughout geological time; evolution is the process by which species undergo modification for various reasons and develop into new forms. The number of well documented examples of this evolutionary process is extremely small.

Uses of Fossils

Fossils are used mainly for correlating rocks and establishing the position in the stratigraphic column in which they occur, and for determining the palaeoecology or environmental conditions under which they were deposited and their palaeogeography.

Although the term palaeontology is applied generally to the study of fossils it is, like other branches of science, divided into a number of specialist fields: palaeobotany—the study of fossil plants; palynology—the study of fossil pollen and spores; invertebrate palaeontology—the study of fossil invertebrates (animals without backbones); vertebrate palaeontology—the study of fossil vertebrates (animals with backbones or vertebral columns); micropalaeontology—the study of microfossils, whether plants or animals, especially foraminifers, conodonts, coccoliths and discoasters. The term palaeozoology should correctly be used only for the study of fossil animals in the sense of recreating from what is preserved in the fossil form the animals as they were in life—their anatomy, bodily functions and the like.

Micropalaeontology and palynology are extensively used for correlating and dating underground strata penetrated during drilling for oil and gas and for groundwater supplies.

2. MOLLUSCS

The most widely collected and prized objects of the sea shore are molluscs or 'sea shells' which belong to the phylum Mollusca. They are also called 'shellfish', an inappropriate term often also applied to the larger crustaceans. Molluscs are highly organised animals forming a large and important group of invertebrates second only to the arthropods in the number of species, estimated at between 80000 and 100000, that have been described. They are very important as fossils, the phylum having a continuous geological range from the Cambrian to the present. During this long period of time (more than 500 million years) they have adapted themselves to all but the most extreme habitats from the land to the abyssal depths of the sea. They feed on every possible kind of plant or animal food, varying in habits from filtering out microscopic organisms to those of active carnivorous predators.

Living molluscs include: cockles, which burrow in sand; mussels and oysters which attach or anchor themselves to rocks, jetty piles and other objects; limpets, abalones and chitons which also attach themselves mostly to rocks; sea snails and slugs of many kinds which crawl or glide over firm surfaces; and squids, cuttlefish and octopuses which jet-propel themselves through the water.

Molluscs have soft bodies without internal skeleton and with no standard shape, as the shape can be modified to adapt to new environments and habits; most have a hard protective three-layered shell consisting of calcium carbonate, either calcite or aragonite, set in a matrix of protein material called conchiolin. Over all a protective horny layer or periostracum is present at some stage of growth. It is necessary to have some knowledge of the soft parts in order to interpret features of the hard shell.

The soft body always consists of four main parts:

1. except for the bivalves, in which it has been reduced to the site of the mouth opening, and the chitons, in which it is separated from the foot by a constriction, a well developed *head* with *eyes* and *tentacles*;

2. a highly muscular *foot* with which to crawl or glide over surfaces, dig, swim or capture food;

3. a dorsal *visceral mass* comprising the internal organs such as the alimentary canal and gonads;

4. the *mantle* or *pallium*, a skin-like membrane which is draped over the visceral mass and lines the shell which it secretes, and also encloses the *mantle cavity* which, in most cases, contains the gills.

The phylum MOLLUSCA is divided into six classes:

MONOPLACOPHORA—a class of simple, primitive, mostly bilaterally symmetrical molluscs with a single limpet-like shell. The soft parts such as the muscles, gills, auricles and kidneys are paired; the number of shell muscles can be as many as eight pairs. Monoplacophorans were thought to have become extinct at the end of the Palaeozoic until species of the genera *Neopilina* and *Vema* were found living at abyssal depths off the coasts of Mexico and Peru and a species, *Vema hyalina*, living on the continental shelf off southern California.

AMPHINEURA—marine molluscs divided into two subclasses: APLACOPHORA, worm-like molluscs without shelly plates, which have not been found fossil and which are not known from southern Australia where they may have been overlooked because of their resemblance to worms; and POLYPLACOPHORA, the chitons or coat-of-mail shells, the shell consisting of a series of usually eight calcareous articulating plates or valves,

GASTROPODA—the largest and most diverse group including spirally coiled snails, limpets, abalones and slugs,

SCAPHOPODA—tusk shells, bilaterally symmetrical, burrowing molluscs with a more or less curved, long, tubular, tapering shell open at both ends,

BIVALVIA (also known as Lamellibranchia, Pelecypoda)—molluscs with two usually hinged valves, such as scallops, oysters, cockles, mussels and other less obvious forms such as shipworms,

CEPHALOPODA—ammonites, squid, nautiloids, octopus, with an internal shell, without shells, or with a chambered internal or external shell. Ammonites are a very important fossil group, representatives of which are found in the Cretaceous of the Great Artesian Basin in South Australia.

The molluscs are a very diversified and complex group, the characters of both the hard and soft parts of living molluscs being such that the construction of simple, clearly defined keys as a guide to classification is difficult. Some indication of these difficulties is given in Table 2 which summarises the characteristics of both hard and soft parts variously used in the classification of bivalves.

It is hoped that the brief descriptions and illustrations of the common and representative species of South Australian marine molluscs given in this book may serve as a guide to what may be found fossil in the Quaternary. At the specific level, names of many species are used cautiously until the families can be properly revised and the nomenclature adjusted as necessary. To assist such studies, collectors and students should record carefully the locality and habitat of the specimens they collect so that a wide range of material can be made available. Under the International Code of Zoological Nomenclature, which applies also to fossils, primary type material resulting from description of new species is regarded as the property of science and holotypes or lectotypes should be deposited in a museum or institution where they will be safely preserved and will be accessible for purposes of research. This is mandatory in the case of neotypes. In any case, it is desirable to lodge voucher specimens in a recognised institution.

The shallow seas of southern Australia support a unique regional molluscan fauna having its origin largely in the Tertiary after the separation of Australia from Antarctica. The fauna is also of local historical interest in that many of the species were described by Lamarck and by de Blainville in the early 19th century from specimens collected by Peron and Lesueur, particularly on Kangaroo Island and in King George Sound WA during early French voyages of the *Géographe* and *Naturaliste* under the command of Nicolas Baudin.

Most of the living molluscs included in this book live in shallow water on the continental shelf in what is known broadly as the intertidal zone. This zone has been further subdivided from the lowest, below the level of extreme low water mark, to the highest, the spray zone, above the level of extreme high water mark. The subdivisions used in this book are those of Bennett & Pope (1953), who, with Womersley & Edmonds (1958) and Kershaw (1958), give information on the distribution of molluscs within these zones.

TIDAL LEVEL	ZONE	
SPRAY ZONE	SUPRALITTORAL ZONE	
Extreme high water		
Mean high water	LITTORAL (EULITTORAL) ZONE	UPPER LITTORAL
		MIDLITTORAL
		LOWER LITTORAL
Mean low water	INFRALITTORAL FRINGE	
Extreme low water SUBLITTORAL	SUBLITTORAL ZONE	

Class AMPHINEURA

Subclass POLYPLACOPHORA (Chitons)

Chitons can usually be recognised as elliptical rather flattened limpet-like molluscs living on or under rocks or other firm surfaces such as seaweeds in the littoral or sublittoral zones. The shell (Figs. 5b,c; 6a,b) is multivalvular, divided into eight imbricating, articulated plates with joints between them running transversely across the body like a coat of mail, so that the animal can either fasten itself tightly to an irregular surface or roll itself up like a slater (wood louse) if it is detached. Like limpets, chitons are able to withstand considerable force before they can be dislodged. This adhesion like a suction cap is achieved partly by secretion of an adhesive mucus and also by muscular action. When a chiton is disturbed, it reacts by clamping down the girdle to exclude the water current and raising the foot to produce a partial vacuum and thus increase the adhesion by suction.

Adhering in this way, chitons may be found on or under rocks in shallow water or in sheltered pools between tide marks or where they are reached only by high tides; they may be on seaweeds or partially buried in sponges.

The Polyplacophora are mostly intertidal herbivores, feeding on minute plant material, intermittently swallowing large amounts of very small algae, diatoms and algal detritus, usually raking them up or scraping them off with the radula, but some feed on minute animals such as bryozoans and hydroids. One genus living in the North Atlantic and North Pacific occasionally captures amphipods by raising the head flap of the girdle.

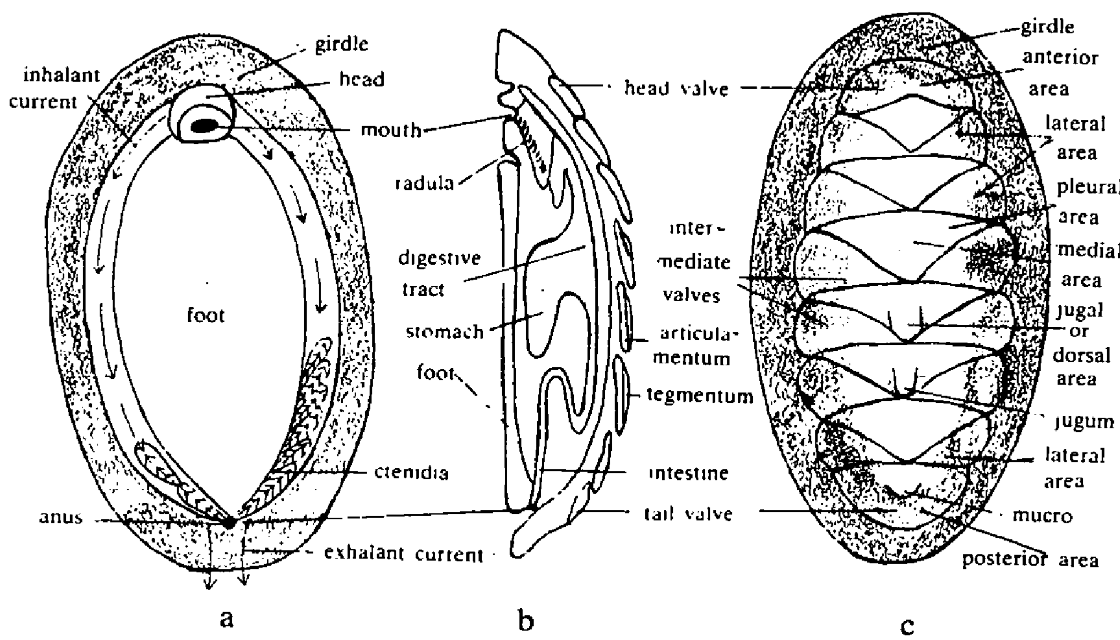


Fig. 5 Principal features of chitons: a. under or ventral side; b. longitudinal section; c. upper or dorsal side.

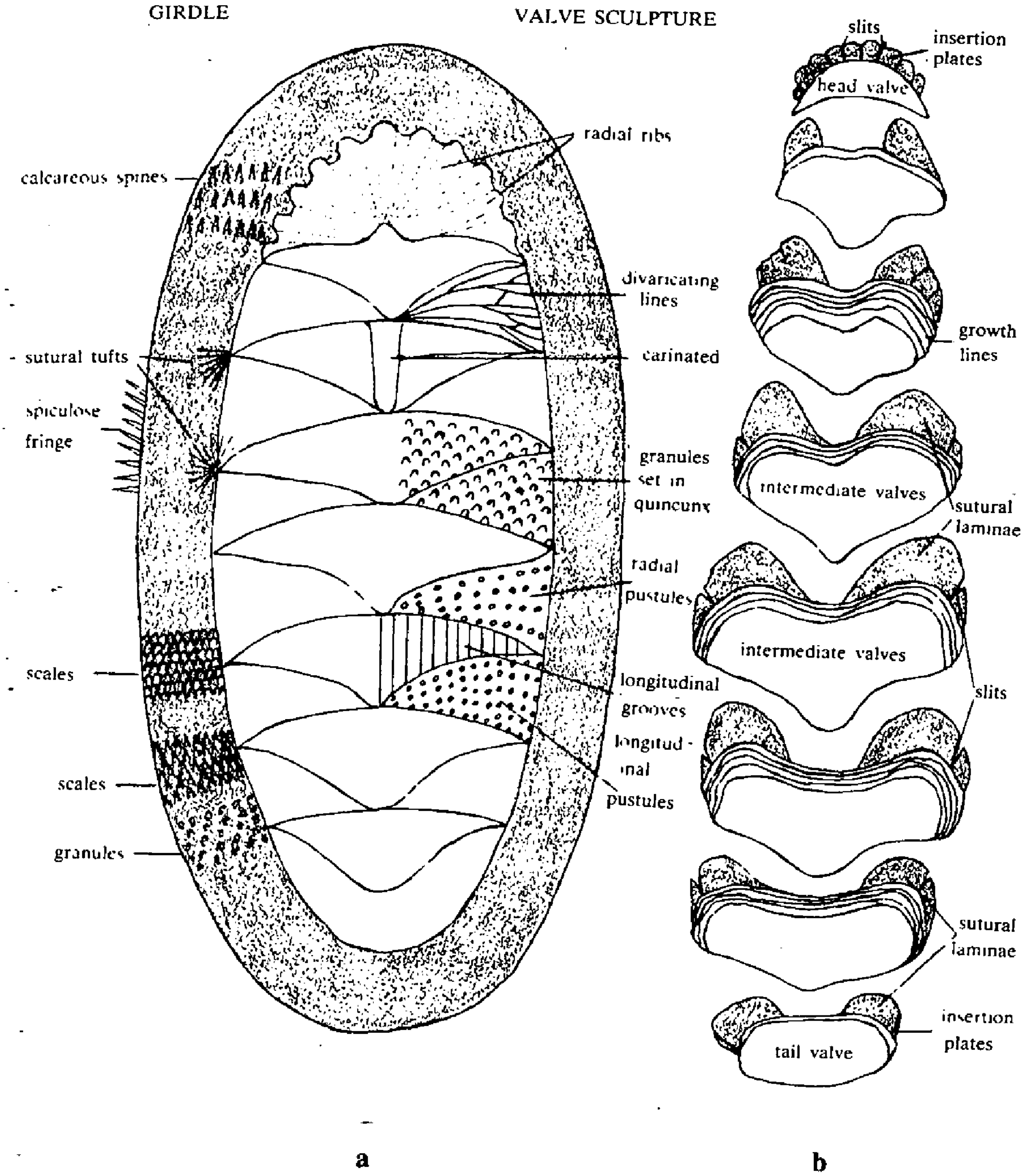


Fig. 6 a. Types of ornament of valves and girdle of chitons; b. Hard parts of chiton valves, separated.

Their biology is inadequately known.

Chitons are bilaterally symmetrical, with the mantle wholly covering the dorsal soft parts of the animal. This bears a dorsal series of usually eight calcareous plates or *valves*, wholly or partly embedded, and overlapping to a greater or lesser degree. Around the periphery, the mantle is thickened to form a muscular scaly, spiny or fleshy *girdle*, variously ornamented with granules, scales, spines and/or spicules, which holds the valves together and enables the animal to fit closely on the surface to which it is attached.

Soft parts

The body is oval, elongate, flattened, with the *head* and *mouth* differentiated at the anterior and the *anus* at the posterior. The *foot* or *sole* is adapted for creeping and adhesion. The *mantle cavity* is modified to suit the close-fitting habit and is reduced to shallow grooves reaching forward to the head and running round the edge of the foot between the foot and the *girdle*. To compensate for the small mantle cavity the *gills* are numerous, as many as 70 pairs, occupying the mantle (pallial) grooves near the posterior and in more advanced types extending to the head. To fit into the narrow mantle cavity the gills are short. They can sometimes be seen in dried specimens in the groove between the foot and the girdle. Each is a *ctenidium* with filaments similar to those of the gastropods.

The girdle may be lifted at any point to allow an inward passage to the inhalant chamber for a water current which bathes the gills and passes out through the exhalant chamber posteriorly with the excretory products. The apertures of the *gonads* and *nephridia* also open into the mantle cavity and the excretory products are passed posteriorly to the anus.

The *mouth* leads to the first part of the alimentary tract, the *buccal cavity*, with a highly complex strong muscular prominence called the *buccal mass*, part of which forms the *odontophore*. The odontophore supports the buccal end of the radula from the *radular sac* and by its muscular action enables the *radula* to scrape or rasp food materials off firm surfaces. The chiton radula is a long flexible rasp-like ribbon with a reduced number of strong rasping teeth in each row.

The nervous and reproductive systems are simple, the nervous system consisting of a circum-oesophageal ring at the anterior end connected laterally to the pedal and pallial cords and dorsally by a cord running over the initial part of the gut and one connecting ventrally. There are no cephalic eyes, tentacles or otocysts, but there are developed in the mantle and embedded in the valves of the shell special sensory structures called *aesthetes* which are sensitive variously to light, touch, chemicals and the like.

The reproductive system of chitons is imperfectly known. The sexes are believed to be separate, with the genital aperture situated between two of the posterior gills in front of the renal aperture. Fertilisation usually takes place externally, eggs being laid in strings or in jelly-like masses. One family is said to be viviparous, brooding the young on the underside in the pallial groove.

Hard parts

The eight valves covering the upper or dorsal side of the chiton consist of the *head valve* at the anterior and the *tail valve* at the posterior, with six *intermediate valves* between. The head valve may be distinguished from the tail valve by the fact that it overlaps the next valve, each valve then overlapping the next in succession, the tail valve being overlapped but not overlapping; the tail valve also carries the point or projection called the *mucro.*

The shell of each valve consists of four layers:

1. the *periostracum*, a very thin, horny outer layer:

2. the *tegmentum* immediately under the periostracum, a soft somewhat porous calcareous layer which may contain the small sensory structures, aesthetes;

3. the *articulamentum*, an intermediate layer projecting past the tegmentum to form the insertion plates and the sutural laminae;

4. the *hypostracum*, the innermost calcareous layer with a somewhat different crystalline structure.

The *insertion plates* (Fig. 6b) are narrow marginal extensions to the head and tail valves and on the sides of the intermediate valves which project into the girdle.

The *sutural laminae* (Fig. 6b) are plate-like projections of the articulamentum overlapped by the posterior part of the previous valve. Both these structures help anchor the valves into the mantle and assist in articulation.

The valves are variously sculptured with granules, pustules, threads and the like and for purposes of description they are divided into different areas (Fig. 6a); the term 'posterior area' is added here to differentiate an area on the tail valve, and the term 'medial area' is used in preference to the more usual 'central area'.

Chitons are unimportant as Quaternary fossils in South Australia. Consisting as they do of separate valves held together by the girdle (Figs. 5b,c; 6a,b) which decomposes on death, they are occasionally found as single valves. It is possible to classify these on the characters illustrated in Figure 6a,b, but most studies on fossil chitons from southern Australia have been made on Tertiary chiton valves from Victoria. As they are inhabitants of rocky shores they are rare in the shallow water environments of most South Australian Quaternary deposits and will not be further considered here.

Class GASTROPODA (Gastropods)

Gastropods (literally 'stomach-footed', from Greek *gaster*-stomach, *pous, podos*-foot) form numerically the largest and most varied class of molluscs and include the sea and land snails and slugs, sea hares, limpets, abalones, whelks and cones. Most are univalve, having one shell, but there is an interesting group of Opisthobranchia, some of which have representatives in southern Australia, which has two shells like the Bivalvia (p. 130); others, including the sea slugs and sea hares and some of the pulmonate slugs, have no external shell at all and are not preserved as fossils. The first true gastropods appear in the Early Cambrian since when they have a continuous record, reaching their greatest abundance and diversity at the present day.

The general structure of a gastropod can be readily illustrated by the garden snail, crawling along by means of the *foot* with the *head* at the front and, dorsally, on top of the foot the single shell which protects the *visceral mass* and *mantle*. In most gastropods the shell and visceral mass are coiled in right-handed (dextral) spiral whorls. The foot and head can also be drawn into the last whorl of the shell for protection, and in most marine groups the aperture can be closed by a horny or calcareous trapdoor, the *operculum*, which is attached to the back of the foot. Not all gastropods are coiled, and not all have an external shell, but whether they are coiled or not, with the exception of the pulmonates and some opisthobranchs, their distinctive feature is that, unlike other Mollusca, they have the mantle cavity in the front part of the body.

This is due to a fundamental and drastic change which takes place early in their development. All gastropods undergo *torsion* or twisting, which is an entirely different process from coiling. It can be observed under the microscope during larval development of gastropods like limpets and abalones.

The early life history of gastropods varies considerably between the major groups, but the following general description applies at least to those that share some stages with the bivalves. The first stage is that of a fertilised egg or group of eggs enclosed in an egg capsule; the young emerge and pass through two larval stages, the first as a *trochophore* (Fig. 7a) and the second as a *veliger* (Fig. 7b). The trochophores, some of which resemble minute lanterns, are pelagic, floating for a brief time near the surface where they develop into free-swimming veligers. These have a minute shell, which later becomes the protoconch of the adult gastropod, and a ciliated velum or sail. They are ciliary feeders on phytoplankton. It is in the veliger stage that torsion begins and the larvae pass from the planktonic to the benthonic habit.

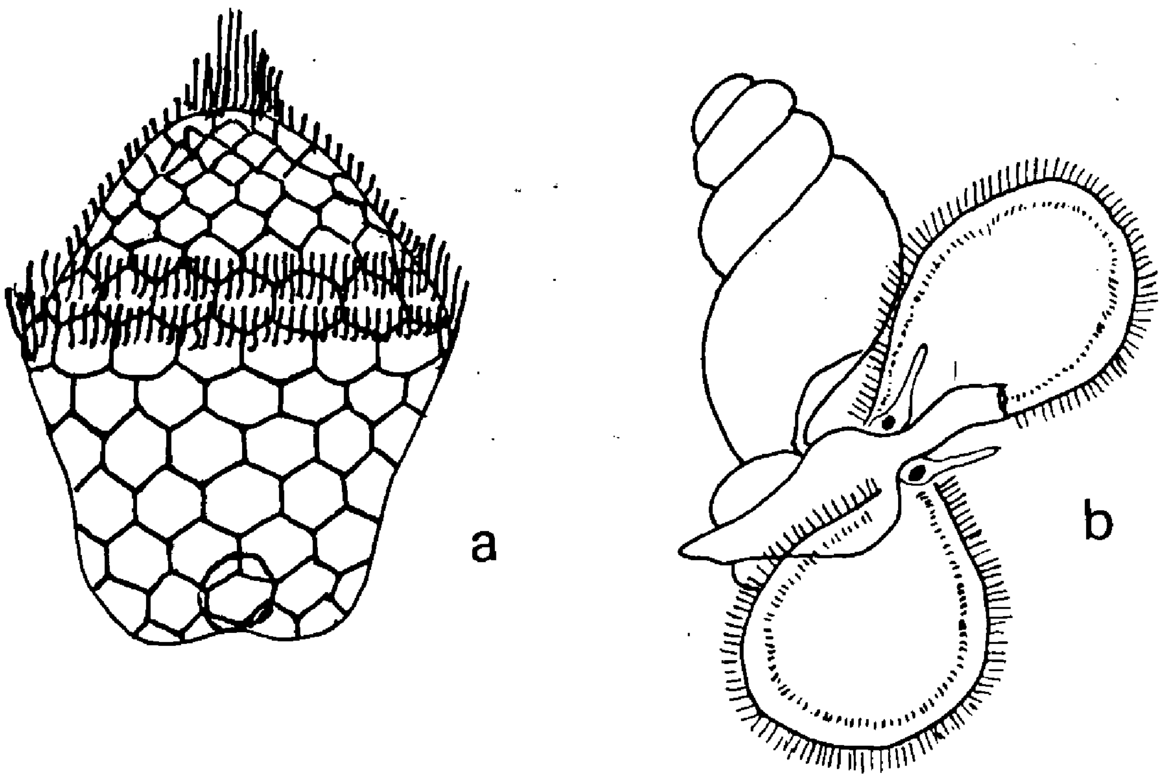


Fig. 7 Larval stages of gastropods: a. trochophore x c.300 after Smith 1935; b. veliger x c.80 after Lebour 1937.

In the veliger stage and before torsion the mantle cavity faces backwards and ventrally. Attached to the shell on the right there is an asymmetrical *retractor muscle* some of the fibres of which extend over the gut to the left side of the head and foot. As torsion begins some of the fibres contract and pull the visceral mass over towards the left, the visceral mass moving with the mantle and shell in a counter-clockwise direction through an angle of 180°. As a result, the mantle cavity becomes dorsal behind the head and faces forwards. The gut and nervous fibres running to it are twisted. The whole very drastic process takes place in two stages. The first stage of rotating through 90° takes place in the planktonic larval stage within three to six hours. The second stage takes place more slowly during transition from the planktonic or swimming stage to the benthonic stage when the larva is adapting to the habit of creeping on the bottom.

Soft parts

Most gastropods have a foot adapted for creeping and, more or less fused with the foot, a distinct *head* with *eyes* and *tentacles*. The well developed head carries sensory organs consisting of one or two pairs of tentacles- the horn-like projections seen in the garden snail- and two eyes. The *mouth* is a simple opening which in some genera is located at the end of a blunt *snout* or of a long retractable *proboscis*. The foot is a flat sole used mostly for creeping, but it may be modified for swimming, digging and other purposes.

The *visceral mass* is contained within, and does not move outside, the shell. It is covered by the *mantle*. A large part of the visceral mass is occupied by the *digestive gland* extending nearly to its apex. Against the inside of the last whorl the edge of the *mantle skirt* (or *mantle flap*) forms a fold where the visceral mass joins the head and foot. The space under the mantle skirt is the *mantle cavity* which is primarily a respiratory chamber. The mantle skirt secretes the shell and differential rates of growth between the breadth and length of the mantle edge and swelling of the mantle skirt results in sculpturing of the shell.

Respiratory system. In some families part of the mantle edge can be extended as a tube-like organ, open on one side, called the *inhalant* or *incurrent siphon* through which water can be drawn into the mantle cavity. Oxygen dissolved in the water is necessary for respiration. In some forms there is also an *exhalant* or *excurrent* siphon through which the exhalant current passes. The mantle cavity generally contains a single plume-shaped *ctenidium* or *gill*, the *osphradium*, on which the inhalant current first impinges for testing before passing over the filaments of the ctenidium, and the mucus-secreting *hypobranchial gland.* Some primitive gastropods have two gills and osphradia. The mantle cavity also contains the *anus, renal* and *female genital openings, and, in most cases, the male genital organ.*

Circulatory system. The circulatory system consists of a heart, arteries, and veins which differ in details in different gastropods. The blood is colourless or faintly blue from the presence of the blood pigment haemocyanin.

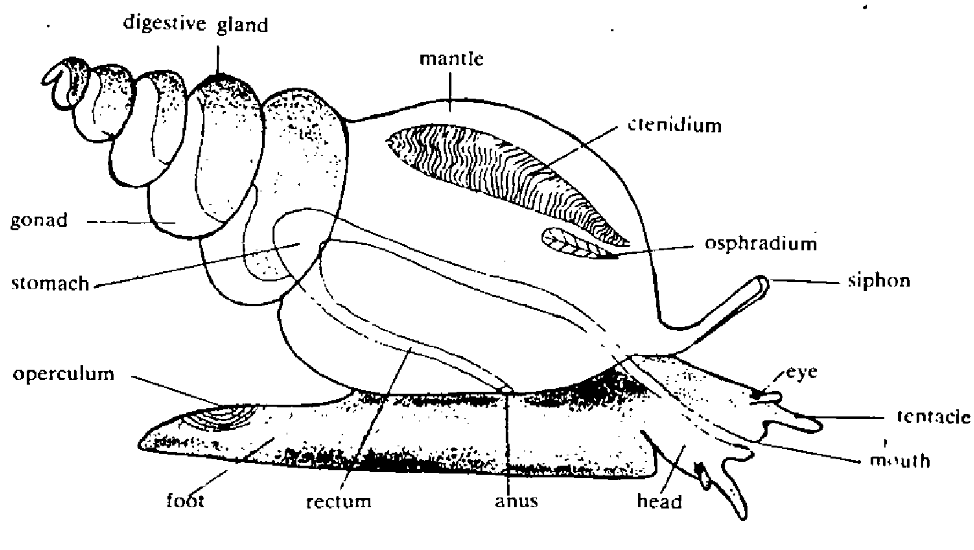


Fig. 8 Principal features of soft parts of a prosobranch gastropod.

Digestion and secretion. Most marine gastropods are herbivorous, feeding on algae and lichens, but others are carnivorous, feeding on other gastropods, bivalves, barnacles, polychaetes, or even fish; still others are deposit-feeding or parasitic. The digestive system consists of a *mouth* at the end of the snout or retractable proboscis opening into the *buccal cavity* or *pharynx*. The pharynx contains the *jaws* and the long ribbon of minute teeth, the *radula*, for rasping and grinding up food or as a boring organ. The radula is a very important feature in the classification of gastropods as it usually reflects the general characters of both the soft and hard parts and the feeding habits. In all but the air-breathing molluscs (Pulmonata) and the opisthobranchs, classification of living gastropods has been based on the radula, the various types of which are illustrated in Figure 9.

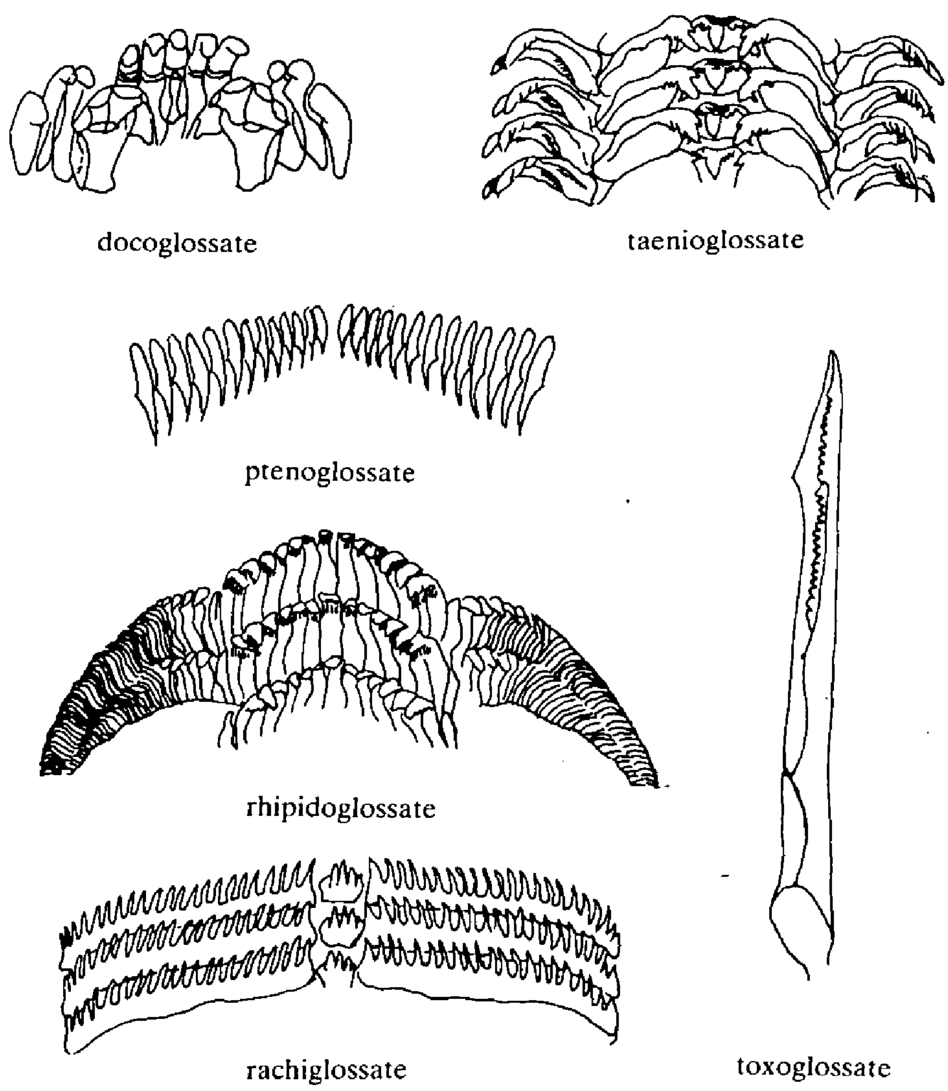


Fig. 9 Types of radulae.

Salivary ducts lead from the *salivary glands* to the *pharynx* near the *radular sac*. The masticated food passes from the pharynx into the *oesophagus* and thence to the *stomach* into which the *digestive gland* opens. From the stomach comes the *intestine* the first part of which in more primitive gastropods is the *style sac* in which the contents of the stomach are mechanically stirred up by the *style*—either a rod of loosely compacted faeces or a crystalline rod—which also contains an enzyme which helps complete the digestive process. The compacted faeces pass along the intestine and are discharged at the anus in the mantle cavity.

Gastropods have either one or, in most groups where there are two auricles, two *kidneys* which extract nitrogenous waste from the blood and pass it out into the mantle cavity either through a duct, the *ureter*, or through simple apertures. In most of the Archaeogastropoda the right kidney is used in the reproductive process, while in most advanced gastropods it is lost as a result of torsion.

Reproduction. Gastropods have a single *gonad*, and most members of the large subclass of the prosobranchs have the sexes separate, although there may be a reversal of sex during life. In both sexes the gonad lies adjacent to the *digestive gland* (Fig. 8) and the spermatozoa from the male gonad collect in the *genital duct* from where they pass in the meso- and neogastropods to the *prostate* gland and thence to the *penis*. In the female, the ova are conducted from the *ovary* by the *oviduct* to the *albumen gland* and, in many groups, the *jelly gland* or *capsule gland*. The ova then pass through the *vagina* to the female opening in the mantle cavity. Fertilisation may take place in the water, sperm and tiny eggs being released by the two sexes, or it may take place internally in the albumen gland. In this case the sperms enter either from the male organ during copulation or, if the sperms are discharged into the sea, by entering the female with the inhalant current.

The fertilised eggs of meso- and neogastropods are discharged in jelly masses or capsules and fixed or protected in a variety of ways. The young commonly hatch as larvae, beginning as a trochophore and rapidly developing into a veliger and undergoing torsion (p. 33). Some, however, pass through the larval stages in the capsule and hatch as juveniles.

Nervous system. The nervous system consists of a number of nerve centres or *ganglia*: the *cerebral* (receiving nerves from the eyes, tentacles and hearing organs), the *pleural* (from the body cavity, siphon) and the *pedal (from the foot).* There may be also a *visceral ganglion*, *subintestinal* and *supraintestinal ganglia* and a pair of *buccal ganglia*.

Hard parts

Most gastropods have a shell, closed at the *apex* and open at the *aperture*. The parts of one type of shell are illustrated in Figure 10. This type of shell

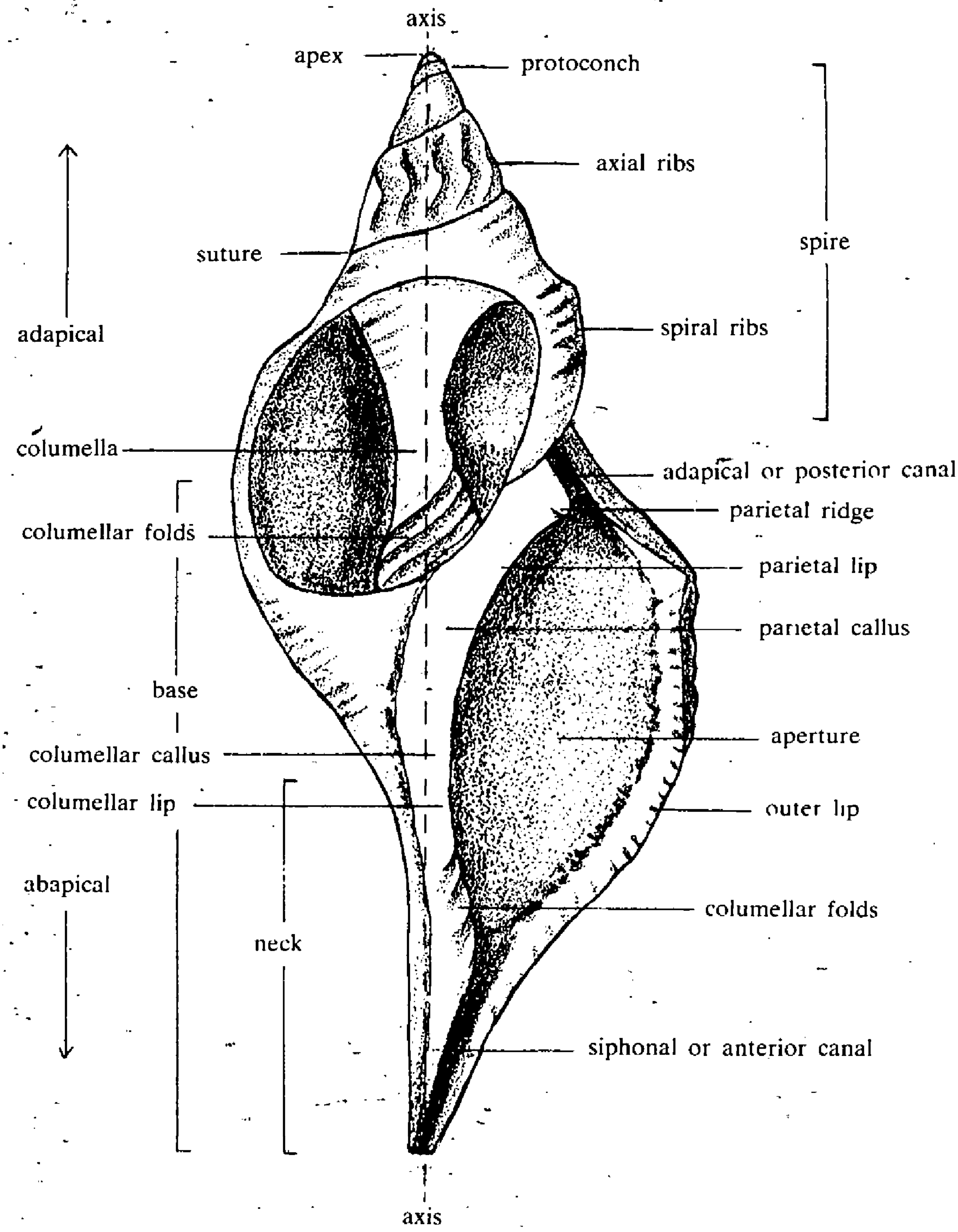


Fig. 10 Parts of shell of *Pleuroploca australasia.*

is coiled in a spiral about an *axis*, each coil being a *whorl*. The animal occupies all the whorls from the aperture to the apex. That part of the shell towards the apex is the *adapical* part, away from it the *abapical*; that towards the axis is *adaxial*, away from it *abaxial*. The earlier whorls form the spire and the *last whorl* with the aperture the last whorl (sometimes inappropriately called the body whorl). The line of junction of the whorls is the *suture* and the pillar formed by the adaxial wall as the shell is coiled is the *columella*. If the shell is tightly coiled the columella may be solid, if it is loosely coiled the columella is hollow, the cavity being known as the *umbilicus* and the shell is said to be umbilicate. The shell illustrated in Figure 10 is non-umbilicate. There may be folds in the columella known as the *columellar folds*, which persist throughout the whorls.

The gastropod shell may take a variety of forms or shapes which are illustrated in Figure 11.

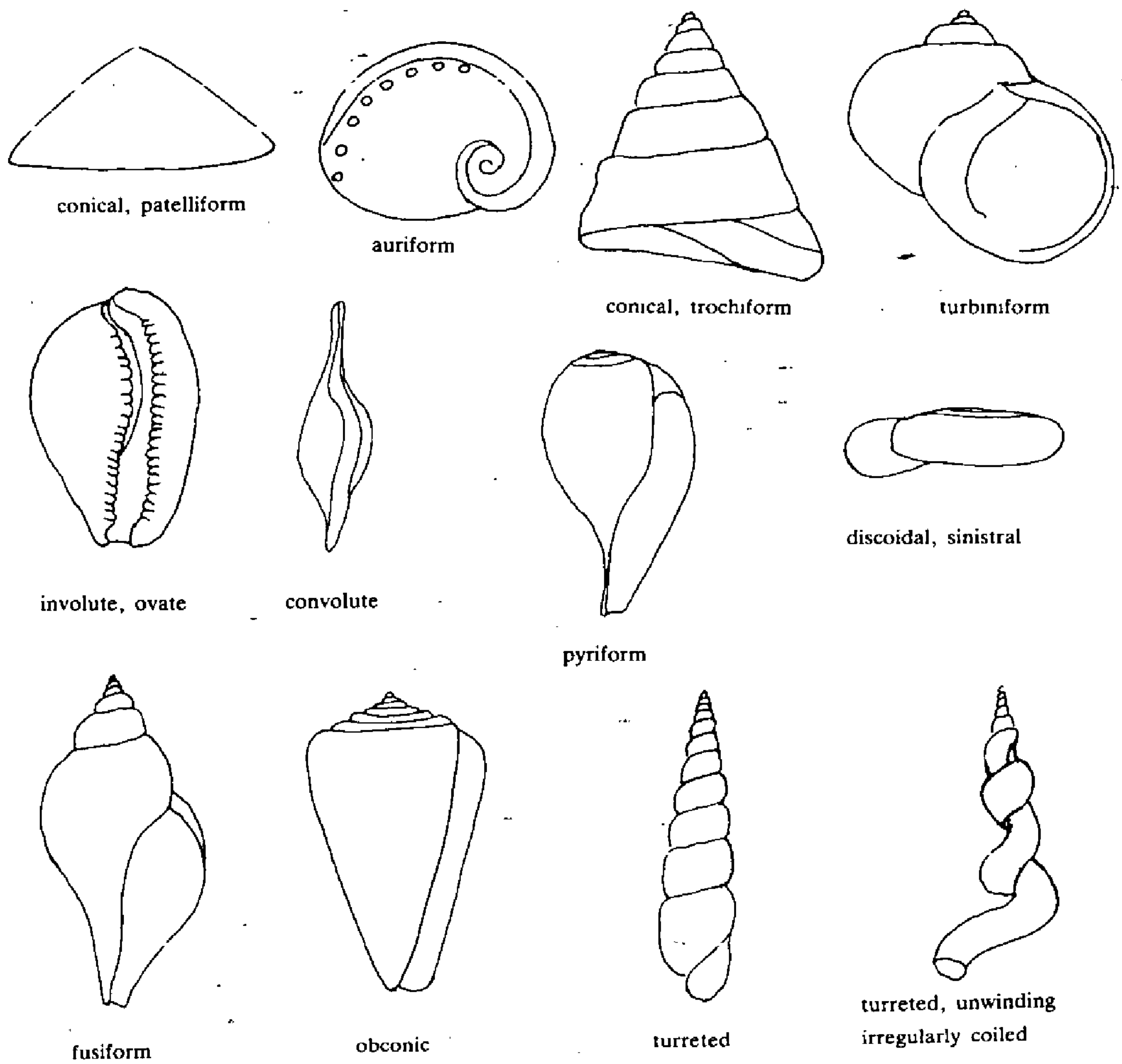


Fig. 11 Gastropod shapes.

The initial whorls of the shell form the *protoconch* and the rest of the shell the *teleoconch*.

The last whorl has the *base* extending from the adapical end of the aperture to the abapical end of the whorl. The narrow abapical part is known as the *neck*. The margin of the aperture is known as the *peristome* which may be entire or interrupted abapically by the *siphonal canal* or *siphonal notch* forming an outlet for the inhalant siphon. The cordlike band of curved lines near the base of the columella, the *siphonal fasciole*, represents successive positions of the siphonal notch. The outer or abaxial side is the *outer lip* and the inner or adaxial side the *inner lip*, divided into the *parietal lip* on the wall of the whorl and the *columellar lip* on the columella. The parietal and columellar lips may have a thin shelly coating called callus secreted by the mantle, and forming respectively the *parietal callus* and *columellar callus*.

In some species there is a short *parietal ridge* on the parietal lip delimiting the small so-called *adapical* or *posterior canal* which accommodates a small fold in the mantle edge to permit faecal products to directed away from the body.

The outer lip may be thickened to form a *varix* the series of varices remaining as conspicuous ridges across the whorls at intervals throughout the growth of the shell. They are not to be confused with axial ribs which may also be present.

The shell may have a relief pattern or *sculpture* of ribs (costae), threads (lirae), cords, granules, tubercles, spines and the like. Living gastropods have a distinctive colour pattern or *ornament*.

The operculum is usually horny, but some are calcareous. It is mostly flat and either spiral, concentric or lamellar. The Turbinidae, for example, have calcareous opercula which fit closely into the aperture. Calcareous opercula are often preserved as fossils, enabling the species to be identified in the absence of the shell.

Classification of the Gastropoda

The gastropods are divided into three subclasses - Prosobranchia, Opisthobranchia, and Pulmonata. Most of the common marine shells belong to the Prosobranchia which some authors prefer to divide into two orders: DIOTOCARDIA (= ARCHAEOGASTROPODA) and MONOTOCARDIA, with two suborders TAENIOGLOSSA (= MESOGASTROPODA) and STENOGLOSSA (= NEOGASTROPODA). For simplicity, classification into the three orders ARCHAEOGASTROPODA, MESOGASTROPODA and NEOGASTROPODA is used here. The Archaeogastropoda have the longest fossil record and the simplest structure; they are all marine, mostly herbivores, grazing on seaweed or scraping up detritus, but some graze on sponges. They are mainly conical, conispiral or top-shaped, and include the limpets, abalones and trochids (top shells). All except the Patellacea have a rhipidoglossate radula (Fig. 9). The Mesogastropoda are adapted to a variety of feeding habits, some grazing on seaweeds, some rasping algae from rocks, some picking up or capturing particles or feeding on faecal pellets of other animals. Some are carnivorous, feeding on foraminifera or using the proboscis to eat ascidians, starfish, sea urchins, other molluscs, etc. All Neogastropoda are carnivorous; they include the whelks, volutes, harps and the poisonous cones.

Subclass PROSOBRANCHIA

Mostly marine gastropods, but some are freshwater or terrestrial. Shell very varied in shape, operculum commonly present. Mantle cavity open to the front with anteriorly directed rectum, and anus on the right side. Ctenidium and osphradium on left side or paired with equal ctenidia and osphradia. Head with a single pair of tentacles with eyes at their bases. Sexes separate in most genera. The full effects of torsion are shown in that the auricle and ctenidia lie anterior to the ventricle and the visceral nerve cords cross.

Order ARCHAEOGASTROPODA

Superfamily PLEUROTOMARIACEA

Shell conispiral, discoidal, auriform or patelliform, mostly with exhalant notch, slit, trema or tremata; outer shell layer calcitic, inner shell aragonitic mostly nacreous; operculum horny and multispiral or absent. Ctenidia paired, right ctenidium reduced, no pallial genital organs, heart with two auricles, ventricle traversed by rectum, radula rhipidoglossate, i.e. a wide ribbon with numerous long marginal teeth for rasping seaweeds or sweeping up detritus. (Fig. 9).

Family HALIOTIDAE. Abalones, Ormers

The Haliotidae or ear shells are a very small family, all members of which are currently placed in one enus, *Haliotis*, but some subgenera appear to warrant full generic status.

Shell ear-shaped, with an eccentric low spire and broad aperture occupying most of the the underside; inhalant current is drawn in under the edges of the shell, passes over the gills and is discharged through a spiral row of small holes (tremata) in the shell wall which become infilled progressively during growth; interior nacreous, no operculum. The large, flat, muscular foot is the popular delicacy of commerce.

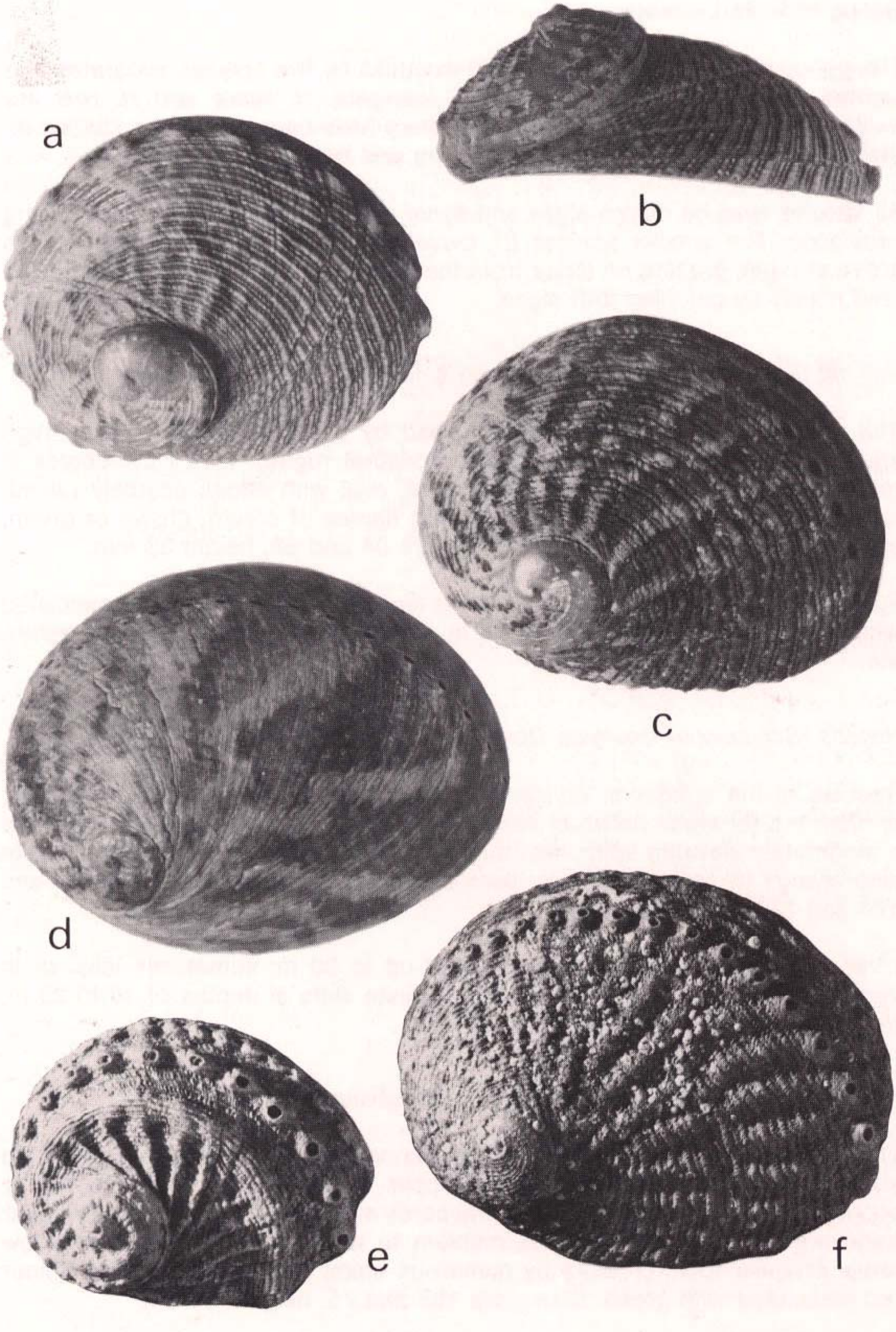


Fig. 12 a,b. *Haliotis (Exohaliotis) cyclobates* a. dorsal, b. side view; c. *Haliotis (Marinauris) roei*; d. *Haliotis (Schizmotus) laevigata*; e. *Haliotis (Padollus) scalaris*; f. *Haliotis (Notohaliotis) rubra*. x2/3.

Genus **Haliotis** Linnaeus

The genus is represented in southern Australia by five species separated into several subgenera. Three species *H. laevigata, H. rubra* and *H. roei* are exploited commercially as abalone and there have been numerous studies on their biology, population, ecology, feeding and behaviour.

All species feed on macro-algae and some will capture and consume floating seaweeds. The smaller species (*H. cyclobates, H. roei.* and *H. scalaris*) are active at night, grazing on algae from the rock surface, but the larger species feed mainly by catching drift algae.

Haliotis (Exohaliotis) cyclobates Peron & Lesueur Figs 12a, b;57c

The subgenus *Exohaliotis* is distinguished by the broadly oval shape, high spire and numerous spiral cords and collabral rugae. *H. (E.) cyclobates* is relatively small with holes (tremata) small, oval with edges scarcely raised, situated near the margin. Colour radiating flames of cream, brown or green, interior iridescent green or pink. Diameters 84 and 66, height 33 mm.

Found on rocks and on the shells of *Pinna bicolor* in sheltered waters associated with sea grasses from low tide to 15 m depth from Esperance WA to western Vic.

Haliotis (Schizmotis) laevigata Donovan Fig. 12d, Pl. 1e

Species of the subgenus *Schizmotis* are large, with evenly convex whorls, smooth but for weak collabral striae, holes small, flush. *H. (S.) laevigata* has a moderately elevated spire, less than one-fifth from the margin. Colour white with orange to scarlet radiating flames, interior silvery iridescent. Diameters 174 and 129, height 60 mm.

Lives on rocks of low relief at depth of up to 30 m, sometimes less, or in very rough water at the base of steep granite cliffs at depths of 10 to 25 m, from southern WA to eastern Bass Strait.

Haliotis (Notohaliotis) rubra Leach (= *improbulum* Iredale) Fig. 12f.

The subgenus *Notohaliotis* has the tremata on tubular projections situated on an angular elevation separating the upper whorl surface from the flat or concave outer face. Sculpture of spiral cords and threads crossed by irregular transverse ribs. *H. (N.) rubra* is medium to large, oval, wrinkled, with low radial irregular folds crossed by numerous spiral cords and threads. Colour red maculated with green. Diameters 102 and 75, height 40 mm.

It lives in crevices, caves, or on vertical rock faces from one to 20 m depth.

The relationship between this species and the western form *H. conicopora* is obscure; they possibly form a species complex ranging from southern WA to northern NSW.

Haliotis (Marinauris) roei Gray Fig. 12c; Pl.1d

The subgenus *Marinauris* is distinguished by having no angulation at the row of large holes, which are scarcely raised, sculpture of spiral cords. *H. (M.) roei* is of medium size, roundly oval, with a slightly elevated spire, sculpture of strong knotted spiral cords crossed by axial growth striae, holes small, scarcely raised; colour white maculated with olive-green and red. Diameters 90 and 72, height 30 mm.

Lives in narrow crevices in rocks on high energy coasts in the upper littoral zone to a depth of two to three metres, from Shark Bay WA to western Vic.

Haliotis (Padollus) scalaris Leach Fig. 12e; 63f

The subgenus *Padollus* (= *Neohaliotis* Cotton & Godfrey) has two rows of holes; it has a broad spiral rib on the adapical side of the inner row of holes, with a corresponding groove on the interior of the shell; thin short collabral lamellae on the adapical side then a second outer rib with holes on tubular projections. *H.(P.) scalaris* is of medium size, with a strong spiral rib and marginal nodose rib; reddish, variegated with olive green and green, interior silvery iridescent. Diameters 65 and 55, height 20 mm.

Lives under boulders or in narrow crevices on rough-water or sheltered coasts to depth of 50 m from Geraldton WA to Vic. and Tas.

Superfamily FISSURELLACEA

Shell ovately conical, porcelaneous, with a spiral protoconch and a hole, perforation, slit or notch for excretion or passage of exhalant current. Muscle scar horseshoe shaped, open anteriorly. Members of the superfamily are all algal or micro-algal feeders.

Family FISSURELLIDAE. Keyhole limpets

Genus **Scutus** Montfort

Shell large, depressed, shield-shaped, oblong without a hole, smooth.

Scutus antipodes Montfort Fig. 13g. The duck-bill limpet or elephant snail.

Shell thick, solid, white up to 83 mm long; animal black and tough, large, with a mantle fold which almost conceals the shell.

The species lives under boulders or in crevices from where it emerges at night to catch drift algae, on moderate to high energy coasts to a depth of about 20 m.

Genus **Tugali** Gray in Dieffenbach. False limpets

Oval-conical, with apex at the posterior third, slit anterior to the apex, represented by anterior sinus, surface radiate-cancellate, margin crenulate within.

Tugali cicatricosa A. Adams Fig. 13h

Elongate-oval, with a depressed apex resembling a scar; the mantle of the large orange-coloured animal covers the shell except for the cicatrix. Length 38, width 23, height 10 mm.

Found in association with an orange sponge, under rocks, on *Pinna* and jetty piles, on medium energy coastline to 20 m depth from southern WA to Vic. and Tas.

Genus **Notomella** Cotton

Oval, conical, apex posterior, recurved, both radial and concentric sculpture, anal slit long and narrow, fasciole raised.

Notomella candida (A. Adams)

Small, rather high, coarsely sculptured with about 22 to 25 strong radial ribs, the interspaces latticed by concentric lirae, margin denticulated by the ribs. Colour white, in life dark green. Length 13, width 10, height 6 mm.

This is the most common of the six species of *Notomella* occurring in southern Australia. It lives under stones to a depth of 70 m from Fremantle WA to Vic. and Tas.

Genus **Clypidina** Gray

Oval-conical, elevated, apex not recurved, anterior notch short, sculptured with radial ribs.

The subgenus *Montfortula* has the internal groove distinct.

Clypidina (Montfortula) rugosa (Quoy & Gaimard) Fig. 13i-k; 57b

Small, apex almost central, sculptured with about 15 primary radiating ribs, with two or three secondary ribs rising by intercalation between them, crossed and roughly granulated by concentric ridges. Colour greyish-brown, bleaching to white, interior white or greenish, muscle scar outlined with olive green. Length 18, width 13, height 9 mm.

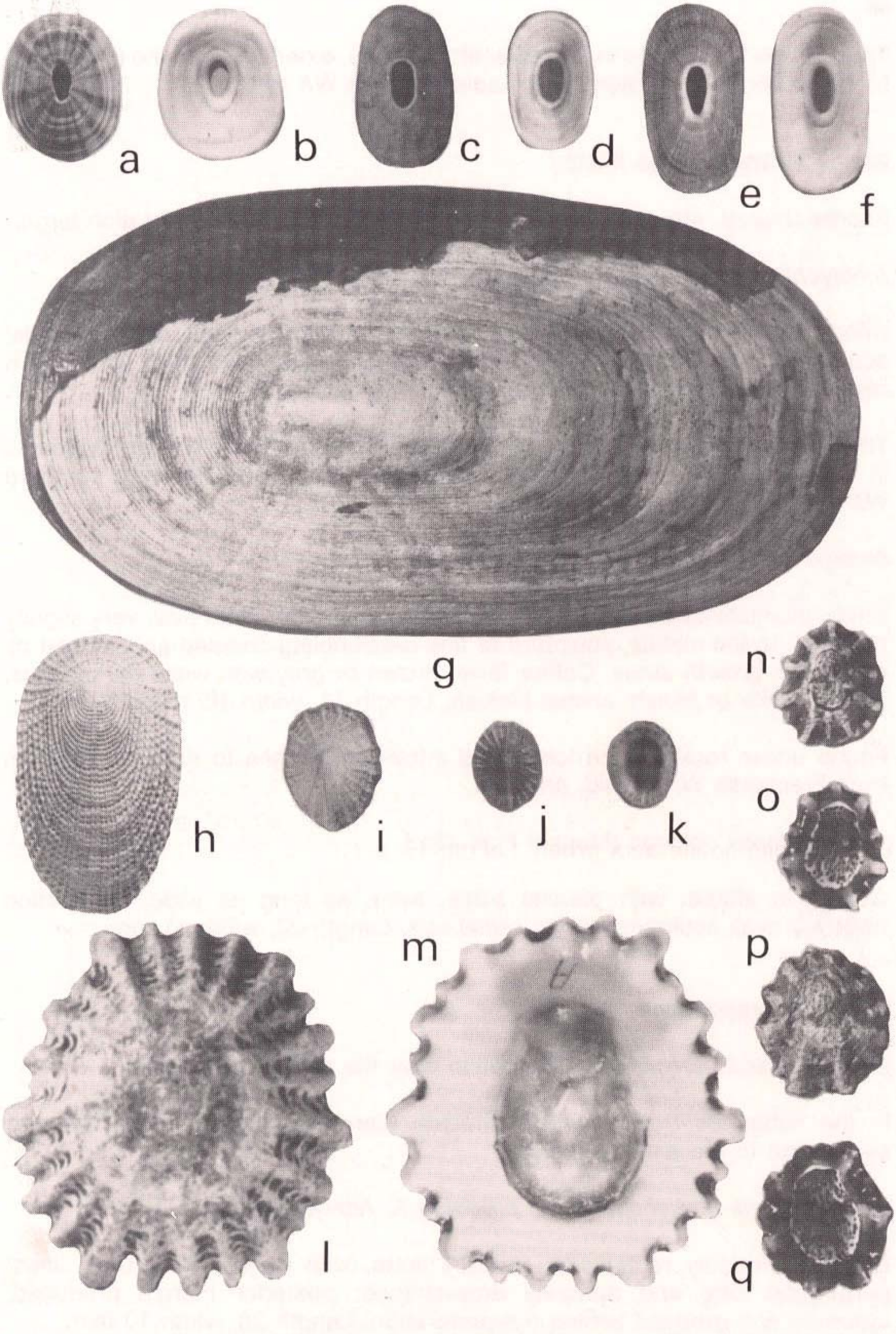


Fig. 13 a,b. *Amblychilepas javanicensis;* c,d. *Amblychilepas nigrita*; e,f. *Amblychilepas oblonga;* g. *Scutus antipodes; h. Tugali cicatricosa;* i-k. *Clypidina (Montfortula) rugosa;* l,m. *Patelloida alticostata;* n-q. *Patelloida latistrigata;* x1.

The species is common in the lower littoral zone, extending into the infralittoral fringe to about 10 m depth, from southwestern WA to Qld.

Genus **Amblychilepas** Pilsbry

Saddle-shaped, elevated at both ends, margins thickened, perforation large.

Amblychilepas javanicensis (Lamarck) Fig. 13a,b; Pl.1b

Short, roundly quadrate, hole pear-shaped, a little in front of the middle; sculpture of fine radial and concentric striae; colour fawn, with light-brown rays. Length 25, width 17, height 7 mm.

The species is common, living under rocks on medium to high energy coasts in the lower littoral and infralittoral zones to a depth of 10 m from southern WA to NSW and Tas.

Amblychilepas nigrita (Sowerby) Fig. 13c,d

Small, elongate-oval, depressed with thickened margin, hole oval, very slightly posterior to the middle, sculpture of fine radial riblets crossed and latticed by concentric growth striae. Colour fawn, brown or grey with weak darker rays, interior white or bluish; animal pinkish. Length 14, width 10, height 4 mm.

Found under rocks in the lower and infralittoral zones to a depth of 70 m from Fremantle WA to Qld. and Tas.

Amblychilepas oblonga (Menke) Figs 13e,f

Oblong in shape, with parallel sides, twice as long as wide, perforation narrowly oval; sculpture of fine radial ribs. Length 22, width 11 mm.

Genus **Macroschisma** Sowerby

Shell long and narrow with perforation near the posterior margin.

In the subgenus *Dolichoschisma* Iredale there is a broad ridge from the perforation to the anterior margin.

Macroschisma (Dolichoschisma) producta A. Adams Fig. 63e

Elongate, roundly rectangular, radially lirate, with concentric growth lines; perforation long and narrowly drop-shaped; posterior margin produced, upturned and grooved behind the perforation. Length 28, width 10 mm.

Lives below tide level to 40 m.

Superfamily PATELLACEA

Shell conical or cap-shaped, bilaterally symmetrical, without perforation, slit or notch, which distinguishes them from the Fissurellacea, no operculum, with or without a single bipectinate ctenidium, heart with a single auricle, radula long, with claw-like teeth.

From their general shell shape and habit, the Patellacea are likely to be confused with the pulmonate limpets or siphons (p. 124). The shell of the Siphonariidae has an external double ridge corresponding to an internal siphonal groove and sinus, the muscle scar is horse-shoe shaped with the pulmonary groove on the anterior side. Anatomically the primitive patellids differ markedly from the air-breathing siphonariids.

Family ACMAEIDAE. Limpets

Shell porcelaneous, without accessory apertures or slits; a single bipectinate ctenidium; radula without rachidian teeth. Three genera of Acmaeidae—*Notoacmea, Collisella and Patelloida*—were revised by Ponder & Creese (1980), which should be consulted for a more complete coverage of the genera and the synonymies of the species. The nomenclature previously used in southern Australia is completely confused.

Genus **Patelloida** Quoy & Gaimard
Radula with two marginal teeth.

Patelloida alticostata (Angas)

Large, solid, with approximately 18 radial ribs, shell whitish or grey-green, with darker ribs and fine black lines in the interspaces between the ribs, interior white, margin black. Commonly covered with algal growth. Animal dull yellow grading to brown. Length 40, width 37, height 15 mm.

P. alticostata is one of the commonest temperate limpets in southern Australia, occurring on exposed rocks feeding on algae in the lower littoral and shallow sublittoral zones from Geraldton WA to the mid-north coast of NSW.

Patelloida insignis (Menke) Fig. 15g,h,i

Size moderate, shell rather thin, oval, elevated, sculptured with numerous fine, smooth, radial lirae equal to or narrower than the interspaces, apex slightly anterior, anterior slope straight, posterior slope straight or slightly convex; colour whitish, overlain with variable dark brown radial markings often in the form of a Maltese Cross. Interior porcelaneous, spatula brown and bluish, clearly delineated, external pattern showing through. Length 18, width 13, height 8 mm.

Found in the lower littoral and sublittoral zones on sheltered coasts from Geraldton WA to SA and Tas.

Patelloida latistrigata (Angas) Figs. 13n-q

Small, elevated, with 12 to 15 ribs, often pitted and worn. Colour brown, interior porcelaneous, with spatula characteristically spotted with blue or brown and often bordered with white. Length 23, width 17, height 8 mm.

Lives in holes and crevices on medium to high energy coasts in the mid- and upper littoral zones from eastern SA, Tas., to southern Qld.

Patelloida nigrosulcata (Reeve) Fig. 15d, e; 63g,h

Oval, with forty to fifty ribs; white or cream often with a light brown tinge, interior creamy white, porcelaneous, sometimes with a few brown blotches. Length 41, width 32, height 21 mm.

Lives in the lower littoral and sublittoral zones, often on the shells of other gastropods (notably *Patella laticostata*) from Geraldton WA to western SA.

Genus **Collisella** Dall
Radula with one marginal tooth.

Collisella mixta (Reeve)

Solid, relatively tall, apex at the anterior one-third, sculptured with irregular radial ribs, usually eroded, or nearly smooth; colour grey-brown to yellowish with dark rays or reticulations; interior white blotched with dark brown on the spatula, margin dark brown. Length 23, width 18 mm.

Common in holes and crevices on exposed rock platforms in the mid- and upper littoral zones from eastern SA to Lakes Entrance Vic. and Tas.

The species has been recorded under a variety of names in SA.

Genus **Notoacmea** Iredale
Radula with no marginal teeth

Notoacmea flammea (Quoy & Gaimard) Fig. 14f,g

Size small to medium, thin, flattened to conical, apex slightly anterior, anterior slope slightly concave, posterior slope gently convex; sculpture of widely spaced, minutely granular, fine, radial striae. Colour cream to black with reticulate or radial pattern of brown and black, interior white to bluish with exterior pattern showing through, particularly near the margin. Length 16, width 14, height 6 mm.

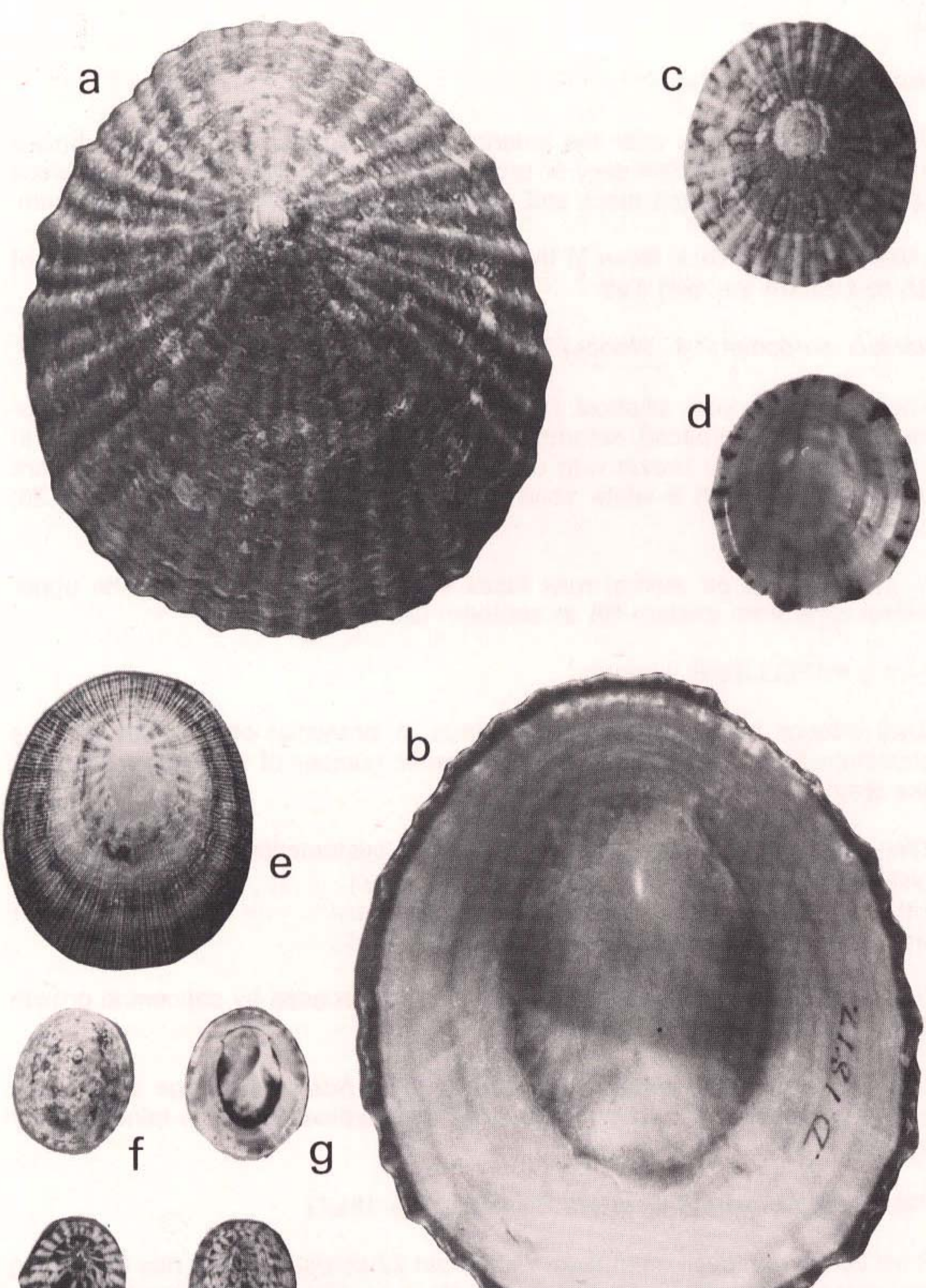


Fig. 14 a,b. *Cellana solida* a. apical view, b. interior; c,d. *Cellana tramoserica* c. apical view, d. interior; e. *Patella (Scutellastra) peronii;* f,g. *Notoacmea flammea* f. apical view, g. interior; h.i. *Notoacmea petterdi;* x1

Notoacmea mayi (May)

Shell thick, low, apex near the anterior margin; surface smooth, light brown to grey mottled with dark grey or brown; interior with white to brown or black spatula, margin spotted black and yellow. Length 25, width 21, height 8 mm.

Lives on vertical rock faces in the upper littoral zone from the southeast of SA to western Vic. and Tas.

Notoacmea petterdi (T. Woods) Fig. 14 h,i

Shell of medium size, elliptical, flattened, apex anterior, slopes convex, sculptured with widely spaced, smooth, radial riblets crossed by concentric growth ridges. Colour light brown with darker radiating bands, interior pale to dark brown, usually with a white zone inside the margin. Length 23, width 20, height 8 mm.

N. petterdi lives on vertical rock faces exposed to ocean surf in the upper littoral zone from eastern SA to southern Qld and Tas.

Family PATELLIDAE. Limpets

Shell interior iridescent to porcelaneous; a branchial cordon but no true ctenidium. Radula docoglossate with a small number of lance-like and claw-like teeth.

The general biology was described and the systematics of the family were revised by Powell in 1973.

Genus **Patella** Linnaeus

Round to elliptical in section, with radial ridges crossed by concentric growth lines; branchial cordon complete.

Members of the subgenus *Scutellastra* H. & A. Adams are large solid shells with a porcelaneous interior. They differ from typical *Patella* in minor radular details.

Patella (Scutellastra) laticostata Blainville Figs 15a,f,j

Shell very large, oval, often high, with about 22 coarse primary ribs increasing by intercalation to about 50. External surface usually eroded to greenish-grey, internally with a well defined spatula either white or brownish maculated with brown in a marginal border. As much as 100 mm long, 82 mm wide, 47 mm high.

Inhabits the lower littoral zone from southwestern Australia to Port Lincoln SA.

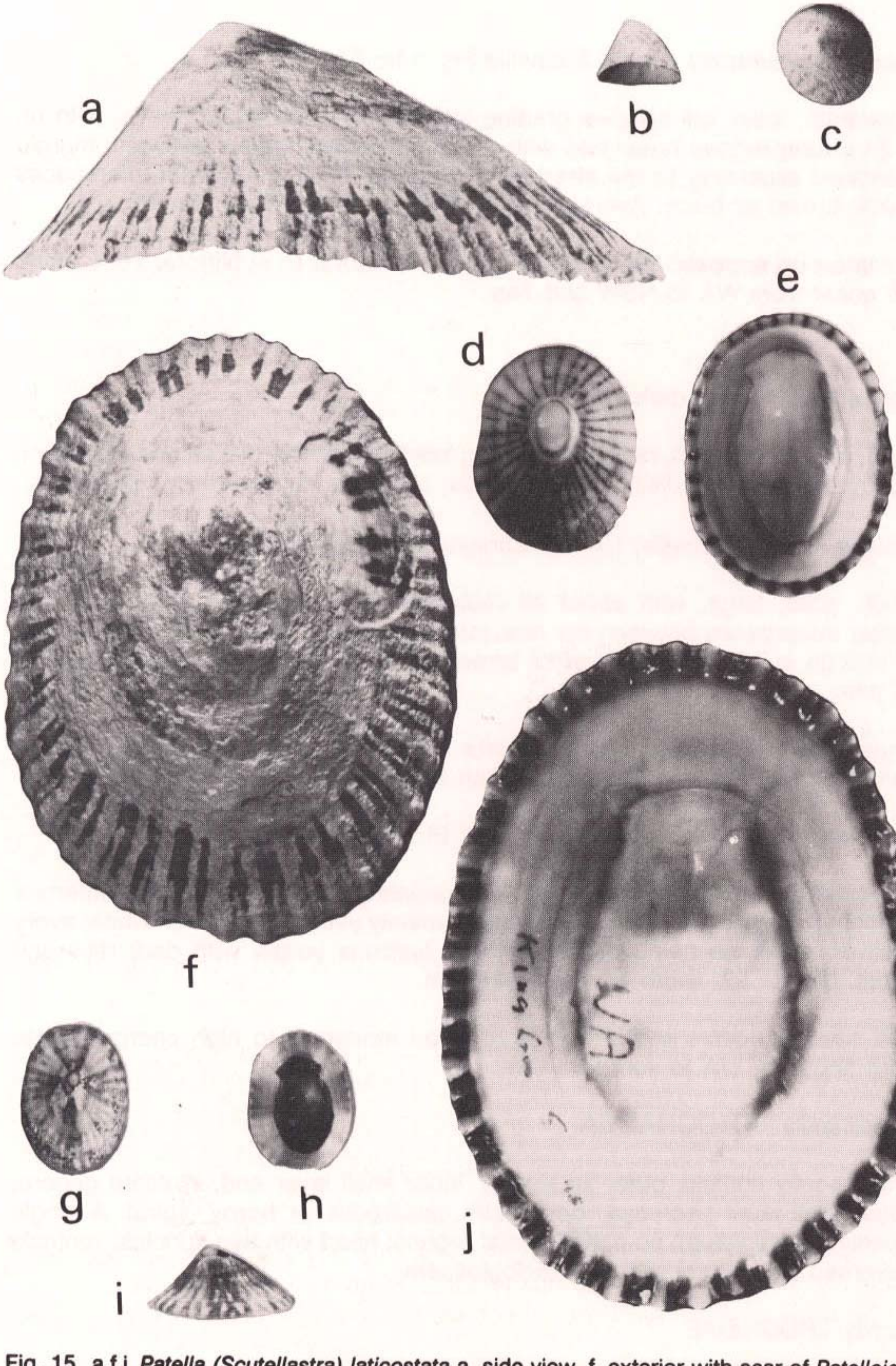


Fig. 15 a,f,j. *Patella (Scutellastra) laticostata* a. side view, f. exterior with scar of *Patelloida nigrosulcata,* j, interior; b,c. *Patelloida profunda calamus* b. side view, c. apical view; d,e. *Patelloida nigrosulcata;* g,h.i. *Patelloida insignis* g. apcial, h. internal, i. side view; x1.

Patella (Scutellastra) peronii Blainville Fig. 14e; 57a

A variable, solid, tall species grading into *P. (S.) squamifera* Reeve, with up to 24 strong rugose radial ribs with a few secondary radials between; margin scalloped according to the strength of the ribs. Ribs white, with interspaces yellow-brown or black. Average length 35, width 28, height 15 mm.

Common on exposed platforms in the lower littoral to sublittoral zone along the coast from WA to NSW and Tas.

Genus **Cellana** H. Adams

Solid, apex subcentral, radial ribs strong; interior brilliantly glazed and iridescent. Radula very strong, distinct from *Patella*; branchial cordon discontinuous.

Cellana solida (Blainville) (= *C. rubraurantiaca*) Fig. 14a

Thick, solid, large, with about 26 radiating ribs. Light grey to orange with darker interspaces between the ribs, interior grey in young shells, yellow, pink or orange in adults with claret or brown margin. Length 78, width 65, height 34 mm.

Lives on rocks on high energy coasts or open beaches in the lower littoral zone from the eastern Great Australian Bight to Vic. and Tas.

Cellana tramoserica (Holten) Fig. 14c,d; Pl.1c

Thick, large, variable, with about 36 radiating ribs crossed by numerous concentric growth lines. Colour variable, mainly yellow, orange or white, every third or fourth rib being darker. Interior lustrous yellow with dark rays and spots. Length 53, width 45, height 28 mm.

The species occurs in the littoral zone on moderate to high energy coasts from southern WA to southern Qld.

Superfamily TROCHACEA

Shell mostly conical, outer lip simple, inner shell layer and, in some genera, outer shell layer nacreous; operculum calcareous or horny, spiral. A single bipectinate ctenidium, no pallial genital organs; heart with two auricles, ventricle traversed by rectum; radula rhipidoglossate.

Family TROCHIDAE

Outer lip mostly discontinuous with the outer and columellar lips in different planes. Operculum horny, thin, multispiral, with a central nucleus.

This large family includes top shells, kelp shells and peri-winkles, represented by numerous genera and species living among seaweeds or on rocks among weeds. Large numbers of kelp and top shells are frequently washed up on beaches along strand lines. Most of them are herbivorous, but a few species of *Calliostoma* feed on hydroids. One feeds on diatoms in the littoral zone and detritus in the sublittoral.

Genus **Granata** Cotton

Ear-shaped with a low spire and few whorls; aperture large; sculpture of numerous scaly or beaded spiral ridges.

Granata imbricata (Lamarck) Figs 16a, b; Pl.1k

Whorls four, rapidly widening, strongly sculptured with fine scaly ribs; aperture horizontal, transversely oval, interior nacreous, spirally incised by external ribs. Diameters 31 and 25, height 15 mm.

Commonly found on medium to high energy coasts in aggregations under rocks on silty reefs in the littoral zone to 20 m depth.

Genus **Monodonta** Lamarck

Thick shelled, spirally sculptured. In *M. (Austrocochlea)* the spiral ribs are widely spaced; columellar tooth weak.

Monodonta (Austrocochlea) constricta Lamarck. Periwinkle. Figs 16c,d, 63l, Pl.1f

A moderate sized turbiniform solid shell with rounded whorls, sculptured with five low, widely spaced spiral ridges and numerous oblique growth striae. A weak tooth at the base of the columella. Colour pattern varying from purplish grey to grey with wavy axial bands of dark purple and brown. Height 32, diameter 28 mm.

This very common species is found in a variety of habitats on low to medium energy coasts in the littoral zone. The large *torri* form is typically found on the pneumatophores and lower trunks of mangroves, the smaller forms are common on *Heterozostera* seagrass on mudflats and in sheltered silty pools.

A number of other specific names have been applied to this common and variable shell—*M. zebra, Trochus taeniatus, Labio porcatus, M. obtusa, Trochocochlea multicarinata, Austrocochlea torri*—but these are now generally regarded as synonyms of *M. constricta*.

Genus **Bankivia** Krauss. 'Kelp shells'

Slender, high spired, nearly smooth, brilliantly nacreous, columella with a weak fold.

Bankivia fasciata (Menke) Fig. 16j,k; Pl.10h

Small, slender, elongate-conical with a blunt apex. Mostly white, pink to purple, variously ornamented, but markedly with narrow zigzag oblique dark lines or spiral bands. About nine flatly convex whorls, the last whorl rounded. Aperture ovate, somewhat produced below. Height varies from 15 to 35 mm and diameter 6 to 13 mm.

This very common species is found in large aggregations in fine sand near seagrass, on low to medium energy coasts, from 1 to 5m depth. It is commonly washed up by the tide in countless millions, forming a colour line at high-tide mark.

Genus **Cantharidus** Montfort

Small to medium size, with a columellar fold of varying strength. The subgenus *Phasianotrochus* has a well developed fold and is by many authors given full generic rank.

South Australian species are colourful shells with a nacreous inner layer, commonly known as necklace or kelp shells. They are grazers living among kelps, laminarians and seagrasses, mostly in the littoral zone. The colour patterns vary within each species, but they may be broadly distinguished as follows:
Cantharidus (Phasianotrochus) apicinus (Menke) Fig. 78h

Finely spirally striate, colour grey or brownish yellow with numerous oblique axial brown lines. Height 20 mm.

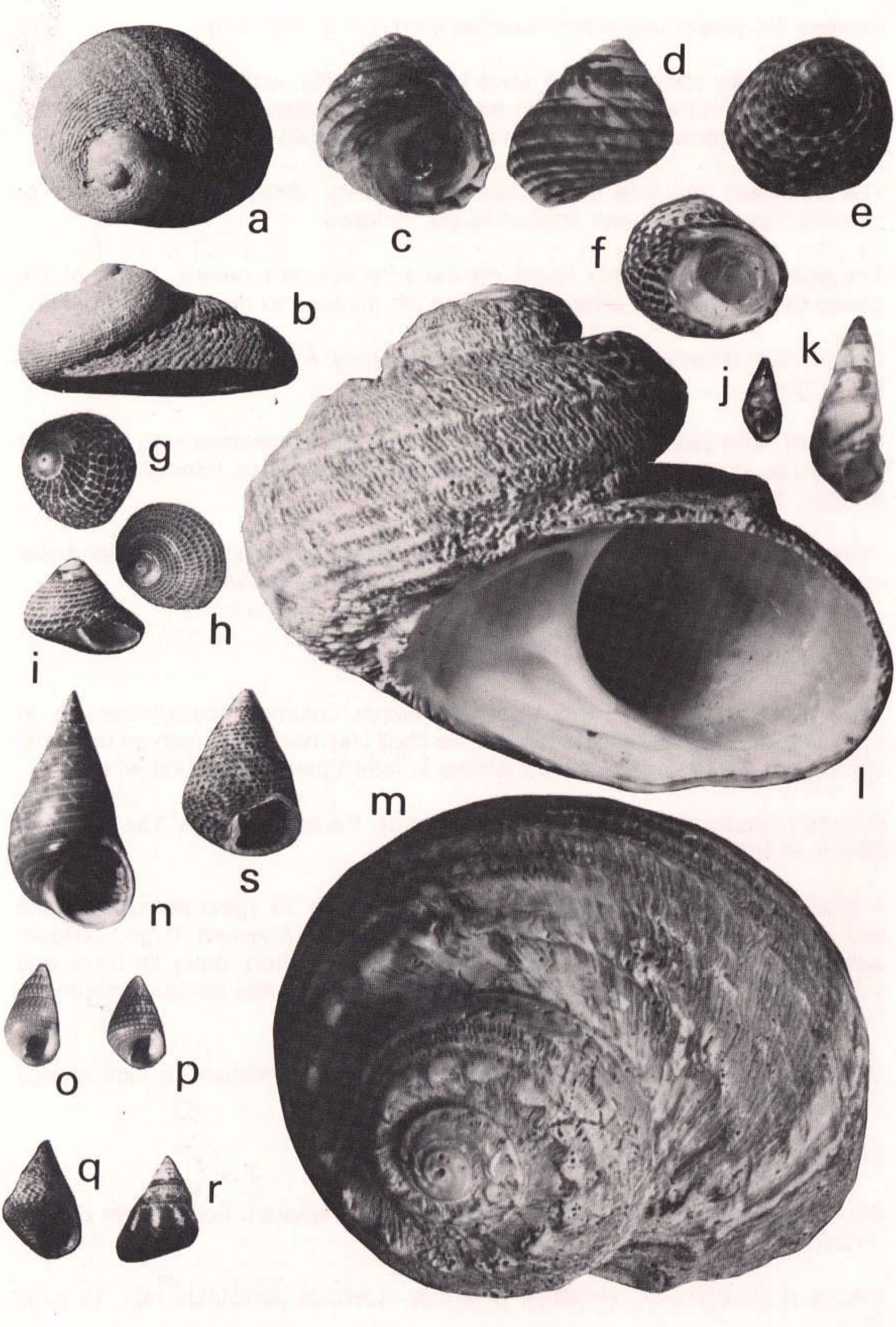
Commonly found on the kelp *Ecklonia radiata.*

Cantharidus (Phasianotrochus) bellulus (Dunker)

Shining, pinkish to brown with orange-red spiral bands, between the bands pairs of white, axial lines, often curved in a figure 8; outer lip lirate within. Height 15 mm.

Commonly found on brown algae, particularly *Scaberia*, on medium energy coasts.

Fig. 16 a,b. *Granata imbricata* a. apical view, b. side view, c,d. *Monodonta (Austrocochlea) constricta*; e,f. Diloma *(Fractarmilla) concamerata* e. apertural, f. apical view; g-i *Diloma (Chlorodiloma) adelaidae* g,h. apical view showing variation in colour pattern,i. apertural view; j,k. *Bankivia fasciata* j. x1, k.x2; l,m. *Turbo (Ninella) torquatus* l. apertural, m. apical view; n. *Cantharidus (Phasianotrochus) eximius*; o,p. *Cantharidus (Phasianotrochus) irisodontes*; q.r. *Thalotia (Prothalotia) ramburi*; s. *Thalotia conica*; x1 unless otherwise stated.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Cantharidus (Phasianotrochus) eximius (Perry). Fig. 16n, 57g

Microscopically spirally striate, fawn to brown in life, with narrow spiral lines; aperture brilliant iridescent green and lirate within. Beach specimens are red, due to a breakdown of the brown pigment. Height 40 mm.

The ornament and size of this species are very variable and a number of specific names have been applied to the varieties.

The species is commonly found on the kelp *Ecklonia radiata*, kelps of the genus *Cystophora* and other laminarians on medium to high energy coasts.

Cantharidus (Phasianotrochus) irisodontes (Quoy & Gaimard) Figs. 16o,p;63 j,k; Pl.10e

Greenish, with yellow, pink, red or brown tonings, sometimes with reddish or olive-green axial lines crossed by white-spotted spiral lines. Interior of aperture smooth, brilliantly iridescent. Height 15 mm.

This very common species is found on seagrasses of the genera *Amphibolus* and *Posidonia*, and is usually encrusted with marine growths.

Genus **Diloma** Philippi

Spire moderately high to low, aperture oblique, columella weakly dentate. In *D. (Chlorodiloma)* the spire is higher, the shell less nacreous, with an umbilical chink. In *D. (Fractarmilla)* the peristome is interrupted by the last whorl.

Diloma (Fractarmilla) concamerata (Wood). Periwinkle Figs 16e,f; 57d,e; 63m,n; Pl.1h

A globose-conical thick and solid *Fractarmilla*, with 13 spiral cingulae on the last whorl. Colour black tessellated with yellow. Aperture large, oblique, nacreous within, peristome interrupted by the last whorl, outer lip black and yellow, within which there is a nacreous band then a white opaque thickening. Height 25, diameter 25 mm.

Gregarious on or under rocks in sheltered areas on medium to high energy coast in the littoral zone.

Diloma (Fractarmilla) rudis (Gray) Figs 57f, 68c

Similar to *Diloma (Fractarmilla) concamerata,* but smooth. Found from Gulf St Vincent to WA.

Diloma (Chlorodiloma) adelaidae (Philippi). Adelaide periwinkle Figs 16 g,h,i; Pl.1i

Relatively small, thick, narrowly umbilicate, with six spiral grooves on the last whorl and five on the base, axially marked with regularly spaced white lines between the grooves. Protoconch usually bright orange. Height 17, diameter 18 mm.

On rocks or weed in pools in the lower littoral zone and infralittoral fringe to 4 m depth.

Genus **Thalotia** Gray. Top shells

Elevated-conical shells, solid, granular or spirally ribbed, periphery rounded, aperture small.

Thalotia conica (Gray) Figs 16s; 63i; Pl.10f

A small, solid, elevated-conical shell, varying in colour but mostly pinkish with reddish-brown fine, even, weakly granular spiral ribs, from five to six or more on the whorls, six on the base; ribs tessellated by whitish axial lines and on the base by fine closely spaced axial threads; protoconch smooth, of 2½ whorls, red in colour. Aperture small, quadrate- ovate, outer lip thick, dentate within, columella straight, crenulate above and truncate with a prominent tooth below. No umbilicus. Height 28, diameter 13 mm.

Commonly found on seagrasses of the genera *Amphibolus* and *Posidonia*, usually covered with marine incrustations.

Most members of the subgenus *Prothalotia* are swollen above the suture with otherwise flat whorls and base, which are spirally lirate. They are colourful small shells, commonly cast up on the beach or on weed in rock pools.

Thalotia (Prothalotia) ramburi (Crosse) Figs 16q,r; Pl.10g

Shell solid, elevated-trochoid and tending to be gradate, coarsely spirally lirate throughout, considerably swollen above the suture, non-umbilicate. Colour pattern variable but commonly red, particularly on death, with white axial rays; aperture roundly rhomboidal, white inside. Height 15, diameter 10 mm.

In the subgenus *Odontotrochus* the periphery is angulate and the spire tall.

Thalotia (Odontotrochus) chlorostoma (Menke)

Shell solid, trochiform, with flat whorls angulate at the periphery, whorls and base each sculptured with from 10 to 12 spiral lirae the interspaces crossed by microscopic collabral threads; aperture rhomboidal, prosocline; colour reddish brown tinged with buff and olive green, maculated with white. Height 24, diameter 20 mm.

Genus **Clanculus** Montfort

Mostly rather small, rounded, turbiniform shells, usually with beaded sculpture, columella with a conspicuous tooth, umbilical pit bordered with a crenulate ridge. Aperture crenulate within.

Clanculus (Euriclanculus) flagellatus Philippi Figs 17a-c

Shell of medium size, deeply umbilicate with flatly convex whorls, the last whorl roundly angulate at the periphery, base flattened, sculpture of beaded spiral ribs, six on the penultimate whorl, eight on the last whorl and eight to nine finely beaded spirals on the base; outer lip prosocline, plicate and dentate within, columella oblique, dentate, with a strong elevated bifid tooth at the base. Colour whitish with more or less transverse irregular reddish splashes. Height 11, diameter 18 mm.

Commonly found under rocks on reefs with *C. (E.) limbatus*, preferring silty reefs on medium to high energy coasts to a depth of 20 m.

Clanculus (Euriclanculus) limbatus Quoy & Gaimard
Figs 17d-g, Pl.1j

Shell of medium size, turbiniform, apex acute, carinate at the periphery, with six beaded spiral ribs on the penultimate whorl and last whorl, that on the keel on the last whorl being somewhat larger, and eight to ten on the base. Aperture quadrate, outer lip prosocline, thick, strongly lirate within with about ten long lirae and short ones intercalating between; columella oblique, entering the oblique umbilicus, denticulate, with a small bifid tooth at the base. Colour white, yellow or pink, spotted and maculated with reddish brown. Height 14, diameter 18-21 mm.

Commonly found under rocks on reefs on medium to high energy coasts to 20 m depth.

Clanculus (Mesoclanculus) plebejus (Philippi) Figs 17n-p; 68f

Shell small, turbiniform, umbilicate, protoconch small, adult whorls three, strongly ribbed with four or five beaded spiral ribs, the two below the suture close together, the third in the middle of the whorl and the fourth and fifth just above the periphery and often contiguous, interspaces wide, with fine microscopic spiral lirae crossed by oblique fine axial lirae in the interspaces; outer lip curved, prosocline, denticulate, lirate deep within; columella strongly concave, smooth with a blunt denticle near the base, umbilical margin coarsely dentate. Colour pink, grey or light brown with black dots on the ribs. Height 7, diameter 11 mm.

Found on reefs under rocks in relatively calm waters of the littoral zone.

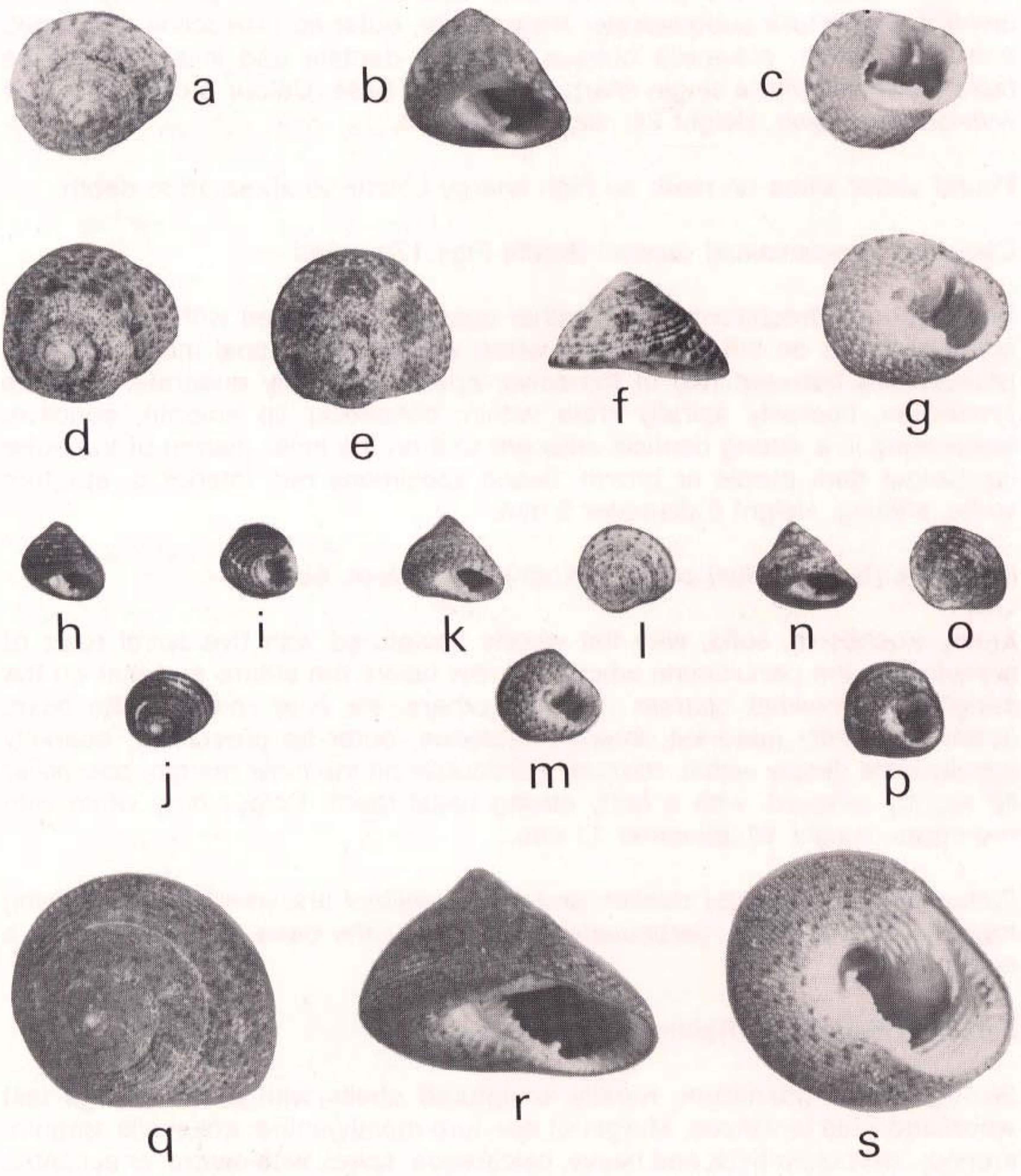

Fig. 17 a-c. *Clanculus (Euriclanculus) flagellatus*; d-g. *Clanculus (Euriclanculus) limbatus*; h-j. *Clanculus (Isoclanculus) dunkeri*; k-m. *Clanculus (Isoclanculus) philippi*; n-p. *Clanculus (Mesoclanculus) plebejus*; q-s. *Clanculus (Macroclanculus) undatus*; x1.

Clanculus (Macroclanculus) undatus (Lamarck) Figs 17q-s; Pl.1n

Shell large, turbiniform, falsely umbilicate, whorls rounded, protoconch small, adult whorls five, evenly sculptured with fine beaded ribs, about ten on the penultimate whorl, 25 on the last whorl and base, becoming finer and closer from the suture to the periphery, then coarser from the periphery to the umbilicus; aperture subquadrate, lirate within, outer lip prosocline, thickened and lirate within, columella oblique, strongly dentate and inserted into the false umbilicus with a single sharp tooth at the base. Colour brown, speckled with darker brown. Height 24, diameter 31 mm.

Found under slabs on reefs on high energy coasts to about 15 m depth.

Clanculus (Isoclanculus) dunkeri (Koch) Figs 17h-j; 68d

Small, roundly trochiform, solid, rather coarsely sculptured with four rows of spiral granules on the penultimate whorl with an occasional microscopically granular lira between two of the rows; aperture roundly quadrate, outer lip prosocline, coarsely spirally lirate within; columellar lip smooth, concave, terminating in a strong denticle adjacent to it on the inner margin of the outer lip. Colour dark purple or brown, beach specimens red, interior of aperture white, shining. Height 9 diameter 9 mm.

Clanculus (Isoclanculus) philippi (Koch) Figs 17k-m; 68e

Small, trochiform, solid, with flat whorls sculptured with five spiral rows of granules on the penultimate whorl, the row below the suture and that on the periphery somewhat coarser than the others, six finer rows on the base; aperture roundly quadrate, interior nacreous, outer lip prosocline, coarsely spirally lirate deeply within, coarsely denticulate on the inner margin, columellar lip slightly reflexed, with a fairly strong basal tooth. Colour dirty white with red spots. Height 10, diameter 11 mm.

Clanculus (Isoclanculus) dunkeri and C. (I.) philippi are weed dwellers, living together in sea grass, particularly *Posidonia*, at the base of the blades to a depth of 15 m.

Family TURBINIDAE Rafinesque. Turban shells

Strong, solid, turbiniform, mostly sculptured shells with a wide, large last whorl and wide umbilicus. Margin of aperture mostly entire, columella smooth, arched; operculum thick and heavy, calcareous, spiral, with central or eccentric nucleus, convex outwards.

Genus **Turbo** Linnaeus

Generally large shells with rounded whorls and a convex base; smooth to strongly sculptured, aperture rounded, inner lip calloused, operculum with a flat inner face.

Turbo (Ninella) torquatus Gmelin Figs. 16l,m; 64a,b

A large thick, turban shell with coarse spiral ribs and a row of coarse nodules below the suture, all crossed by oblique axial growth lamellae. Colour greyish-green, aperture white within, inner layer nacreous. Umbilicus wide, deep, bordered by columellar callus with two broad spiral grooves, Operculum sculptured, with four whorls, nucleus eccentric, internally brown, flat, externally with two strong concentric ribs surrounding a deep eccentric depression, outside area prickly. Height 90, diameter 110 mm.

Found on limestone platforms from the lower littoral to the sublittoral zone south of latitude 28° except Victoria and Tasmania.

Turbo (Subninella) undulatus Solander. Common warrener

Figs. 18c,d; Pl.1g

Early whorls sculptured with low spiral ribs, last whorl may be smooth; umbilicus deep, columella rounded, columellar callus encircling the umbilicus; aperture circular, operculum paucispiral, flat on the inner side, nucleus eccentric, with a thick central area on the outer side. Colour dark green, axially marked with white zigzag streaks, covered with a brown epidermis (Fig. 18c), inner layer nacreous.

This is a common species found on rocks and boulders on reefs and platforms in the lower littoral zone and infralittoral fringe on medium to high energy coasts to 6 m depth. It is edible.

The subgenus *Dinassovica* is very large, globose, smooth, with an oval operculum the inner side of which is elevated. The subgenus *Ninella* is depressed, with lirate, rounded to carinate whorls; the operculum has an eccentric nucleus, its outer face concave in the centre with two strong spiral ribs and a thin outer margin. *Subninella* is globose, umbilicate, with fine spiral ribs and an operculum strongly convex in the middle.

Turbo (Dinassovica) jourdani Kiener. Giant turban Figs 18a,b.

Very large, solid, turbinate, with a moderately high conical spire and large last whorl, umbilicus sealed by columellar callus; surface smooth but for weak spiral ribs on the early whorls and irregular growth lines; aperture roundly oval, nacreous within, columellar lip and outer lip smooth; operculum oval, thick and heavy with a smooth porcelaneous convex outer side; colour reddish brown with darker waving axial lines. Height 200, diameter 170 mm.

This is the largest mollusc in southern Australia and the largest Australian turban. It is not uncommon at depths of 20 to 30 m in the eastern Great Australian Bight. It grazes on red algae and the animal is red. The specimen figured provided the substrate for a variety of other organisms: *Hipponix (Sabia) conicus* of all sizes surround the aperture, while worms, Bryozoa, sponges, adhere to the rest of the shell.

Genus **Astraea** Röding

Conical shells with a more-or-less carinate periphery which is variously ornamented with spines. Those of the subgenus *Bellastraea* are stellate with a prosocline aperture.

Astraea (Bellastraea) squamifera (Koch) Fig. 68g; Pl.8k

Shell with a moderately high spire, umbilicus covered by columellar callus, whorls with curved axial plicae between the sutures, periphery sharply carinated, the margin extended in a thin undulating flange projecting over the suture; base spirally lirate, the spirals crossed and weakly tuberculated by axial lirae. Diameter 26, height 20 mm.

In the subgenus *Micrastraea* the whorls are plicate, the aperture small and the columellar callus spread over the umbilical region.

Shell small, solid, roundly conical, somewhat depressed, with about 30 oblique axial plicae which tend to bifurcate towards the periphery, crossed by spiral lirae with granules at the intersections; aperture small, oblique.

Astraea (Micrastraea) rutidoloma (Tate) Figs 64c,d

Similar to A. (M.) *aurea*, but having a prominent lira below the suture which is transversely crenulate-ridged, periphery bluntly carinate and weakly crenulate; between the subsutural lira and the keel three granulose lirae, base with four granulose lirae; umbilicus bounded by a broad ridge with oblique tubercles. Diameter 12, height 7.5 mm.

Family CYCLOSTREMATIDAE

Genus **Munditia** Finlay

Shell very small, depressed, strongly sculptured, with a varicate outer lip and beaded cord in the deep umbilicus.

Munditia hedleyi (Pritchard & Gatliff)

Shell with flat spire and convex base; adult whorls two with two prominent keels, each whorl with 15 to 20 prominent axial plicae which are nodulose on

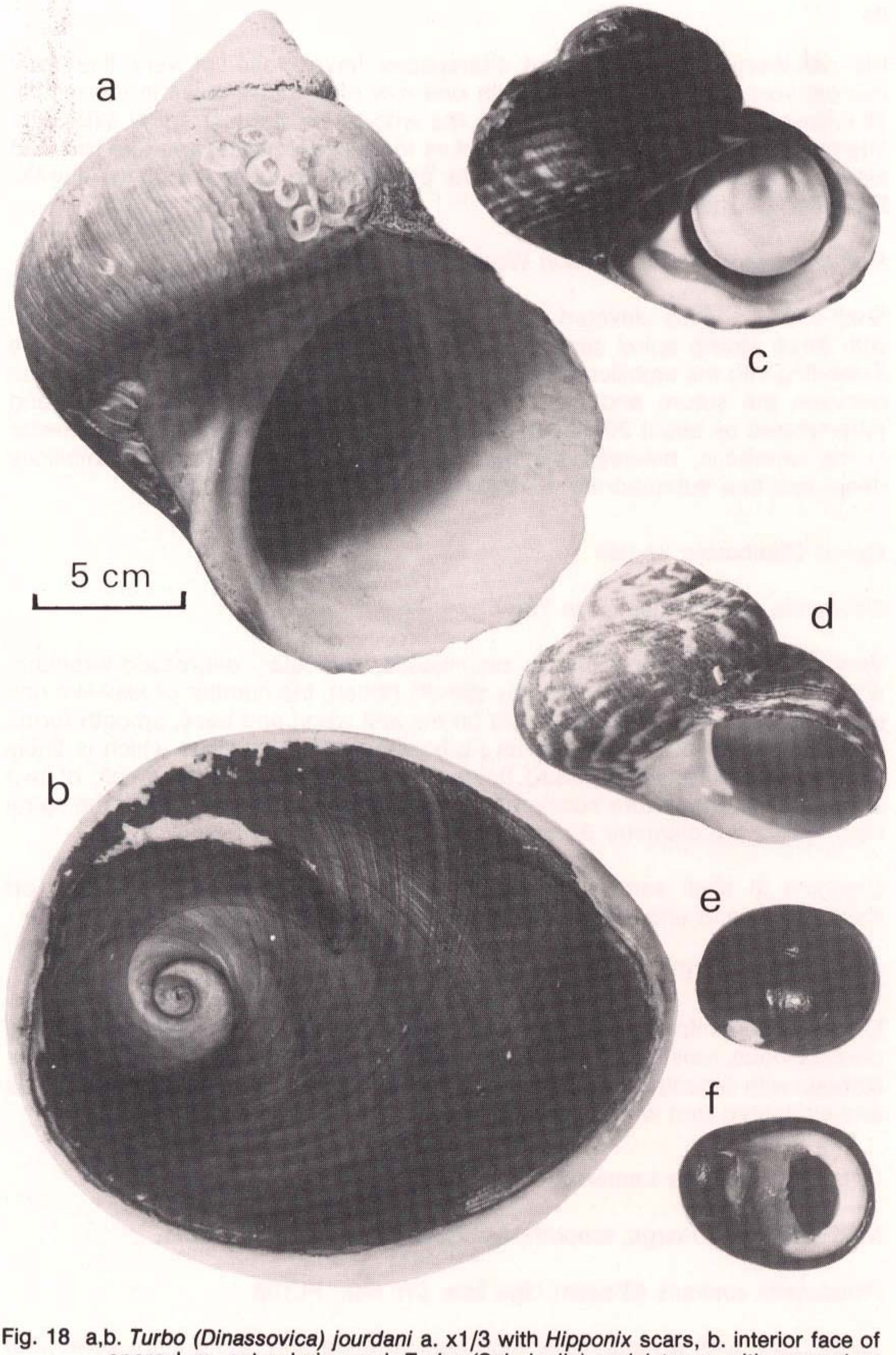

Fig. 18 a,b. *Turbo (Dinassovica) jourdani* a. x1/3 with *Hipponix* scars, b. interior face of operculum, natural size; c,d. *Turbo (Subninella) undulatus* c. with operculum and *periostracum*, d. without *periostracum*; e,f. *Nerita (Melanerita) atramentosa*. x1 except a.

the periphery, both plicae and interspaces have close-set very fine axial microscopic lirae; base convex with one row of spiral nodules in the middle all crossed by fine axial lirae as on the whorls, on the last spiral extending into the umbilicus the axial lirae project as tooth-like lamellae; aperture rounded within, hexagonal without, following the profile of the tubercles on the spirals. Diameter 2.5, height 1.5 mm.

Munditia subquadrata (Tenison Woods) Figs 78a,b

Shell with a slightly elevated spire, adult whorls 3½, subquadrate in section with three strong spiral carinate cords on the whorl and three on the base extending into the umbilicus, suture well defined, undulating, imbricating, area between the suture and the first carina below it flat, cords crossed and tuberculated by about 20 elevated smooth axial cords which become lamellar in the umbilicus, between the cords microscopic growth striae; umbilicus deep; aperture subquadrate, varicate. Diameter 3.5 height 2.5 mm.

Genus **Elachorbis** Iredale

Elachorbis tatei (Angas) Figs 78c-g

Very small, widely and deeply umbilicated, orbicular, depressed-turbinate, whorls convex, smooth to strongly spirally ribbed, the number of keel-like ribs usually four on the whorl and eight on the last whorl and base, smooth forms have very weak ribs; between the rib bordering the umbilicus which is finely axially lirate; whorls depressed below the suture; protoconch small, of two smooth whorls; aperture subcircular but tending to be crenulated by the spiral ribs. Height 2.5 diameter 3 mm.

Common in shell sand, Gulf St Vincent and westward, also dredged off Kangaroo Island and the Lower South-East.

Family PHASIANELLIDAE. Pheasant shells

Elongate- turbiniform, smooth shells without periostracum, polished, entirely porcelaneous, mostly non-umbilicate, peristome discontinuous, operculum calcareous with eccentric nucleus. Animal with pectinated head-lobes and tentacles and elongated foot with filaments.

Genus **Phasianella** Lamarck

Medium-sized to large, smooth, elongate-ovate, non-umbilicate.

Phasianella australis (Gmelin) Figs 20a; 57l; 64k; Pl.10p

Large, thin, with a moderately high conical spire and about eight somewhat convex whorls. Highly and variously ornamented with lines and waves of red, pink, brown and cream on a flesh-pink polished background. Aperture ovate. Columellar callus white, operculum white, solid. Height 60, diameter 26 mm.

Commonly found on brown algae and seagrasses of the genus *Posidonia* and occasionally *Amphibolis* on low to medium energy coasts.

Phasianella ventricosa Swainson Fig. 20b; Pl.10a

Similar to *P. australis*, but with a thicker, more solid shell, shorter spire, five to six swollen whorls and relatively large last whorl.

Commonly found on kelps and laminarians (adults) and under rocks (juveniles) on reefs on medium to high energy coasts to 10 m depth.

Superfamily NERITACEA. Nerites

Coiled, ovate or globular, with few whorls and a low spire; outer shell layers calcitic, inner layers thick, aragonitic, not nacreous, operculum usually calcareous with processes projecting from the inner side. Left kidney only, single bipectinate ctenidium on left, single hypobranchial gland, heart with two auricles or only one, pallial genital organs complex, radula rhipidoglossate.

The Neritacea are the highest group of the Archaeogastropoda and the only group with a special genital duct. Some are able to live in brackish water or freshwater and the Helicinidae are entirely terrestrial.

Family NERITIDAE

Thick, globose turbiniform or cap-shaped shells without umbilicus, inner walls of whorls resorbed, columellar lip thickened by callus and protruding as a septum (also called a shelf or deck), that narrows the aperture, commonly with a dentate margin.

Genus **Nerita** Linnaeus

Solid shells, smooth to spirally ribbed, with a well-developed pustulose or ribbed septum on the columellar lip. The subgenus *Melanerita* with a smooth shell and smooth, weakly dentate columellar lip is retained tentatively here, although it is regarded by some authors as a synonym of *Amphinerita.*

Nerita (Melanerita) atramentosa Reeve. Black periwinkle

Figs 18e,f; 64i,j; Pl.1o

A moderate sized *Nerita* with a low flat spire. Shell and operculum black, outer and columellar lips white. Surface smooth or with fine spiral striae, outer lip solid, denticulate with a nodule near the posterior end, columellar lip slightly concave, weakly dentate, columellar lip a broad shining callus. Operculum externally granulate. Height 28, diameter 22 mm. Common all along the southern coast in the supralittoral and littoral zones; feeds on algae or algal slime growing on rocks. The synonym *Melanerita melanotragus* (Smith, 1884) has been widely used for this, the only nerite living in southern Australia, described by Reeve in 1855.

Order MESOGASTROPODA (= TAENIOGLOSSA)

The Mesogastropoda are in general equivalent to the Taenioglossa, i.e. prosobranchs mostly with a taenioglossate radula, but there are some with ptenoglossate and rachiglossate radulae. The aperture often has a spout-like projecting siphonal canal for a pallial siphon which brings water into the pallial cavity. The animals are mobile and some are carnivorous.

Figure 19 (from Wilson & Gillett, 1971, by kind permission of Dr Wilson and the publishers A.H. & A.W. Reed) is an illustration of a generalised mesogastropod showing details of the soft parts.

Superfamily LITTORINACEA Winkles, periwinkles

More or less high, fairly small, turbinate shells with thick walls and more or less strong spiral or axial sculpture. Mostly non-umbilicate and lacking a siphonal canal. They form a group of mostly marine molluscs with a worldwide distribution, particularly common on rocks in the littoral zone, but some species are able to survive above tide-level in the supralittoral zone.

Family LITTORINIDAE

Generalised mesogastropods either browsing on seaweeds, rasping lichens and algae, or feeding on detritus. They have a very long taenioglossate radula with strong rasping teeth adapted for sweeping and grazing, cutting and shredding and picking up particles.

There is an extensive and detailed literature on the family, including that on Littorinidae in the Indo-Pacific (Rosewater 1970) and Ponder & Rosewater (1979).

The common southern species known as *Melaraphe unifasciata* has been excluded from the predominantly Atlantic subgenus and redefined as the type of a new subgenus *Austrolittorina* which has a predominantly Southern Ocean and tropical distribution.

Genus **Littorina** Ferussac

The anatomy of *Littorina* has been described in detail by Fretter & Graham

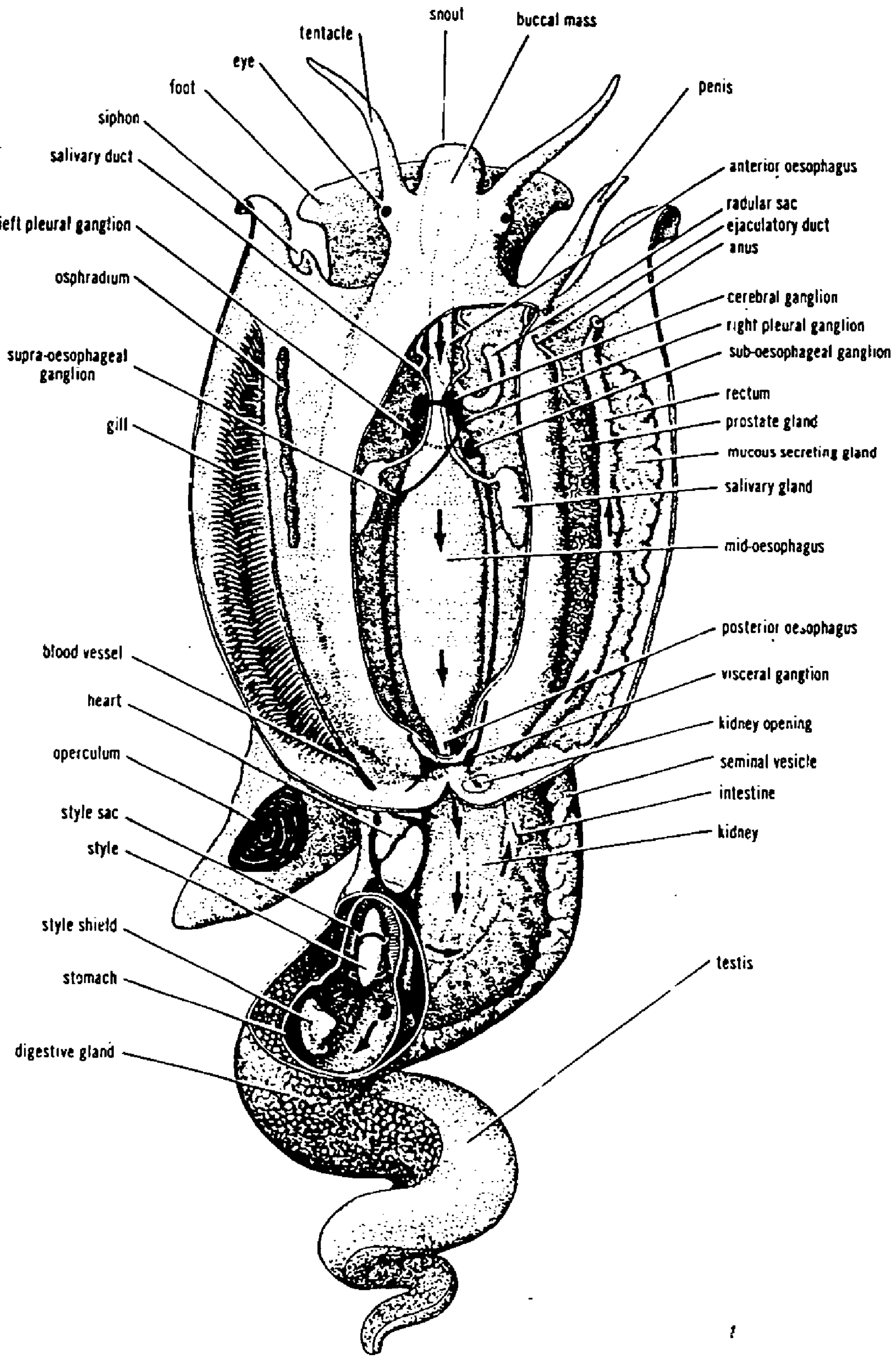

Fig. 19 Generalised anatomy of a mesogastropod (from Wilson & Gillett 1971).

(1962); the subgenus *Austrolittorina* is based on the characters of *L. (A.) unifasciata*. This species and *L. (A.) praetermissa* are the gregarious and numerous bluish-grey winkles so common on medium to high energy coasts in aggregations in crevices and cracks in rocks in the upper littoral and supralittoral (spray) zones that the interval is also known as the littorinid zone.

Littorina (Austrolittorina) unifasciata Gray
Figs 20j,k; 68i; Pl.1m

A small conical to subturbinate shell with five to seven whorls, flattened columella and crescent-shaped area adjacent to the columellar callus. Non-umbilicate. Sculptured with fine spiral striae and irregular axial growth lines. Colour greyish-white to bluish-grey, apex brown; aperture oval to subquadrate, brown inside. Operculum chitinous, moderately thick, paucispiral. Average specimen height 16, diameter 9.6 mm.

It is found on rocky coasts throughout Australia south of the Tropic of Capricorn.

Littorina (Austrolittorina) praetermissa May

The species may be distinguished from *L. (A.) unifasciata* by its more rounded whorls, coarser spiral sculpture and by its distinctive colour pattern of greyish-white with brown zigzag lines. The umbilical crescent is less deeply impressed. Height 16, diameter 11 mm.

Ponder & Rosewater (1979) describe the juveniles as being black and globular; they may occur in the lower midlittoral zone, possibly migrating as adults to the upper littoral.

Genus **Bembicium** Philippi

Trochiform, wide, depressed-conical, non-umbilicate, not nacreous. Base flat or slightly concave, with spiral ridges, an angulate basal margin. Whorls variously smooth or with nodulose ribs, or crenate. Aperture strongly prosocline. The genus has distinctive characteristics of the mantle cavity and pallial organs.

Studying three southern species, *Bembicium melanostoma, B. nanum* and *B. auratum,* Anderson (1958) concluded that they can be separated with

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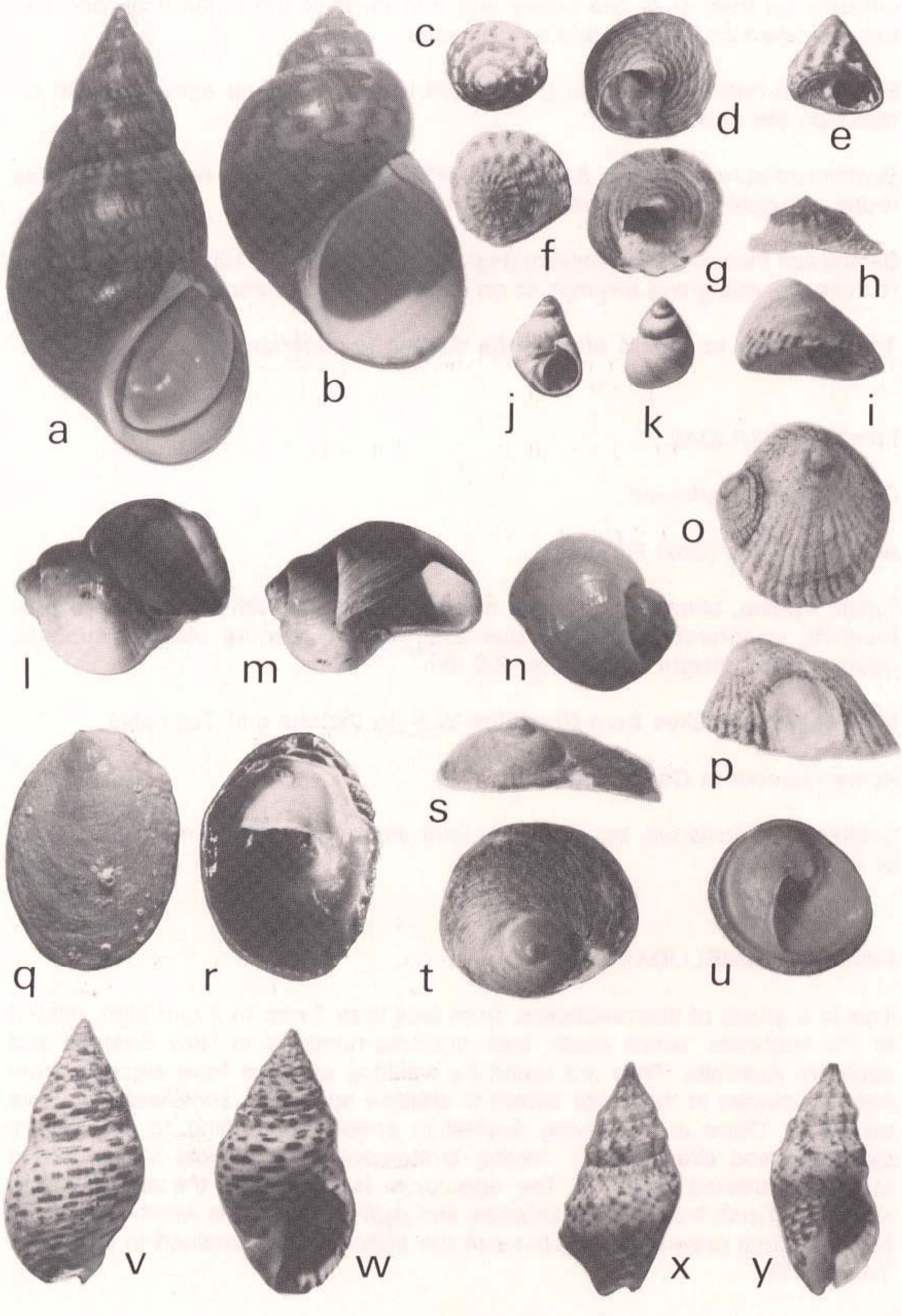
Fig. 20 a. *Phasianella australis*; b. *Phasianella ventricosa*; c,d.e. *Bembicium auratum* c. apical, d. basal, e. side view; f,g,h. *Bembicum melanostoma* f. apical, g. basal, h. side view; i. *Bembicium nanum*; j,k. *Littorina (Austrolittorina) unifasciata*; l,m,n. *Janthina* in floating position; o,p. *Hipponix (Sabia) conicus* o. with male attached, p. with scar left by attached male; q,r. *Crepidula (Zeacrypta) immersa* q. exterior, r. interior; s,t,u. *Calyptraea (Sigapatella) calyptraeformis*.. s. side view, t. apical view, u. apertural view; v,w. *Cominella lineolata;* x,y. *Cominella eburnea.* x1.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difficulty on their shell characters and that most of the differences occur in the reproductive systems and egg masses.

Bembicium nanum (Lamarck) (Fig 20i, Pl.1l) is the striped species found on rocks on the open coast.

Bembicium auratum (Quoy & Gaimard) (Figs 20c, d,e) is the nodulose species found principally in estuaries and on mangroves.

Bembicium melanostoma (Gmelin) (Figs 20f, g,h; 57m,n; Pl.10j) lives in sheltered rocky bays, mangrove swamps or on mudflats. It is common in the Port River.

They all occur as fossils and can be difficult to separate.

Family ACICULIDAE

Genus **Acme** Hartmann

Acme scalarina (Cox) Fig. 67g

Small, hyaline, bluntly turreted, of three adult whorls with a submerged protoconch, sculptured with numerous axial riblets; aperture oblique, suboval, margin entire. Height 6, diameter 2.5 mm.

In marginal salt lakes from Geraldton W.A. to Victoria and Tasmania.

Acme vincentiana Cotton Fig. 67j

Similar to *A. scalarina*, but with only faint axial ribs; may be merely a variety of *A. scalarina*.

Family EATONIELLIDAE

This is a group of micromolluscs, from less than 1 mm to 2 mm high, related to the littorinids, which reach their greatest numbers in New Zealand and southern Australia. They are found by washing samples from algae or from beneath stones in the lower littoral to shallow sublittoral zone were they live on algae. There are 18 living Australian species belonging to the genera *Eatoniella* and *Crassitonella*, having ovate-conical or conical shells with a strongly retracted outer lip. The operculum is horny and the animal has a simple foot with from 0 to 2 tentacles and cephalic tentacles which lash about as the animal crawls. Descriptions of the species are contained in Ponder & Yoo (1977).

As fossils they have been completely neglected.

Superfamily RISSOACEA

This is a large group of mostly micromolluscs, conical-turbinate, living mainly on algae in the lower littoral and sublittoral zones or under rocks on rocky shores. The whorls of the shell are more or less swollen, smooth or sculptured; aperture ovate to rounded, mostly without canal, no umbilicus. Animals dioecious, with no oesophageal glands, a short intestine, taenioglossate radula, crystalline style, and a long narrow foot with well developed pedal glands. They feed on diatoms, algal fragments and detritus, not all of which is vegetable.

Of the several families which are represented in southern Australia, two have species living in great abundance in hypersaline habitats—*Coxiella striata* and *Hydrococcus brazieri.*

Family POMATIOPSIDAE

Genus **Coxiella** Smith

Moderately large to small, non-umbilicate or with an umbilical chink, operculum either an indistinct spiral or spiral with an eccentric nucleus.

Coxiella striata (Reeve) Fig. 21a; Pl.11t

Truncated-turriculate, small, with an olivaceous epidermis when alive, but becoming flesh-coloured with a dull lustre after death; protoconch high, with three smooth whorls, spire whorls six, gradually increasing, usually decollated and closed apically with thin, smooth shell; whorls swollen, sutures impressed; aperture oval, reddish-brown within, entire, margin slightly thickened and expanded over the columella, operculum chitinous, black, thin, paucispiral, subovate. Height 7.5 diameter 2.5 mm. This is the shell found in countless millions in the Coorong to which various names have been attached, including *Coxiella confusa* Smith. The nomenclature, however, is still somewhat fluid.

Family HYDROCOCCIDAE

Very small, rounded conical, with a low spire, whorls convex, smooth, last whorl large, umbilicate, aperture rounded, entire, operculum with five to six small whorls. The family contains only one genus, **Hydrococcus** Thiele.

Hydrococcus brazieri (Tenison Woods) Figs 21b, 78i,j

A very small solid turbinate shell with a small protoconch of two whorls and three adult whorls, rapidly increasing, inflated, sutures impressed. Protoconch pinkish-brown, adult whorls cream with two small pinkish-brown bands on the last whorl. Aperture slightly oblique, margin entire, columellar lip slightly reflected over the umbilical chink, basal lip slightly produced abapically; operculum chitinous with a central nucleus and about five turns. Height 2.5 diameter 1.8 mm.

Originally described from Tasmania, it was also described by Thiele as *Hydrococcus graniformis* from the Swan Estuary.

Studies by Ponder (1982) of the anatomy and relationships of *H. brazieri* have shown that *H. brazieri, H. graniformis* and *Ampullarina minuta* Tenison Woods belong to one widely distributed estuarine species. However, the shells of Western and South Australian material have the short spire, convex periphery and inflated whorls of the *H. graniformis* form, while typical *H. brazieri* from Victoria and Tasmania have a higher spire, flatter whorls and weakly angulate periphery.

The small species prefers marginal salt lakes, back dune swamps, estuaries and tidal flats. It has a wide temperature and salinity tolerance as shown by Wells & Threlfall (1982) and occurs abundantly with *Coxiella striata* in the Coorong and with *Eubittium lawleyanum* in Lake MacDonnell on the west coast of South Australia.

Superfamily CERITHIACEA

Shell usually turreted, sometimes conical, discoidal or irregularly coiled, whorls numerous with smooth or tubercular spiral ribs with or without axial folds; aperture small with a short upturned siphonal canal, columella simple or with folds, curved or twisted; operculum chitinous, subcircular, nucleus central or eccentric. Tendency in both sexes for parts of the genital duct to be open ciliated grooves and for males to be without penis; egg capsules small, nervous system moderately concentrated.

The Cerithiacea are best represented in tropical waters, but several small species are very numerous in estuaries, marginal lakes, mangrove swamps and on tidal mudflats along the southern coast. They all graze on debris or algal films.

Family TURRITELLIDAE. Screw or auger shells

Slender, turreted, non-umbilicate, with spiral threads, cords or keels and

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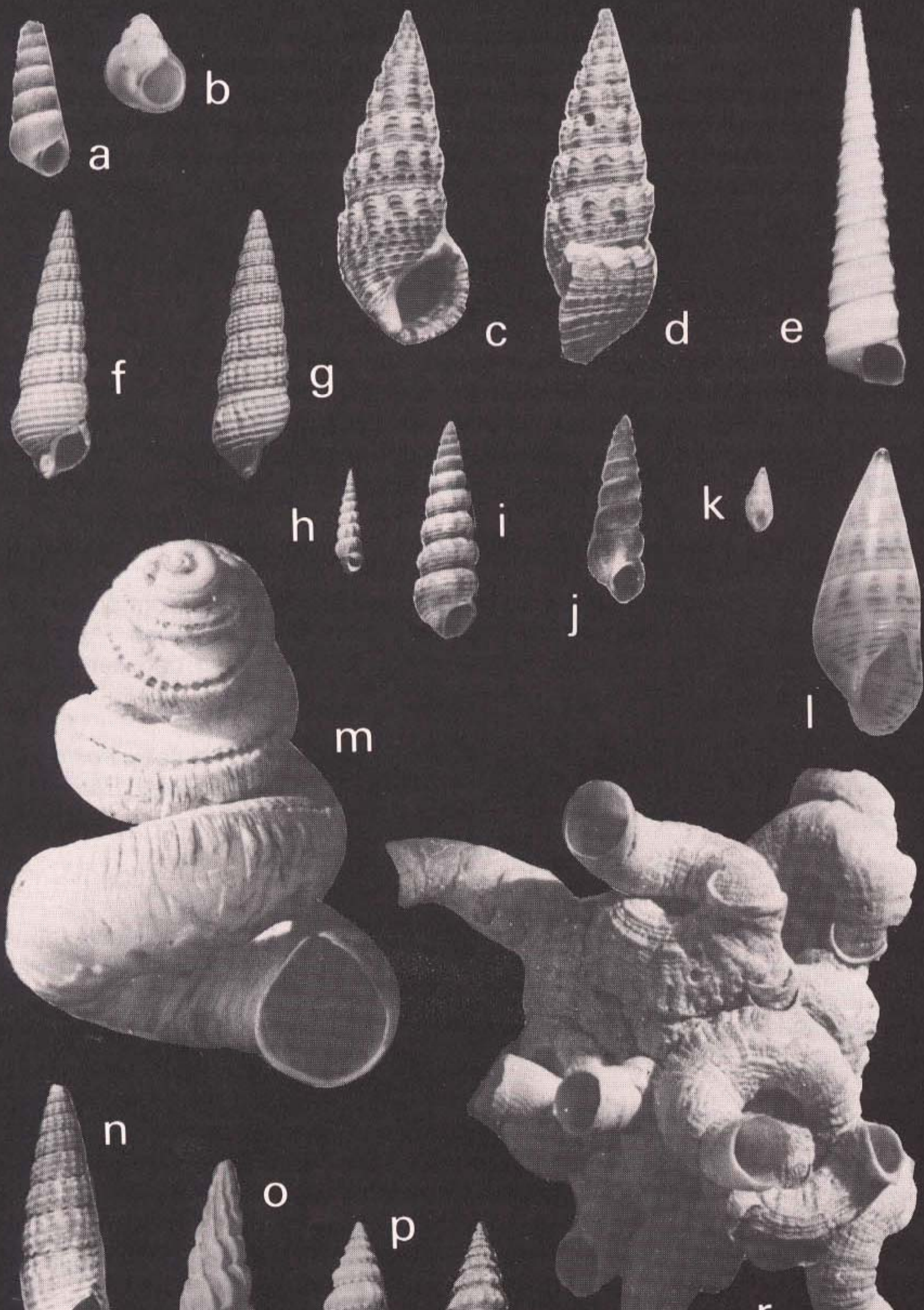
Fig. 21 a. *Coxiella striata* x 2; b. *Hydrococcus brazieri* x 4; c,d. *Batillaria australis* x 1; e. *Gazameda iredalei* x 1; f,g. *Batillaria (Zeacumantus) diemenensis* x 1; h,i. *Batillaria (Batillariella) estuarina* h.x 1, i. x 2; j. *Eubittium lawleyanum* x 2; k,l. *Diala lauta* k. x 1, l. x 5; m. *Tenagodus australis* x 1; n. *Bittium (Semibittium) granarium* x 2; o. *Opalia australis* x 1; p,q. *Hypotrochus monachus* p. varicate form, q. non-varicate form x 1; r. *Serpulorbis sipho* x 1.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curved growth lines; aperture rounded or roundly quadrate, usually entire but sometimes canaliculate or with an abapical sinus, outer lip thin, arched, columella smooth, concave; operculum thin, chitinous, usually multi-spiral with a central nucleus and edged with bristle-like extensions.

The turritellids are gregarious ciliary feeders, living just below the surface of sandy and muddy substrates on phytoplankton and floating detritus. The position of the inhalant and exhalant siphons opening near the surface may be indicated by two depressions. The inhalant siphon has a veil of cilia around the opening which acts as a sieve in preventing large particles or excessive salt from entering.

Genus **Gazameda** Iredale

Spire whorls convex to concave, usually with spiral threads or keels; aperture small, subquadrate, outer lip sinuous, base flat to slightly concave; operculum circular with a central nucleus and concentric growth rings.

Gazameda iredalei Finlay Fig 21e, 64f; Pl.8m

Acutely lanceolate with a high, pointed apex of two turns and from sixteen to eighteen whorls with two strong spiral cords in the lower half. Aperture subquadrate, columella arcuate. Colour white, purple brown between keels. Height 37, diameter 9 mm.

Lives in sand and silt among the roots of seagrasses, particularly *Posidonia sinuosa* and *P. angustifolia*, along the southern coast from Western Australia to Tasmania.

Vermetids. Worm shells

This is a group of abundant sessile gastropods living in the infralittoral fringe and sublittoral zones; they are easily confused with annelid worms which also build irregularly coiled tubes. Like the annelids, they attach themselves to rocks or other shells, either singly or gregariously, or live in sponges sometimes in great colonial masses. They are found as fossils in the Cainozoic.

Vermetid shells are three-layered with an inner glossy layer and initially coiled whorls, while annelid tubes are two-layered and lustreless, initially either open or uncoiled.

The vermetids themselves have a most confused nomenclature, which is not yet fully clarified. They require a great deal more study, both of the shell and the soft parts.

In the past, two distinct families have been included in the Vermetidae: the first, Vermetidae proper, including species of *Serpulorbis* and *Vermetus*, and the Siliquariidae containing *Vermicularia and Tenagodus. Siliquaria* Bruguière is a synonym of *Tenagodus* Guettard.

Family VERMETIDAE

Shell sessile, three-layered, more or less irregularly coiled. The juvenile animal attaches itself to the substrate and begins coiling at an angle of 90°; in the adult stage it coils in different ways in different genera and finally uncoils. The shell is longitudinally or transversely sculptured. The operculum, when present, is chitinous.

The vermetids secrete long mucous strings to trap plankton for food; some filter feed with their gill as well.

Genus **Serpulorbis** Sassi

Shells large, coiling in roughly concentric loops and later coiling in densely contorted colonial masses. Sculpture of spiral lines intersected by growth striae to form nodules or scales. No operculum.

Serpulorbis sipho (Lamarck) Fig. 21r; 79a

Light brown, irregularly coiled, in masses up to 15 cm across, roughly sculptured with rugose growth striae crossed by numerous irregular spiral riblets. Lives attached to stones or other shells in the littoral zone to 30 m depth.

Genus **Dendropoma** Morch

Sessile, coiling planorboid in early whorls when each volution is embedded in the substrate, coiling looser in later whorls; sculpture of lamellar growth striae which may or may not be intersected by longitudinal lines; operculum well developed. (? = *Magilina* Velain)

Dendropoma caperata (Tate & May) Fig. 79b

The generic position of this species is uncertain because of a lack of definition of the genus *Magilina* (? a synonym of *Dendropoma*) in which it has been placed by some authors.

Shell small, solitary, base of attachment broad, whorls tubular, more or less tightly coiled in a broad cone with distinct sutures and ending in a free, irregularly bent tube, sculptured with close-set annular ridges. Diameter of base 4 to 5 mm, height of coil 3, diameter of tube 1 mm, thickness of shell 0.1 mm.

Family SILIQUARIIDAE

The siliquariids have the appearance of turritellids that have begun to unwind. They are closely related to the turritellids from which they differ mainly in embedding themselves in a substrate, adopting a sessile habit and proceeding to uncoil. Like the turritellids, they are adapted for sedentary ciliary feeding with the veil of tentacles to keep detritus from the pallial cavity. The radula is similar to that of *Turritella*. The operculum is not bristled like the turritellids but fits tightly into the aperture of the tube.

Genus **Tenagodus** Guettard

Solid, medium to very large, initial whorls spirally wound, later whorls unwinding in an irregular spiral, over the whole length of the tube externally from the apex to the aperture an open or partly closed longitudinal fissure. Sculpture of longitudinal threads crossed and granulated by annular growth lines. Operculum horny, thick. Inhabits sponges.

Tenagodus australis (Quoy & Gaimard) Fig. 21m

Large, thick, with a fissure from the apex to the aperture. Sculptured with fine longitudinal threads and irregular growth lines. It lives in sponges, sometimes in enormous colonies, on medium to high energy coasts to 30 m depth. It is frequently cast up on the beaches with the sponges.

Tenagodus weldii Tenison Woods Fig. 64h

A small *Tenagodus*, loosely twisted, thin, whorls finely obliquely striate, slit closed in the first three whorls then open with subundulating acute margin, aperture subcircular.

Family DIASTOMATIDAE

Genus **Diastoma** Deshayes

Diastoma melanioides (Reeve) Fig. 57r

Turreted, with 12 adult whorls in a height of 42 mm, with about 30 axial plications on each whorl, weakly tuberculate at the intersections with the primary spiral lirae; aperture oblique, loop-shaped, with an adapical channel, basal lip reflected towards the columella. Height 42, diameter 14 mm.

Living in southwest Australia, common in the Early Pleistocene.

Family POTAMIDIDAE. Mud whelks

These include the gregarious *Pyrazus ebeninus* which is extremely abundant on muddy flats exposed at low tide in estuaries from southern Queensland to eastern Victoria. The southern Australian potamidids are small, but locally abundant on mud flats.

Shell solid, more or less turreted, elongate-conical, with numerous whorls sculptured with spiral ribs, axial folds or both; aperture ovate, outer lip with a short siphonal canal, operculum round, paucispiral, with a central nucleus.

Genus **Batillaria** Benson

Turreted-conical, with plain or granular ribs, aperture rounded to ovate, dark within, outer lip with a slight sinus at the adapical one-third, flared and inturned in the abapical two-thirds, striped and denticulated within by the external spiral ribs, basal lip with a very short broad canal or a broad siphonal groove. Columella concave, smooth, straight or slightly thickened below, columellar callus narrow to moderately wide.

Batillaria australis (Quoy & Gaimard) Figs 21c,d

This is the common southern mud whelk, having the shell typical of *Batillaria* and very close to the type species, *Batillaria zonalis.* There seems no justification for the introduction of the generic name *Velacumantus* unless anatomical studies confirm that *australis* is generically distinct from *zonalis. B. australis* is sculptured with axial ribs, about 10 per whorl, both interspaces and ribs crossed and surmounted by about four prominent spiral cords with finer cords intercalated between them. Colour greyish white with dark grey to black axial ribs and spiral cords. Height 32, diameter 14 mm.

B. australis is locally abundant in estuaries, mangrove swamps or mud-flats from southern Queensland to Western Australia, but appears to have died out in South Australia since the last high sea level. It is chiefly notable for harbouring larval trematodes which complete their life cycle in aquatic birds. One of these, *Austrobilharzia terrigalensis* can produce "swimmers' itch" or "Schistosome dermatitis" on the New South Wales coast where *B. australis* is common.

Batillaria (Zeacumantus) diemenensis (Quoy & Gaimard) Figs 21f,g; 57q; 64g; 78p; Pl. 11b

Small, many-whorled shells with an acuminate spire, flatly convex whorls sculptured with from 10 to 16 axial ribs on each whorl surmounted and granulated by four spiral lirae; axial ribs weaken on the last whorl and only the spiral lirae continue over the base; columella nearly straight, siphonal canal short and slightly reflected, outer lip thin, slightly sinuous. Height 32, diameter 10 mm. The animals live in great abundance on sandy and muddy flats where they feed by crawling just below the surface of the sand and leaving behind a network of grooves. They live in the Port River and are piled in banks at St Kilda S.A. where most of the shells have been derived from the St Kilda Formation left by the retreating sea about 4000 years ago.

Batillaria (Batillariella) estuarina (Tate) Figs 21h,i; 64e; Pl.11c is another small estuarine species with many convex whorls, spiral ribs and weak axial ribs tuberculate at the intersections; aperture rounded, weakly sinuous below, columella concave, not truncated below.

Genus **Eubittium** Cotton

Shell with a brown polished protoconch and spirally grooved convex whorls; aperture oval.

Eubittium lawleyanum (Crosse) Figs 21j; 68o; 78m; Pl. 11f.

Spire high, whorls with about eight flat spiral lirae on each whorl, fourteen on the last whorl and base. Aperture oval with slightly expanded outer lip. Colour dark bluish-brown. Height 10, diameter 3 mm. Lives in great abundance in Lake MacDonnell with *Hydrococcus brazieri* and *Spisula (Diaphoromactra) versicolor*, and on sandy mud on salt flats and in salt creeks in the mid-littoral zone.

Family CERITHIIDAE

Shells varying from moderately small to very large, mostly turreted. Whorls usually with distinct spiral and axial sculpture; aperture more or less sinuous below or with a distinct well-developed siphonal canal. Operculum horny, spiral, with an eccentric nucleus.

Genus **Diala** A. Adams

Small, elongate-conical, mostly smooth shells with the last whorl rounded or angular, base spirally grooved, non-umbilicate. Aperture roundly ovate, angular adapically, basal lip slightly produced, columella gently concave, smooth, slightly thickened. The southern Australian species live in sheltered inlets such as Port Philip or Western Port Bays.

Diala lauta A. Adams Figs 21k, l; 68j; 78k; Pl.11e

Very small, thin, translucent, whorls flattish, cream-coloured with reddish brown short spiral lines. Height 5 mm. Lives on algae.

Genus **Bittium** Leach

Small, mostly slender turreted-conical shells with four smooth or spirally striated embryonic whorls, adult whorls flattish mostly with granular spiral ribs; aperture ovate with a very short broad siphonal canal.

Bittium (Semibittium) granarium (Kiener) Figs 21n; 68p

A rather neat *Bittium* with a distinctive shape in profile, the whorls tapering adapically from the last whorl to the apex and abapically in a moderately high pointed arch to the siphonal canal. Regularly sculptured with four rows of granulose spiral ribs per whorl, five simple spirals on the base; last whorl may have a weak varix. Aperture ovate, oblique. Colour cream, pinkish to brown. Height 20, diameter 5 mm.

It is a grazer, living on mud flats.

Genus **Hypotrochus** Cotton

Shell small, thin but solid, rather broadly turreted, whorls convex, carinate, with or without varices; aperture subquadrate, columella straight, siphonal canal short, oblique.

Hypotrochus monachus (Crosse & Fischer) Figs 21p,q; 68k; 78l; Pl.11d

Protoconch of two smooth whorls, followed by six to eight adult carinate whorls, the last whorl bicarinate; 12 axial ribs and three varices per whorl in the typical form (Fig. 21 p) but the varices may be absent (Fig. 21q); whorls sculptured with fine striae; columellar and parietal lips with thin callus which is continuous with the thin outer lip. Height 14, diameter 7 mm. Colour cream marked with chestnut.

Found in large numbers on algae on silty bottom, or occasionally on *Posidonia* seagrass from 5 to 20 m depth. It is a common and distinctive species at Outer Harbor.

Genus **Campanile** Bayle in Fischer

Large subulate shells with numerous flat whorls.

Campanile symbolicum Iredale Fig. 58a

Shell thick, concave in profile, with about 30 whorls in a height of 140 mm; earlier whorls with two spiral cords, one below the adapical suture weakly gemmulate; adult whorls smooth except for sinuous axial growth striae; outer lip thin, columella concave, siphonal canal short, reflected, deep. Large specimens are over 200 mm high, diameter 90 mm.

Lives today in southwest Australia from Geraldton to Recherche Archipelago. Found in the Early Pleistocene but not in the Late Pleistocene.

Families CERITHIOPSIDAE, TRIPHORIDAE

These are families of very small elongate shells which require the use of the microscope for identification. The Triphoridae are usually sinistrally wound, with the aperture on the left.

Family CERITHIOPSIDAE

Genus **Seila** A. Adams

Shell small, subulate, with flat whorls and spiral ribs, nucleus of protoconch inrolled.

Seila (Notoseila) crocea (Angas) Figs. 68q; 79f

Shell small, elongate with a heterostrophic protoconch of three whorls, adult whorls 11, flat, with three narrow spiral ribs narrowing and slightly flattened at the top on each whorl, interspaces finely axially striated. Height 8, diameter 3 mm.

Superfamily EPITONIACEA

The Epitoniacea include two curious families—the Epitoniidae (= Scalidae), Wentletraps or ladder shells, and the Janthinidae, Violet snails.

The Epitoniidae are polished elegant shells with axial ribs or thin lamellae extending across the whorls and often continuous over the sutures. They are carnivorous, feeding on anemones or corals to which they attach themselves by the proboscis and then use their ptenoglossan radula to rasp off fragments. When disturbed they can emit a violet fluid. Several species occur in southern Australia but they are not very common.

Family EPITONIIDAE (= SCALIDAE)

The use of generic names in this family is tentative.

Genus **Acutiscala** Boury

Acutiscala minora Iredale Fig. 68n

Elongate, thin, with ten adult whorls with nine varices on each whorl, narrow, high, not forming a basal rib, some broadened and appressed to those of the previous whorl, aperture oval, entire, outer lip broad. Height 16, diameter 7 mm.

Genus **Epitonium** Röding

Epitonium (Limiscala) helicornuum (Iredale) Fig. 68m

Small, with deep sutures and inflated whorls sculptured with 17 lamellae on the last whorl and base, lamellae sharp on the early whorls but becoming flattened or rounded towards the last whorl, interspaces smooth; aperture oval, umbilicus small and obscured by the expanded columellar lip. Height 16, diameter 8 mm.

Epitonium (Pomiscala) cf. perplicata (Iredale) Fig. 68l

Small, with inflated whorls sculptured with about 12 lamellae on the last whorl and base, lamellae continous except for a slight kink at the deep sutures; somewhat umbilicate, but umbilicus obscured by columellar lip; aperture oval. Height 7, diameter 4.5 mm.

Opalia australis is figured (Fig. 21o)

Family JANTHINIDAE

The Janthinidae are a pelagic family related to the Epitoniidae. They are fragile, lavender to purple-coloured globular snails which can also emit a violet fluid. They are wholly planktonic, floating on the surface of the sea with the aperture upwards (Figs 20 l-n) and either attached to *Velella*, a siphonophore on which they feed, or to a raft of bubbles secreted by the foot. *Janthina* everts the whole buccal mass to expose the ptenoglossan radula with which it rasps the *Velella*. Shells are found cast up on ocean beaches.

Because of their pelagic habit, they are important for purposes of correlation, particularly in the Pliocene.

Superfamily HIPPONICACEA

Shell spiral, mostly roundish to turbinate or cap-shaped. Operculum thin, horny, weakly spiral with an eccentric nucleus or absent. The small superfamily includes two families of unusual gastropods living in southern Australian waters.

Family HIPPONICIDAE. Bonnet limpets

Bowl- or cap- shaped, smooth or with radial ribs, spiral protoconch. No operculum. The Hipponicidae live fastened like limpets to stones, worm and other gastropod shells, corals, coralline algae etc. Some live commensally with other shells to which they fix themselves and erode a hollow beneath them. As the host shell grows the bonnet limpet moves very slowly, leaving behind a scar trail (Fig. 18a). Some hipponicids feed on the faecal pellets of the host.

Genus **Hipponix** Defrance

Hipponix (Sabia) conicus (Schumacher) Figs 20o,p; 57t; 64l; Pl.5h

Rather small, elevated, cap-like, with apex at the posterior and directed over the margin, sculpture of irregular radial ribs. Height 10, diameter 12 mm. Lives commonly on reefs in southern Australia fastened to *Haliotis* spp., *Pleuroploca australasia, Pterynotus triformis, Chlamys (Equichlamys) bifrons* and *Pinna*. The small males attach themselves to the larger shells of females in which they excavate a communication notch (Figs 20 o,p). *H. (S.) conicus* is not a ciliary feeder, but feeds by lifting the anterior shell margin and searching for food particles with the proboscis.

Genus **Cheilea** Modeer

Species of the genus *Cheilea* have a broad, chute-like process fastened internally to the apex. Although they are not commonly found, a large species of *Cheilea, C. flindersi*, occurs in southern Australia and *C. occidua* in south-western Australia.

Superfamily CALYPTRAEACEA

Families of the Calyptraeacea have either spiral or cap-shaped shells which have developed from spiral shells either to simple conical shells or to conical shells retaining the spiral. They include the Chinamen's hat shells and slipper limpets, and attach themselves to rocks and other shells. The radula is taenioglossan.

Family CALYPTRAEIDAE. Chinaman's hat shells

Shell depressed, with a small but distinct spire and wide base; aperture circular or oval occupying the base of the shell; inside with a partition or diaphragm. Ciliary feeders, mainly on plankton and floating detritus. They are protandrous hermaphrodites, changing sex at particular stages in the life cycle.

Genus **Calyptraea** Lamarck

Shell round, apex central

Calyptraea (Sigapatella) calyptraeformis (Lamarck). Cup and saucer limpets Figs 20s-u

Rather small depressed-conical shell with a distinct spire, covered with a light-brown fibrous epidermis; white or cream coloured, apex and interior sometimes stained with violet; inner basal plate white. Height 15, diameter 20 mm.

It is a suspension feeder which lives attached almost exclusively to the interior of dead bivalves, e.g. *Glycymeris, Tawera* etc.

Genus **Crepidula** Lamarck. Slipper limpets

Shell oval, apex at the posterior margin. Individuals of *Crepidula fornicata*, a Northern Hemisphere species, are commonly attached to one another in chains, the youngest at the top being males, lower in the chain hermaphrodites, and the oldest at the bottom females.

Crepidula (Zeacrypta) immersa Angas Figs 20q-r

Smooth, convex, the shell adapting itself to the external curve of the shell to which it attaches itself. Colour brown, with a thin epidermis, interior chocolate-coloured, polished, with a white shelf-like basal plate. Length 20 mm.

The species appears to prefer being attached to living host shells; it is very common on *Chlamys (Equichlamys) bifrons.*

Superfamily CYPRAEACEA

Shell varying in size, mostly ovate, sometimes rostrate; whorls low, wholly or partly enveloped by the last whorl; last whorl smooth or sculptured with ribs or tubercles, covered with a glossy layer of enamel deposited by the enveloping lobes of the mantle; aperture long and narrow, with a siphonal canal in front and usually a posterior canal; outer margin thickened with infolded outer lip almost always dentate or plicate, columellar lip dentate. No operculum. The Cypraeacea include both herbivores and carnivores. Some are grazing herbivores, living on algae or detritus and some are carnivorous living on sessile colonial animals such as sponges and ascidians.

Family CYPRAEIDAE. Cowries

Cowries are attractive and sought- after mesogastropods.

The are generally moderately large with a high gloss, dorsally banded or flecked. Southern Australian cowries feed mostly at night on sponges. They were abundant and diverse in South Australia during the Miocene when they attained their maximum development in the region.

Genus **Cypraea** Linnaeus

Large, ovate to pear-shaped, sides mostly mottled, dorsum with dark variegated flecks, ventral side and teeth white.

Cypraea (Zoila) friendii thersites Gaskoin Figs 23a,b. Black cowry

Cypraea friendii is a very variable species ranging from Shark Bay to Beachport. Two subspecies are recognised, the western one *C. (Z.) friendii friendii* found west from the Great Australian Bight, and the eastern one *C. (Z.) friendii thersites* from Streaky Bay to Beachport.

Large, broad, with a flat base and short spire; shell colour dark brown with cream blotches, base pale. There are usually one to four teeth at the posterior end of the columella; sides of the siphonal and posterior canals low. Length to 75 mm.

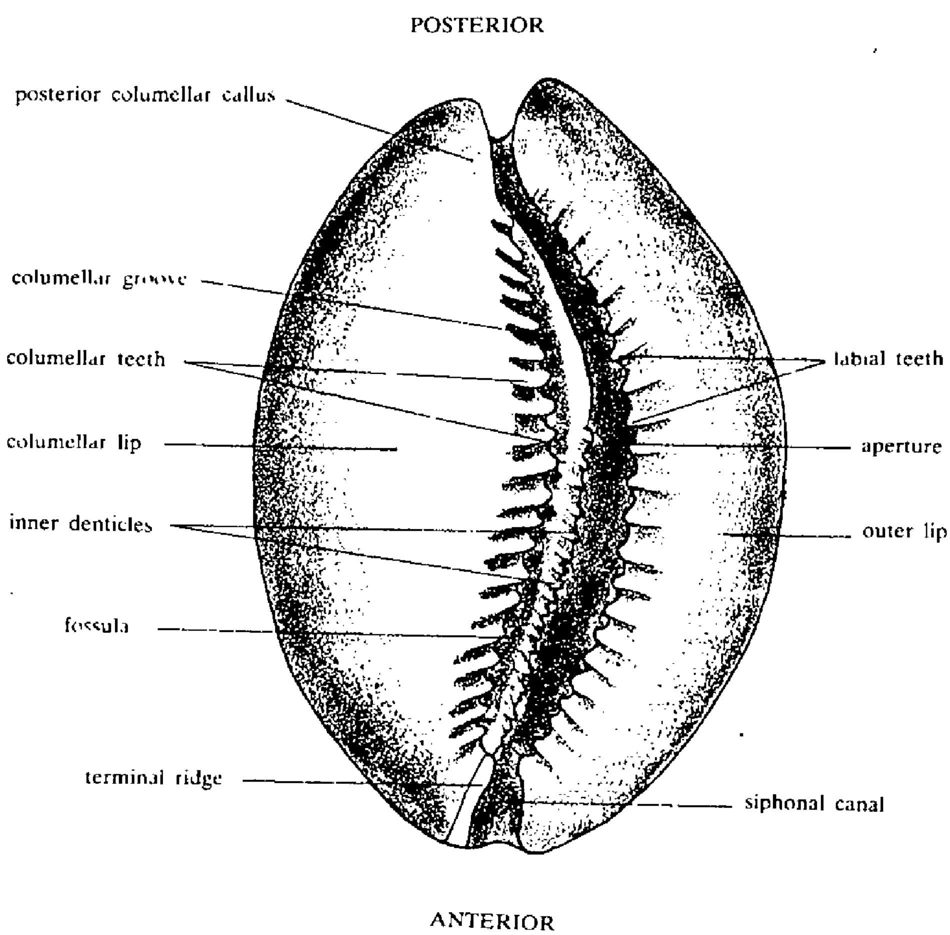


Fig. 22 Morphological features of shell of *Cypraea*.

Notocypraea group

The group of small cowries found in southern Australia, often placed in the genus or subgenus *Notocypraea* is extremely difficult to separate consistently into distinct species. Miss Karen Gowlett has provided the following notes on the group:

'In these cowries, the female broods her batch of bright yellow or orange eggs, usually under a rock, and they hatch into crawling snails. Dispersal is limited to how far the animal can crawl, and since they feed on encrusting sponges under rocks, they have little reason to move far. This leads to limited and slow gene dispersal, and the formation of local populations with characteristics which differ from nearby populations. It also means that should a local population be destroyed, it takes a long time for it to recover, as recruitment from neighbouring areas is limited.

Various species have been recognised by different authors, some giving each form its own specific name, others attempting to place all forms within four or five species. Only one species appears to be quite distinct, *Cypraea (Notocypraea) declivis* Sowerby, which is shorter, more inflated and with a wider aperture than other forms; it is also fairly consistent in colour, being cream to pale pink-tan with small discrete chestnut spots on the dorsum and a few larger blurred spots around the periphery. The animal is white to cream in colour. It also appears to have a restricted habitat, living under rocks and slabs in the intertidal zone to 1m depth on high to very high energy coasts. Other forms are rarely found in as rough water and are usually at greater depths.

The dorsal spots on this form are added only when the shell is very mature, from the periphery upwards. Adult unspotted specimens are found quite often.

From the remaining forms a number of basic types can be distinguished, but intermediate forms between all of them can be found:

1. *Cypraea (Notocypraea) albata* Beddome—pure white shell with white, cream to yellow animal; mainly South-East of S.A.

2. *C. (N.) subcarnea* Beddome—white base with pink dorsum, unspotted white cream to yellow animal; mainly South-East of S.A., also West Coast of S.A.

3. *C. (N.) comptoni* Gray—(Figs 23c,d) white to pink base, dorsum chestnut with darker bands, occasionally with spots on dorsum, periphery with numerous dark brown spots, animal orange; both gulfs to West Coast of S.A.

4. *C. (N.) mayi* Beddome—white to pale pink base, dorsum orange-pink with darker bands, unspotted dorsum (usually), periphery with distinct dark spots, usually brown, occasionally purple, animal cream to yellow-orange; mainly South-East of S.A.

5. *C. (N.) piperita* Gray Figs 23e,f; Pl. 5i,j)—cream to pale tan base, pink to pale tan dorsum, sometimes with darker bands, with small brown brown spots on dorsum, larger spots at periphery, animal yellow; yellow, West Coast, both gulfs and South-East of S.A.

6. *C. (N.) verconis* Cotton & Godfrey—base cream, dorsum brown, unbanded, unspotted, periphery with distinct dark brown spots, animal grey to red; mainly South-East of S.A. *(C. (N.) angustata* Gmelin is as above with grey dorsum).

All through their distribution and in certain areas, particularly in the South-East, many specimens can be found that cannot be placed into any of the above or into other named variants. The most probable explanation is that these "species" are not yet totally reproductively isolated, and therefore any attempt at a classification is bound to have faults. Forms 1 and 2 are probably albinistic forms of one or more of the others, although which ones is open to doubt'.

Family TRIVIIDAE. Trivias

Small cowries with apertural teeth continuing as ribs over the sides and dorsal surface.

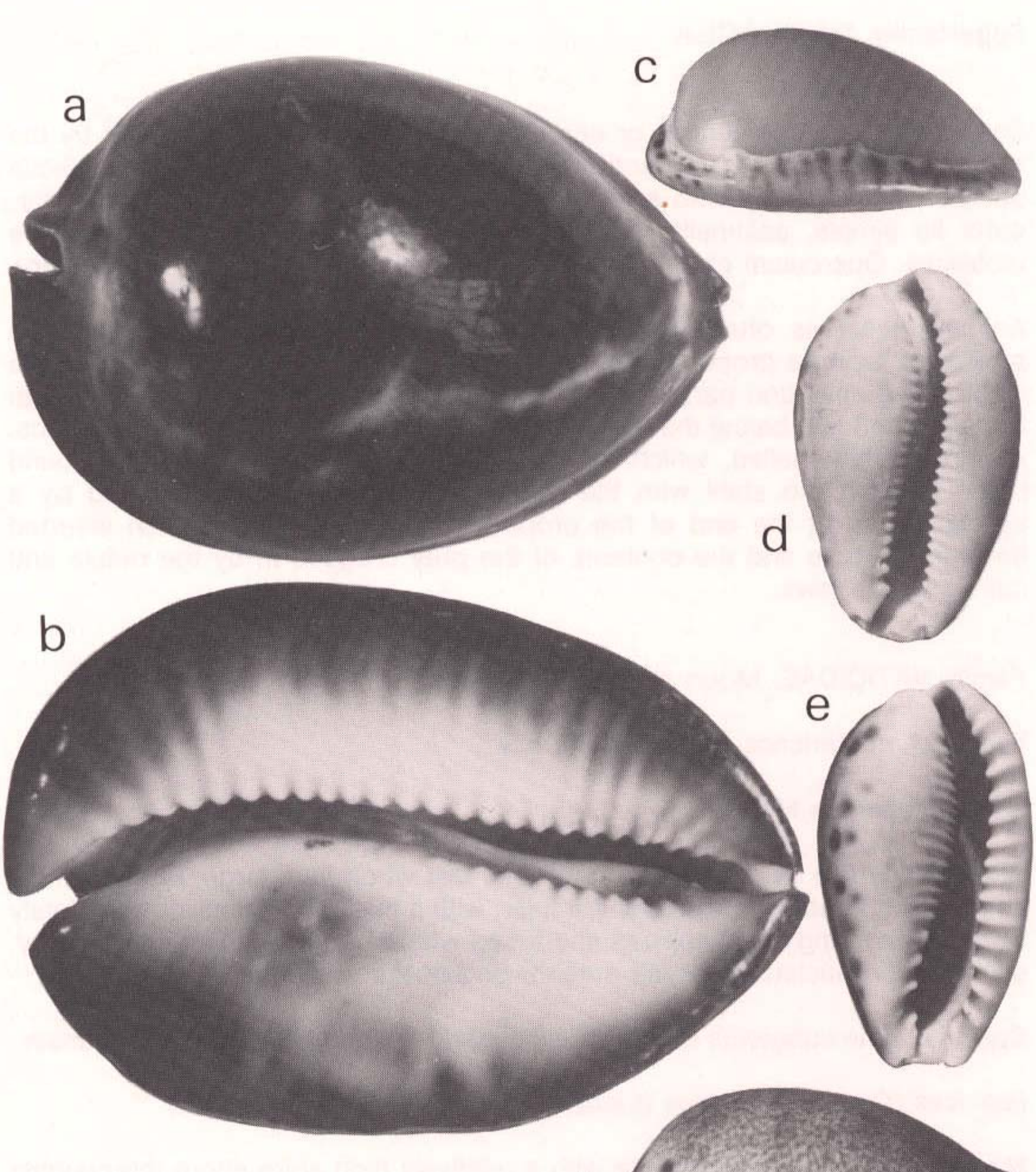
Genus **Ellatrivia** Iredale

Rather long, dorsal ribs often indistinct in the middle, outer lip rather narrow, inner lip blunt behind.

Ellatrivia merces Iredale Figs 23i,j; Pl. 5k,l

Small, ovate, ribs becoming obsolete dorsally, dorsum smooth. Colour pinkish-white with brown spots on the dorsum. Length 10 mm. Lives in bryozoan colonies.

Fig. 23 a,b. *Cypraea (Zoila) friendii thersites* a. dorsal view, b. apertural view; c,d. *Cypraea (Notocypraea) comptoni* c. side view, d. apertural view; e,f. *Cypraea (Notocypraea) piperita* e. apertural view, f. side view; g,h. *Polinices (Conuber) incei* g. basal, h. side view; i,j. *Ellatrivia merces* i. apertural, j. dorsal view. x 1.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Superfamily NATICACEA

Shell ovoid, globose-conical or ear-shaped, wholly or partly enclosed by the animal, whorls inflated, smooth, last whorl very large, rounded, umbilicus open or closed, often with a funiculum. Aperture large, oval or semicircular, outer lip simple, columellar margin with a thick callus spreading over the umbilicus. Operculum calcareous or horny, nucleus eccentric or rudimentary.

Animals dioecious, often showing sexual dimorphism in shells. They are active predators, using a propodium built into a head shield reaching back over the front of the shell and parapodia to cover the sides of the shell. They plough through sand just below the surface searching for mussels or other molluscs, preferably thin-shelled, which they capture and hold while they drill round holes through the shell with the radula aided by enzymes secreted by a special organ at the end of the proboscis. The proboscis is then inserted through the hole and the contents of the prey dragged in by the radula and cut up by the jaws.

Family NATICIDAE. Moon shells, sand snails

Family characteristics as of Superfamily

Genus **Polinices** Montfort

Shell globose to ovate-conical, spire low, last whorl very large, rarely spirally striated, umbiicate; aperture seimicircular, with a thick parietal callus completely or partly covering the umbilicus and fused with the funicle. Operculum horny, semicircular, nucleus near the anterior end of the straight side.

Species of the subgenus *Conuber* lay sausage-shaped gelatinous egg masses.

Polinices (Conuber) conicus (Lamarck) Figs 24a; 64n; Pls 8j, 10c

Moderately large, conical-ovate with a relatively high spire about three-eights height of shell; a small protoconch of 2½ whorls and four rapidly increasing adult whorls; aperture ovate, parietal callus thick, terminating at about half the length of the columellar lip leaving uncovered the lower part of the umbilicus and sometimes part of a narrow funicle. Cream-coloured, glossy. Height 42, diameter 27 mm.

Common in the mid-littoral zone on sandy beaches of low to moderate wave energy.

Polinices (Conuber) sordidus (Swainson) Pl.10b

More ovoid than P. *(C.) conicus*, with a shorter spire and larger last whorl. It is usually lead grey in colour, with a resinous bloom and a light-brown orange band beneath the suture. Height 49, diameter 45 mm.

Lives in muddy sand in the lower littoral zone.

Polinices incei (Philippi) Figs 23g,h; Pl. 5e,f

Rounded, with a very low depressed spire. Umbilicus filed with a button-like plug of callus surrounded by a groove. Height 19, diameter 28 mm.

Common in the mid-littoral zone on high energy coasts.

Genus **Notocochlis** Powell

Notocochlis gualteriana (Recluz) Figs 64o,p.

Shell thin but solid, subglobose with a low spire, axially wrinkled below the suture; funicle thick and heavy, with a deep posterior channel above. Height 13, diameter 14 mm.

Genus **Sinum** Röding

Shell more or less compressed, rounded or ear-shaped, mostly white, whorls smooth or with spiral ribs, umbilicus narrow or covered.

Sinum (Ectosinum) zonale (Quoy & Gaimard) Figs 24b,c; Pl.5g

Rather small, flattish, with a depressed spire; base flat, aperture large and wide, oval; whorls with crowded finely wrinkled microscopic spiral striae and curved growth lines; columellar lip calloused, interior smooth, glossy; colour white with purple-brown apex and weak reddish streaks. A thin yellowish epidermis.

Animal very large, almost completely enclosing the shell with its lateral flaps. Height 15, diameters 31, 25 mm.

The species is found in sand near reefs or in areas of patchy seagrass from 2 m to 20 m depth. A voracious predator, it drills through the shells of bivalves and will actively pursue a bivalve if it attempts to escape.

Superfamily TONNACEA

Predominantly solid shells, often very large, with a moderately high or low spire, last whorl mostly moderately large or very large; more or less inflated. Aperture often more or less long and narrow, with a short siphonal groove or longer canal.

Family CASSIDAE. Helmet shells

Shell medium to large, thick, ovate, with a low spire and large last whorl, one or more varices and usually well-developed parietal or columellar callus or shield; protoconch small, rather glassy; aperture long, narrow, with a short, oblique reflexed and excavated siphonal groove; outer lip thickened, often dentate within; columella with folds and denticles in the columellar callus; operculum horny, semicircular. Radula taenioglossate, proboscis retracted within the head when not in use, eyes at the base of the long thin tentacles. The females lay eggs in small capsules which are built into tower-shaped egg masses.

Cassids are carnivorous, some feeding on sea urchins which are attacked by everting the proboscis and squirting out what appears to be a neurotoxin to immobilise the spines. They then pin down the urchin and either rasp a hole in the test with the radula to insert the proboscis or insert it through the anus and devour the contents.

Indo-Pacific species of the family have been described by Abbott (1968).

Genus **Cassis** Scopoli

Shells large, up to 35 cm high. Parietal shield large, thick, bounded on the left by a large varix. Operculum small, horny, oblong.

Cassis (Hypocassis) fimbriata Quoy & Gaimard Figs 24d,e; 65l,m; Pls2c, 8l

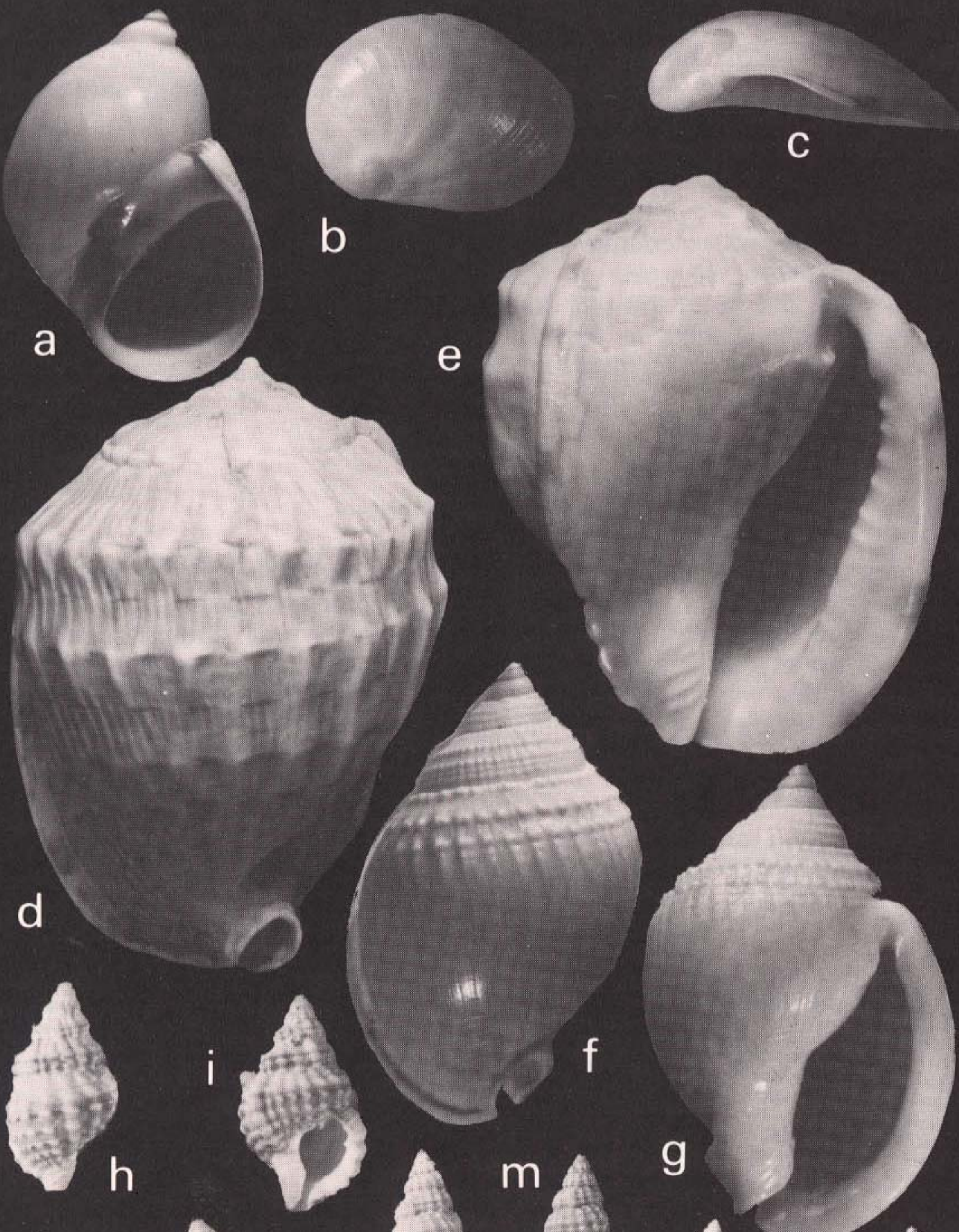
The subgenus *Hypocassis* differs slightly from true Cassis in having a large, bulbous protoconch.

C. (H.) bicarinata Jonas is a synonym.

Spire whorls sculptured with axial ribs and fine spiral striae, five to seven former varices on the spire; last whorl with two or three spiral rows of nodules on and in front of the shoulder. Columellar shield broad, outer lip usually smooth, thickened, widest near the centre. Colour cream to pinkish with axial brown patches and broken, brown spiral lines. Length to 120, width to 80 mm.

The species lives in sand near reefs and emerges at night to prey upon the sea urchin *Heliocidaris erythrogamma*, rasping a hole through the test, then consuming the animal. It is common in southern Australia from the Houtman Abrolhos WA to western Vic.

Fig. 24 a. *Polinices (Conuber) conicus*; b,c. *Sinum (Ectosinum) zonale* b. apical view, c. side view; d,e. *Cassis (Hypocassis) fimbriata* d. dorsal, e. apertural view; f,g. *Phalium (Semicassis) semigranosum*; h,i. *Cymatiella verrucosa*; j,k.n,o. *Cymatiella lesueuri*; l,m.*Cymatiella gaimardi*; x1.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Genus **Phalium** Link

Medium sized with high spire and well-rounded last whorl; both false and true umbilicus; one to seven varices on spire; parietal shield moderately developed, outer lip with one row of denticles.

Phalium (Semicassis) semigranosum (Lamarck) Figs 24f,g; Pl.10o

Elongate-ovate, with moderately high spire; spire whorls and shoulder of last whorl with five or six rows of granules on the upper one-third; columellar shield weak but seals the umbilicus. Colour cream or pinkish, interior and columella white. Length to 60, width 40 mm. Common along the southern coasts on sandy bottoms from the littoral zone to 400 m; very active predator of bivalves.

Family CYMATIIDAE. Tritons and trumpet shells

Varying in size from small to very large, thick and heavy, fairly high-spired with a hairy, scaly or bristly periostracum; protoconch with a few smooth whorls, whorls with strong varices strongly sculptured with nodular spiral ribs; aperture ovate with a more or less long siphonal canal, outer lip thickened, mostly dentate within, parietal margin with an adapical tooth or fold which borders the posterior canal. Radula taenioglossate.

Genus **Charonia** Gistel

The genus contains the familiar Indo-West Pacific trumpet shell *Charonia tritonis*, one of the largest shells in the world, which preys on the Crown of Thorns and other starfish.

Shell with a tall spire and short base and siphonal canal; sculpture of low spiral cords with interstitial threads and low axial folds forming knobs where they cross the spiral cords; varices spaced at every 270°; columella with one or two parietal ridges near the posterior canal and several folds on or near the siphonal canal. Radula typically taenioglossate, but with the central tooth broad and low.

Charonia lampas rubicunda (Perry) Fig. 24h

A number of specific names have been given to this southern Australian *Charonia* which is considered by Beu (1970) to belong to a widely distributed single species. *C.l. rubicunda* is a moderately large *Charonia* with a relatively high spire, weak varices, low spiral ribs the two or three central of which are broad and nodulose, the others narrow; outer lip flaring, denticulate, one parietal ridge long and strong; columella concave with weak short plicae near the siphonal canal. Colour yellow-brown, cream or reddish with darker brown blotches, apex pink, outer lip white, teeth brown, aperture white inside. Height 150, diameter 75 mm. On rocks in the infralittoral fringe.

Genus **Cymatiella** Iredale

Shell small to medium size, cancellated by spiral and axial threads nodulose at the intersections, with strong irregular varices at about every three-quarters of a whorl; aperture rather small, ovate, outer lip with a varix and with strong denticles within. Members of the genus are found mainly in rock pools on rock platforms, dredged or washed up on beaches.

Cymatiella gaimardi Iredale Figs 24l, m; 65j,k; P.10i

Small and elongate with six adult whorls; there are about seven primary cords and finer threads crossed and tuberculated by about twelve transverse ridges between the varices; colour golden brown, length 25, diameter 12 mm.

Usually found in pairs in association with small communal ascidians on medium to high energy coasts in the littoral zone to 15 m depth.

Cymatiella lesueuri Iredale Figs 24j,k,n,o

Smaller and more finely sculptured than *C. gaimardi*, with 15 spiral threads between the varices, beaded by axial ridges. Dead shells (Figs 24n,o) are somewhat chalky with well defined sculpture, but there are forms such as those figured (Figs 24j,k) from Port Lincoln with thick shells on which the sculpture tends to be obscured; colour white with pink protoconch and brown periostracum.

The species is found under rocks with encrusting sponges and ascidians, in sheltered areas on high energy coasts in the littoral zone to a depth of 5 m.

Cymatiella verrucosa (Reeve) (Figs 24h,i; 57z)

Strongly sculptured with about nine axial cords between the varices crossed and tuberculated by spiral cords of which the adapical forms a shoulder; two spiral threads above the shoulders and between the cords two or three finer threads. Aperture heavily variced, outer lip with six denticles within, columella with four or five denticles anteriorly. Colour cream. Height 24, diameter 13mm.

Found with *C. lesueuri*, but less common.

Genus **Cabestana** Röding

Medium to very large, thick, heavy shells, with three varices every two whorls; last whorl large, umbilicate, aperture with a short siphonal canal, outer lip with a thick varix and dentate within, columellar callus smooth.

Cabestana spengleri (Perry) Fig. 25b

Large, sculptured with broad spiral ribs crossed by numerous axial ridges, about six nodules on the shoulders between the varices, outer lip expanded with the spiral ribs projecting beyond the margin; colour yellow-brown with a brown hairy epidermis, interior and columella white. Height 150 mm.

Either dredged or found in rock pools from southern Qld to SA.

Cabestana tabulata (Menke) Fig. 25c; Pl.2e

This is the shell commonly known as *Cabestana waterhousei* Adams & Angas. It is smaller than *C. spengleri* and sculptured with seven to ten strong paired spiral ribs with fine spiral lirae in the interspaces, all crossed by numerous fine axial ribs or cords. Colour yellow-brown with a brown hairy epidermis. Height 100 mm.

Usually found on rock in association with solitary ascidians in the littoral zone to a depth of 15 m on medium to high energy coasts. It is common from NSW to Fremantle WA.

Genus **Negyrina** Iredale

Moderately large; sculpture of spiral knots and small knotted spiral ribs. Aperture oval, outer lip with a varix, dentate within; columellar callus smooth or wrinkled below.

Negyrina subdistorta (Lamarck) Figs 25f,g

Somewhat distorted, with a row of conspicuous knots on the shoulder and numerous spiral nodulose ridges and fine axial striae. White or cream mottled with reddish brown, with a white spiral band in the middle of the last whorl; epidermis brown. Height 40, diameter 24 mm.

Mostly found washed up on beaches.

Order NEOGASTROPODA (= STENOGLOSSA)

The Neogastropoda are usually regarded as being the most highly advanced prosobranch gastropods. Most of them have large, heavy, fusiform, non-nacreous shells with long or short siphonal canals and strong folds on the columella. They have rachiglossate or toxoglossate radulae; they are usually

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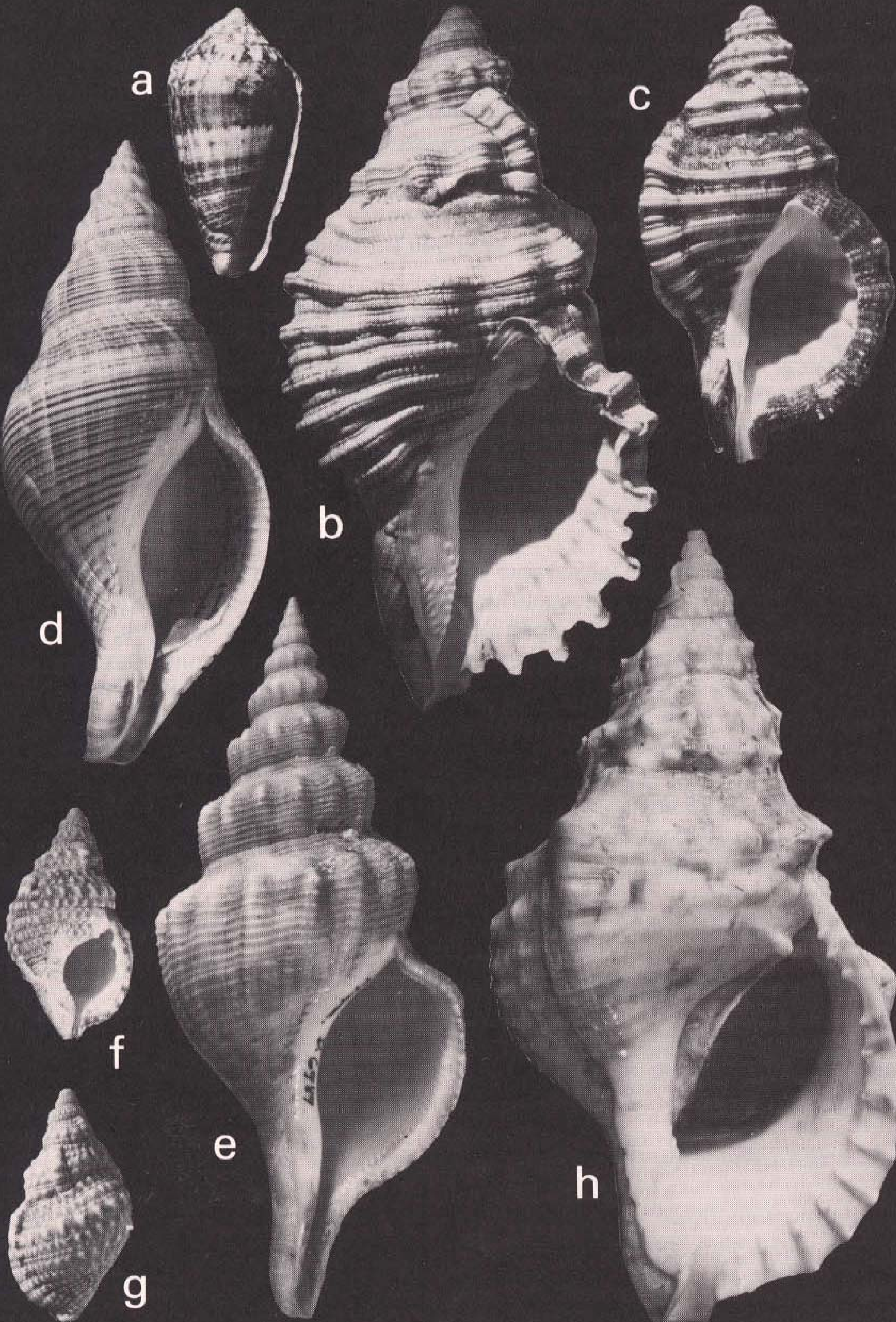
Fig. 25 a. *Conus (Floraconus) anemone*; b. *Cabestana spengleri;* c. *Cabestana tabulata*; d,e. *Penion mandarinus* d. unribbed form (*Siphonalia oligostira*), e. ribbed form (*Austrosipho grandis, waitei,* etc); f,g. *Negyrina subdistorta*; h. *Charonia lampas rubicunda*. x 2/3.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carnivorous and some are poisonous. Ctenidium monopectinate, osphradium bipectinate, siphon anterior, proboscis usually pleurembolic (Fig. 26); only left auricle and renal organ. They can withdraw completely into the shell; the foot varies in size according to the nature of the substrate, those on hard surfaces being small and usually bearing a horny operculum with a lateral or terminal nucleus. The females lay eggs in capsules which they attach to the substrate or other shells.

Superfamily MURICACEA (= RACHIGLOSSA)

The superfamily Muricacea is used here as advocated by Ponder (1973) to include also the Buccinacea and Volutacea because of the lack of consistent anatomical characters to separate them. All are scavengers and predators with a pleurembolic proboscis (Fig. 26) and rachiglossate radula (Fig. 9). The families making up the superfamily can usually be distinguished fairly readily from one another by shell characters and radular details.

Family MURICIDAE. Murex or rock shells

Shell mostly relatively large and strongly sculptured, predominantly solid, whorls often with simple or spiny varices, also with scaly or knotty spiral ribs; aperture more or less long, open or closed by fusion of the outer and basal lips; outer lip sometimes dentate, siphonal canal long. Carnivorous, living on other gastropods and on bivalves, barnacles etc, whose shells they drill with an accessory boring organ. Murex shells inhabit tropical and temperate seas. Most of them are highly ornamental, with spiny and even bizarre varices. Some can secrete a poisonous substance identified as urocanylocholine, but never sufficient to act an an external poison; several species of Murex were well known to ancient people as a source of Tyrian purple—a dye secreted by the hypobranchial gland, related to natural indigo.

Southern Australian species are mostly small.

Genus **Chicoreus** Montfort

Solid, medium-sized, with three foliated more or less prickly varices. Last whorl large, aperture roundly oval with a rather long, narrow, nearly closed siphonal canal.

Chicoreus denudatus (Perry) Figs 27c,d

Fusiform, with three frondose varices on each whorl and numerous spiral ridges and striae; aperture with outer lip denticulate, siphonal canal nearly closed, recurved. Colour pinkish-brown, white inside, glossy, operculum brown, horny. Height 49, diameter 26 mm.

Found living in the sublittoral zone.

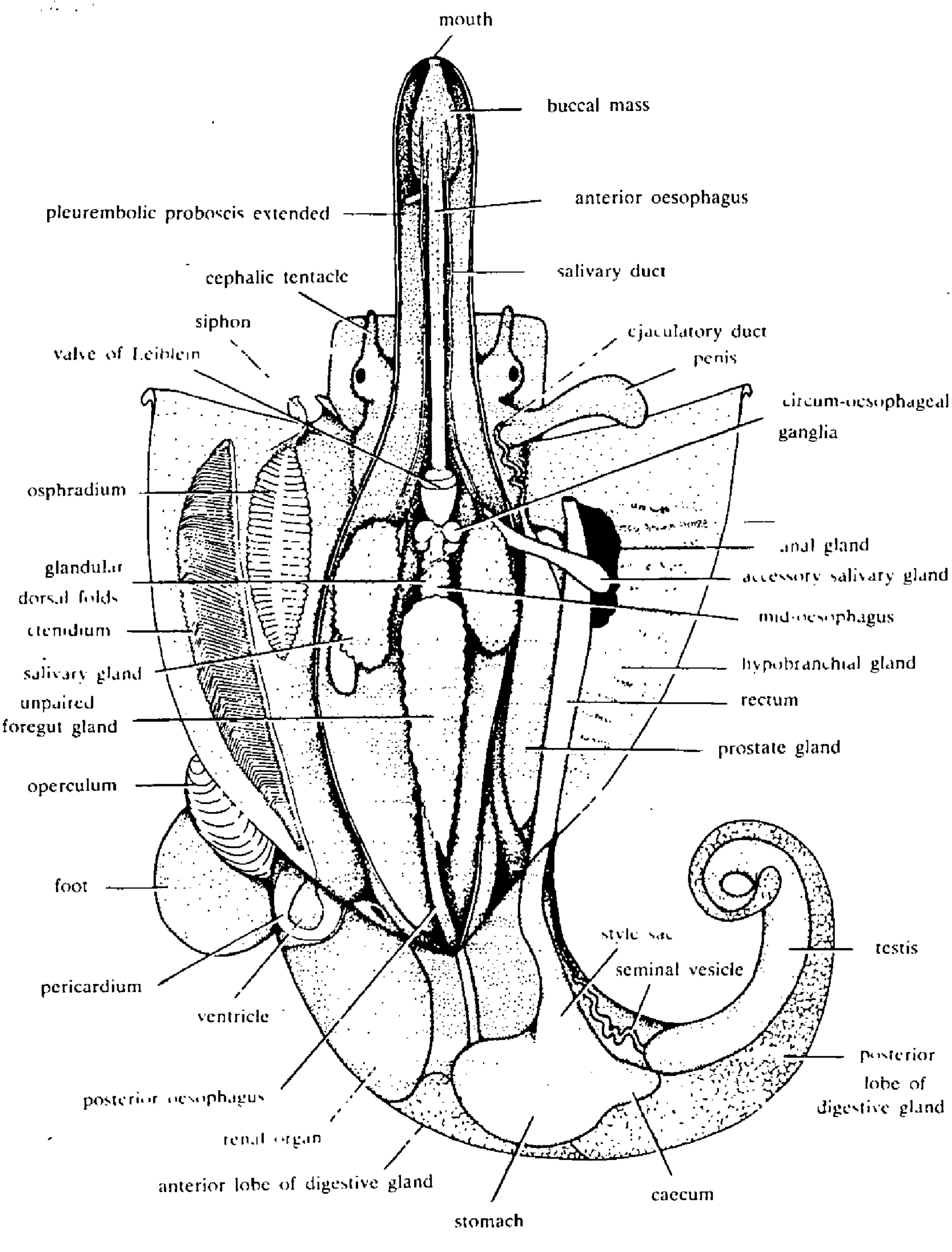

Fig. 26 Generalised anatomy of a *neogastropod*, with *pleurembolic proboscis* extended (after Ponder 1973).

Genus **Pterynotus** Swainson

Spire fairly high, whorls with from three to five flat thin varices; aperture small, ovate, siphonal canal long, curved.

Pterynotus triformis (Reeve) Figs 27a,b; 65a,b; Pl.5a,b

Shell triangular—fusiform with six convex adult whorls somewhat concave at the shoulder; each with three wing-like varices, erect, foliated underneath, spinose at the periphery, forming oblique laminae across the spire and last whorl; between the varices about two intervariceal nodules; spiral sculpture of twelve variable ribs on the spire whorls, about 36 on the last whorl, base and pillar; aperture elongate-oval, outer lip folded into the peripheral spine and crenulated in advance on the varix; siphonal canal fairly long nearly covered by the columellar lip; colour brown. Average specimen height 60, diameter 30 mm.

This species feeds upon small bivalves, particularly mussels, and is found in association with its prey on reefs, *Pinna* beds, etc. on low to high energy coasts to 20 m depth. Shell growth is intermittent, the shell resting and growing a whole new varix before recommencing feeding.

Genus **Bedeva** Iredale

Fusiform shells, angulate at the shoulder, with several broad varices on each whorl. Members of the genus drill mussels and oysters.

Bedeva paivae (Crosse) Figs 27e,f; 65d,e; Pl.10k

Shell of moderate size, sculptured with strong axial ribs with fine growth lamellae between, crossed by close spiral lirae; canal short; colour cream to brown. Height 24, diameter 12 mm.

Common on solid substrate in sand and mud in the littoral zone or in estuaries. Feeds on mussels and oysters.

It is likely that *B. paivae* is a synonym of *B. hanleyi* Angas.

Genus **Thais** Röding

Biconic, thick, solid shells, strongly sculptured with ribs and nodules. Last whorl large, aperture large, ovate, siphonal canal short, fasciole broad; outer lip strongly dentate or lirate within. Operculum horny with a lateral nucleus. The genus *Dicathais* Iredale is now generally considered to be synonymous

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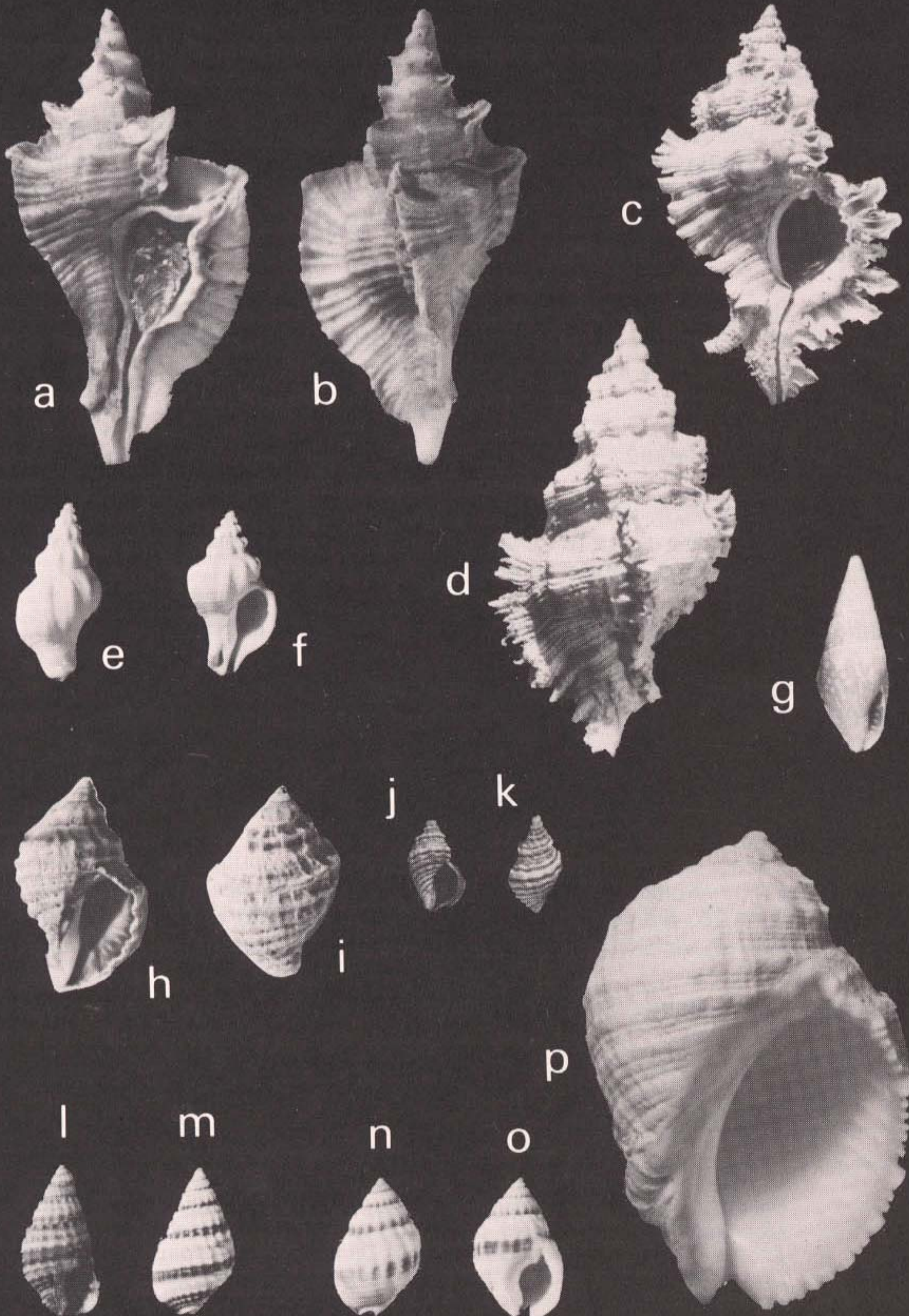
Fig. 27 a,b. *Pterynotus triformis;* c,d. *Chicoreus denudatus*; e,f. *Bedeva paivae*; g. *Mitrella (Dentimitrella) lincolnensis*; h,i. *Lepsiella flindersi*; j,k. *Lepsiella vinosa;* l,m. *Niotha pyrrhus*; n,o. *Niotha pauperata;* p. *Thais orbita*. x 1.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with *Thais*, although no adequate reason for either separating or equating them seems to have been published.

Thais orbita (Gmelin) Figs 27p; 65c; Pl.2d

Large and solid, spire low to medium, variously sculptured with spiral ribs and cords, sometimes nodulose, and axial folds or growth lamellae; columella flattened, with a groove behind, siphonal canal a short, broad notch, posterior canal a shallow notch bordered by a denticle, colour white or cream. Maximum height 80 mm.

This is a variable shell for which both *Thais* and *Dicathais* have been used and to which a number of specific names have been applied. It is common in the littoral zone and infra-littoral fringe on rocks where it feeds mainly on other molluscs.

Genus **Lepsiella** Iredale

Shell of medium size, with a moderately high spire, broadly fusiform with a large whorl; aperture about two-thirds height of the shell and moderately wide. Sculpture with strong spiral ribs or cords.

Lepsiella flindersi (Adams & Angas) Figs 27h,i; 66a,b; Pl.1p,q

Shell solid, roughly sculptured with two strong spiral cords on the spire whorls, seven on the last whorl and base; between the cords and on the sutural ramp adaxial to the periphery one or two fine spiral threads, all crossed by fine axial lamellae; sutural ramp sloping; aperture moderately high and broad with an oblique, fairly short siphonal canal; outer lip crenulated by the spiral cords, lirate deeply within; columella thick, nearly straight.

Colour greenish-white, aperture brown within, columella white edged with yellow. Height 25, diameter 15 mm. Lives on reefs and rocks in the littoral and sublittoral zones to 10 m depth where it feeds on mussels and barnacles.

Lepsiella vinosa (Lamarck) Figs 27j,k; Pl.1r,s

Similar to *L. flindersi* but only half the size. Sculptured with more regular spiral cords, white with dark narrow interspaces; interior of aperture brown,

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PLATE 1 Molluscs of rocky coasts: a. *Plaxiphora (Poneroplax) albida*, a chiton disarticulated to show insertion plates; b. *Amblychilepas javanicensis;* c. *Cellana tramoserica;* d. *Haliotis (Marinauris) roei;* e. *Haliotis (Schizmotis) laevigata;* f. *Monodonta (Austrocochlea) constricta;* g. *Turbo (Subninella) undulatus;* h. *Diloma (Fractarmilla) concamerata;* i. *Diloma (Chlorodiloma) adelaidae;* j. *Clanculus (Euriclanculus) limbatus;* k. *Granata imbricata;* l. *Bembicium nanum;* m. *Littorina (Austrolittorina) unifasciata;* n. *Clanculus (Macroclanculus) undatus;* o. *Nerita (Melanerita) atramentosa;* p,q *Lepsiella flindersi;* r,s *Lepsiella vinosa;* t. *Siphonaria (Hubendickula) diemenensis* (Trans. 24534)

PLATE 1

columella brown-purple, glossy. Height 10, diameter 8 mm. Very common on or under rocks in the midlittoral zone and on mangrove roots where it feeds on barnacles.

Family COLUMBELLIDAE. Dove shells

This is a family of small, solid, elongate-ovate shells evenly tapering, either smooth or with spiral and axial ribs; the last whorl is relatively high with a very short neck, broad and short siphonal canal. The outer lip is almost parallel with the columella, thickened and either simple or dentate within. They are found on algae or crawling around on the surface in shallow water.

Genus **Mitrella** Risso

Small, with flat to moderately inflated whorls, aperture elongate-ovate, about half the height of the shell, mostly with a very short oblique canal. In the subgenus *Dentimitrella* the outer lip is strongly dentate within and the columella has a flat, more or less denticulate, groove within.

Mitrella (Dentimitrella) lincolnensis (Reeve) Figs 27g, 68t; Pl.10m

Spire and last whorl equal in height, protoconch with three whorls, adult whorls six, sides flat. Aperture short, outer lip with seven denticles, columella with six denticles at the position of the lirae on the base. Shell white to brown, variously patterned in chestnut. Height 10.5, diameter 3.5 m.

Found on algae and rocks on low to medium energy coasts in the littoral zone to 10 m depth.

Mitrella (Dentimitrella) semiconvexa (Lamarck) Fig. 68s; Pl.10n

Height of last whorl greater than height of spire, which is equal to that of the aperture, whorls slightly convex; aperture oblique, of moderate width, outer and columellar lips parallel; outer lip with coarse denticles, columellar lip with fine denticles corresponding to the lirae on the base. Height 16, diameter 6.5 mm.

Genus **Euplica** Dall

Euplica bidentata (Menke) Fig. 68u

Conical-fusiform, thick, solid, with height of aperture equal to height of spire, spire elevated, roundly gradate, periphery rounded and weakly tuberculate, suture imbricating, last whorl of moderate width; aperture long, outer lip thickened, slightly sinuate and inflected, both outer lip and columellar lip strongly dentate, columella with two folds within, separated by a shallow groove from the denticular lip,base with about 17 spiral lirae. Colour white with zigzag axial brown lines which are sometimes preserved in fossil specimens. Height 18, diameter 10 mm.

Not common in South Australia today, but one of the characteristic fossils of the Glanville Formation (p. 246).

Family BUCCINIDAE. Whelks

Shell ovate-conical or ovate-fusiform; whorls more or less convex,smooth or sculptured; last whorl mostly large, aperture wide, either deeply excavate abapically or with a canal and siphonal fasciole, columella mostly concave, without folds; operculum horny, usually with a terminal nucleus. Females lay eggs in large clumps of capsules. Whelks are voracious carnivores,some are predators on other molluscs, others are scavengers. Large whelks are not particularly well represented in southern Australia; most are collected by trawling or taken in lobster pots. Species of *Cominella* are, however, common in the littoral zone.

Genus **Penion** Fischer

Shell large with a tall spire and long anterior canal, sculptured with spiral lirae and axial rounded ribs or peripheral knobs; protoconch smooth, small to large, with one- and -a-half to four whorls; operculum pointed with a median furrow. Radula rachiglossan with three cusps on the narrow central teeth and three to four on the lateral teeth.

A number of synonyms, previously used in southern Australia, have been introduced for the genus: *Austrosipho* Cossmann, *Verconella* Iredale, *Berylsma* Iredale and *Largisipho* Iredale. The Australian species of *Penion* have been reviewed by Ponder (1973a).

Penion mandarinus (Duclos) Figs 25d,e

A large heavy fusiform shell with about eight whorls, shoulder more or less concave, periphery angled (Fig. 25e), sometimes rounded; (Fig. 25d) sculptured with from twelve to fifteen rounded spiral cords on the penultimate whorl and finer cords between them; axial ribs in the angled form forming knobs or swellings on the periphery. Aperture medium to large, outer lip dentate within. Dimensions of rounded specimen height 89, diameter 43 mm; of large nodular specimen height 179, diameter 74 mm. Lives in sand under or near rocks on reefs on medium energy coasts in the lower littoral and shallow sublittoral zones from SA to Tas. and the continental shelf in the Great Australian Bight and NSW.

Penion mandarinus is a variable species which changes shape with depth. It has been known by many names which are listed by Ponder.

Genus **Cominella** Gray

Small to medium, biconical to fusiform, with a moderately high spire, whorls constricted below the suture, sculpture with sinuous axial ribs and spiral threads or grooves; last whorl large with a short neck and strong siphonal fasciole; aperture broadly ovate with a short, broad and deep siphonal canal; outer lip insinuated at the constriction below the suture.

Cominella eburnea (Reeve) Figs 20x,y; 57x;66d,e

Moderately small, solid, protoconch with one-and-a-half whorls, six adult whorls, angulate at the shoulder and constricted below the suture; sculptured with nine broad axial ribs per whorl, angulate at the shoulder and fading out on the sutural ramp and base; spiral grooves throughout; aperture half the height of the shell, ovate, strongly lirate within. Colour variable, usually yellow-brown with spiral brown flecks. Height 30, diameter 13 mm.

The species is commonly found in sand near reefs and seagrass on medium energy coasts in the littoral zone to 10 m depth.

Cominella lineolata (Lamarck) Figs 20v,w; 66c; Pl. 5d

Similar to *C. eburnea* but with weaker axial ribs; aperture lirate within; colour very variable. Height 30, diameter 11 mm.

Habitat variable; found in silty sand and *Heterozostera* beds on sandflats or in sand under rocks on silty reefs and in sheltered pools on low to high energy coasts in the littoral zone to 5m depth.

Family NASSARIIDAE. Dog whelks

Shells small to moderate sized, ovate-conical, with a moderate spire, small elevated protoconch, inflated whorls, sculpture spiral, axial or both, or smooth. Aperture with a very short siphonal canal or with a deep siphonal notch; operculum horny. Radula rachiglossan. The animal has a large foot, usually with two short tails at the posterior end. Nassariids are mostly active scavengers feeding on dead or decaying animal matter; some are detritus feeders. They are abundant on intertidal mud- or sand-flats.

Genus **Niotha** H. & A. Adams

Shell of moderate size, with a low conical spire and convex whorls separated by deep, impressed sutures; sculptured with numerous axial ribs granulated by small spiral ribs. Last whorl with a short neck and broad siphonal fasciole.

PLATE 2 Gastropods of rocky coasts: a. *Pleuroploca australasia;* b. *Conus (Floraconus) anemone;* c. *Cassis (Hypocassis) fimbriata;* d. *Thais orbita;* e. *Cabestana tabulata* (Trans. 24535)

PLATE 2

Niotha pyrrhus (Menke) Figs 27l,m; 65f,g; Pl.11h

About 20 axial ribs on the last whorl crossed and granulated by four spiral ribs on the penultimate whorl, eight on the last whorl. Aperture with a varix behind and six denticles within the outer lip; columellar lip with four denticles abapically and a marked parietal ridge; colour cream to light brown with a brown spiral band above the suture and another narrow band below the suture. height 18, diameter 10 mm.

The species is widely distributed, crawling about on sandy bottoms in the littoral zone from 1 to 20m depth on low to high energy coasts.

Niotha pauperata (Lamarck) Figs 27n,o; 65h,i; Pl.11i

Occurs with *N. pyrrhus* from which it may be distinguished by its shorter spire and heavier columellar callus; colour is cream or brown with a darker brown band at the middle of the last whorl.

N. pauperata is commonly found in aggregations on intertidal sand flats and beaches on low to medium energy coasts to 3 m depth.

Full generic rank is here retained for *Niotha*, although Cernohorsky (1972), who revised the family in the Indo-Pacific, reduced it to a subgenus of *Nassarius. Parcanassa* is sometimes used for the species.

Genus **Hinia** Leach in Gray

Hinia (Reticunassa) cf *paupera* (Gould) Fig. 67b

The generic classification of this species is tentative and follows Wenz's classification used by Ludbrook (1958) pending study of fossil nassariids in southern Australia. In revising the family, Cernohorsky (1972) appears to have confused *Hinia* Leach in Gray, 1847, with *Hima* Leach in Gray, 1852, which may be, in fact, a typographic error for the earlier *Hinia*.

The species appears to be variable in shell characters, although the fossil (Fig. 67b) most closely resembles the Sydney Harbour variety figured by Cernohorsky (1972 Fig. 153). It is immature, with four adult whorls sculptured with ten axial ribs and 11 strong spiral lirae on the last whorl and base; aperture ovate, outer lip varicate with a few denticles within, columella not heavily calloused, weakly denticulate or wrinkled. Height 8, diameter 3.5 mm.

Genus **Plicarcularia** Thiele

Plicarcularia burchardi (Dunker in Philippi) Fig. 79e; Pl. 11j

Small, solid, with up to 20 broad axial ribs on the last whorl, somewhat nodulose below the suture, below the nodules the whorls constricted, spiral sculpture weak; aperture oval with a posterior notch and broad, short anterior canal, both outer and columellar lips denticulate, outer lip thickened and calloused, columellar and parietal callus broad and expanded. Height 15, diameter 9 mm.

Lives gregariously in the littoral zone in sheltered bays and tidal inlets.

Family FASCIOLARIIDAE. Tulip shells and spindle shells

Shell more or less fusiform, most with a fairly high spire; whorls strongly sculptured with spiral and/or axial ribs, commonly nodulose, seldom smooth; base tapering with a long straight neck, siphonal canal long and sometimes turned to the left, siphonal fasciole mostly gently curved; columella smooth or with abapical folds; outer lip semicircular or angled on the shoulder, smooth or lirate within; operculum horny, large, ovate, with a terminal nucleus.

The Fasciolariidae include the band shells and the elongate-fusiform spindle shells which have a very long neck and a smooth columella. They are all carnivorous, preying on other molluscs. All have red to red-orange animals with the exception of *Latirus (Dolicholatirus) spiceri* (Tenison Woods) (p. 108).

Genus **Pleuroploca** Fischer

Large to very large, elongate-fusiform, with a moderately high spire; whorls with a more or less nodular or shortly spinose keel; last whorl with a moderately long neck and deep siphonal canal.

Pleuroploca australasia (Perry) Figs 10; 28a, 66p; Pl.2a

Large, broadly fusiform with a moderately long siphonal canal, whorls more or less angled at the shoulder which is nodulose, sculptured with spiral cords; columella with three oblique folds. Colour brown with a shining dark brown periostracum, animal red. Height to 15 cm, diameter 7 cm.

Common in sand pockets on reefs and in patchy seagrass and Pinna beds in the littoral and sublittoral zones to 20 m depth.

Genus **Fusinus** Rafinesque

Small to large, slender, fusiform, mostly with axial ribs which die out on the last whorl, but some with only spiral sculpture; last whorl with a more or less long neck and a short to very long open, straight or slightly twisted siphonal canal.

Fusinus australis (Quoy & Gaimard) Figs 28c,66h,i

Large, elongate-fusiform with a long, nearly straight siphonal canal; adult whorls eight, convex and slightly angulate at the shoulder, sculptured with spiral ribs and low axial folds weakly nodulose on the shoulder; aperture ovate, outer lip wrinkled; colour brown, aperture and siphonal canal white inside, periostracum brown. Height to 11 cm, diameter 4.2 cm.

Commonly found in sand and silt on sandy bottom or near seagrass or Pinna, on low to medium energy coast from 1 to 30 m depth.

Shells of the subgenus Propefusus have strong axial and spiral sculpture and a moderately long curved siphonal canal.

Fusinus (Propefusus) undulatus (Perry) Figs 28b; 66j,k

Slender, rather small, with twelve strong axial folds with close-set axial threads between them crossed by about five axial cords with interstitial threads on each whorl; aperture and canal long, rather wide, gradually tapering. Height 47, diameter 18 mm.

Genus **Latirus** Montfort

Solid, slender, fusiform, spire high, whorls with broad axial ribs or folds and fine spiral ribs; last whorl high with a more or less long neck; aperture ovate, outer lip spirally ridged within, columella nearly straight, mostly with two or three folds.

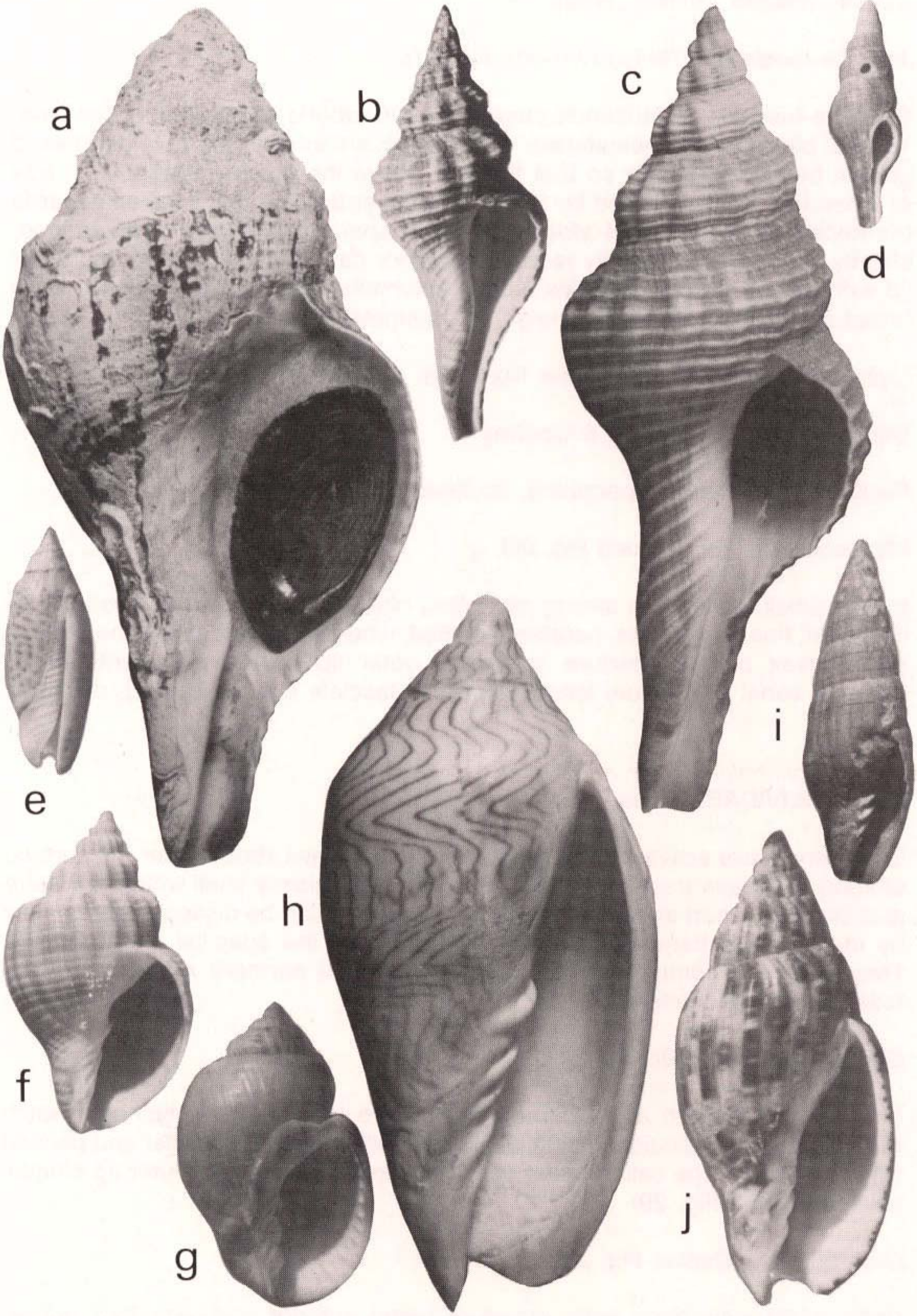
The subgenus *Dolicholatirus* is small, has a rounded protoconch, broad and flat axial ribs and crowded spiral ribs, columella with two weak folds.

Latirus (Dolicholatirus) spiceri (Tenison Woods) Fig. 28d

Shell small, slender but solid, with height of spire about equal to that of aperture; sculpture variable; protoconch smooth, dome-shaped, of 1½ whorls, adult whorls seven, axial sculpture weak to absent except for fine axial growth lirae, spiral sculpture of fine lirae which tend to be cancellated by the axial threads; last whorl with a moderately long neck; aperture ovate, outer lip conspicuously lirate within, anterior canal long, stout, almost straight, columella with one or two very weak anterior folds, columellar lip calloused.

Colour reddish chestnut to light brown, animal dull white, almost translucent with bright white opaque spots; periostracum blue, but quickly rubs off on death. Height 29, height of aperture 14, diameter 8.5mm.

Fig. 28 a. *Pleuroploca australasia*; b. *Propefusus undulatus*; c. *Fusinus australis*; d. *Latirus (Dolicholatirus) spiceri*; e. *Oliva australis*; f. *Sydaphera undulata*; g. *Nevia spirata*; h. *Amoria (Amorena) undulata*; i. *Mitra (Eumitra) glabra*; j. *Lyria mitraeformis*; x 1.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Genus **Josepha** Tenison Woods

Josepha tasmanica Tenison Woods Fig. 67a

Elongate-fusiform, protoconch smooth of 1½ whorls, adult whorls five with 16 axial plicae on the penultimate whorl which are interrupted by a depressed groove below the suture so that the ribs above the groove appear as a row of tubercles, axials crossed by 13 to 15 spiral striae, the ribs weaken towards the neck where the spiral striae dominate; aperture elongate, drop-shaped, slightly oblique with a gently recurved anterior canal notched anteriorly; outer lip with seven narrow denticles within, columella nearly straight, callus fairly broad and thick at the base. Height 19, diameter 8 mm.

Lives on rocks in shallow water from Tas. to southern WA.

Genus **Microcolus** Cotton & Godfrey

Fusiform angled at the periphery, sculptured with prominent axial ribs.

Microcolus dunkeri (Jonas) Fig. 66f, g

Rather small, solid, with strong axial ribs, nine on the last whorl, crossed by close-set, fine, spiral lirae, periphery angled, whorls concave above the periphery, convex below; aperture subovate, outer lip with a peripheral angle, siphonal canal of medium length, siphonal fasciole low. Height 18, diameter 9 mm.

Family OLIVIDAE. Olives

Olives are active scavengers or predators which crawl about under the surface of sand and leave tracks. They have an attractive glossy shell with a low spire and long last whorl and long narrow aperture and can be distinguished mainly by the fasciolar band bordered by a groove on the adapical side. (Fig.29). They are more common in the tropical waters of northern Australia and as fossils in the Miocene.

Genus **Oliva** Bruguière

Shell cylindrical with a conical spire, aperture long, narrow, siphonal notch broad, suture canaliculate; columella ridged, pillar lirate, columellar and parietal walls calloused, the callus being called the 'pillar structure'. Outer lip simple, no operculum. (Fig. 29)

Oliva australis Duclos Fig. 28c

Spire moderately high, pillar structure lirate, anterior end with four ridges. Colour variable, one form white with zigzag brown axial lines and brown fasciolar band, the other form green-yellow with crowded zigzag brown lines. Height 28, diameter 12 mm.

This common species is found in sand on sandy bottom, in pockets on reefs and seagrass beds. It leaves a distinct trail through the sand, preying on small bivalves and gastropods, on low to high energy coasts from 1 to 60 m depth.

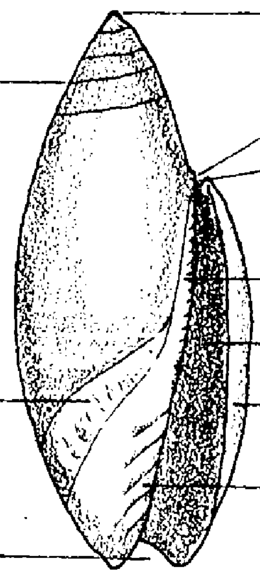

Fig. 29 Features of shell of *Oliva*.

Genus **Zemira** H. & A. Adams

Ovate, spire strongly shouldered, suture canaliculate, spiral groove ending in a slight tooth on the outer lip.

Zemira australis (Sowerby)

Cream to yellow-brown with brown spots and streaks, particularly near the sutures. The species occurs from Vic. to Tas. and NSW; it is included here because it is very easily confused with *Nevia spirata* (Fig. 28g).

Family MITRIDAE. Mitres

Fusiform to ovate, spire moderately high; adult whorls slowly increasing in diameter, not inflated, mostly smooth or weakly (some strongly) sculptured; last whorl large without siphonal canal but with a reflected siphonal notch; outer lip smooth or dentate within, columella straight or weakly concave, with a few columellar folds weakening abapically. Animal with a long proboscis. Scavengers and predators.

Genus **Mitra** Lamarck

Long and tapered, protoconch smooth with a blunt apex, columella with strong folds, aperture elongate-pyriform, slightly oblique, periostracum thin, no operculum.

Mitra (Eumitra) glabra Swainson Figs. 28i, 66l; Pl.10l

Elongate-fusiform, with a high tapering spire and nine, flatly convex adult whorls sculptured with fine punctate spiral grooves; aperture slightly oblique, narrow, columella nearly straight with four or five folds, outer lip gently concave. Height 90, diameter 25 mm. Colour light brown, interior white, a brown epidermis.

Mitra glabra preys on the sipunculan worm *Themiste cymodoceae* which lives in burrows in soft rock or in the root mat of *Amphibolis* and sometimes *Posidonia*. It can be found near its prey hiding under the sand during the day and coming out to feed at night.

Genus **Austromitra** Finlay

Mitrids of this genus are small and axially ribbed.
Austromitra lincolnensis (Angas) Fig. 67d

Shell small, slender, with 18 axial ribs on the last whorl fading out on the base which is spirally lirate, axial ribs slightly nodulose below the impressed suture; columella with four folds, the anterior one weak. Height 14, diameter 4 mm.

Genus **Proximitra** Finlay

Mitrids of this genus are smooth or axially ribbed and spirally lirate, spire low, whorls convex.

Proximitra pica (Reeve)

Spire short, whorls smooth, aperture relatively large, expanding below, columella with three folds. Height 17, diameter 8 mm.

Family VOLUTIDAE. Volutes

Mostly large to very large, more or less thick and solid, spire rather short, last whorl large, aperture long, angular above, truncated below, increasing gradually in width, with a deep siphonal notch, outer lip nearly straight or

PLATE 3 Bivalves of rocky coasts and jetties: a. *Malleus meridianus;* b,c *Brachidontes erosus;* d. *Mytilus edulis planulatus;* e,f *Modiolus areolatus;* g. *Xenostrobus pulex* (Trans. 24536)

PLATE 3

expanding slightly, thickened; columella with or without folds. Volutes are active molluscs, burrowing and crawling in sand where they prey on molluscs and other small animals. Most have attractive glossy shells and a large colourful foot. They are best represented in Australia, living in shallow and deep water. They were common and diverse during the Tertiary in southern Australia.

Genus **Amoria** Gray

Of medium size, ovate-fusiform, with a short conical spire, moderately large roundly conical protoconch and large last whorl; whorls slightly inflated, glossy, smooth, shoulder rounded; last whorl ovate, gradually narrowing abapically with a siphonal fasciole; aperture high, moderately broad and deeply excavate abapically, sharply angled adapically; outer lip heavy, smooth within, columella almost straight, usually with four to five strong folds, no operculum. Most species of *Amoria* are restricted to northern Australia, and southern Australian representatives belong to the subgenus *Amorena.*

Amoria (Amoria) grayi Ludbrook Fig. 58b

A large *Amoria* with a moderately attenuated spire and polygyrate papillate protoconch with a sharp tip; last whorl large, rather narrow, tapering anteriorly, aperture narrow posteriorly, widening anteriorly. Height 92, diameter 31, height of aperture 62 mm.

The species lives today from Perth to Cambridge Gulf, WA. Isolated specimens close to, if not identical with, the species have been found in Early Pleistocene deposits.

The genus *Amoria* was revised by Ludbrook (1953).

Amoria (Amorena) undulata (Lamarck) Fig. 28h

Spire low and broadly conical; protoconch roundly conical, of four whorls; last whorl large, angulate at the shoulder and steeply sloping posteriorly. Colour cream, with angularly undulating orange-brown axial lines; aperture apricot within with a lighter band bordering the outer lip. Height 90, diameter 42 mm. On sandy bottom in the infralittoral fringe.

Genus **Lyria** Gray

Shell of medium size, solid, ovate-fusiform, spire conical, last whorl large, constricted below; sculpture of strong axial ribs, aperture narrow, angled above, with a short, deep, reflected siphonal canal, outer lip thickened with a varix; columella with two or three strong folds.

Lyria mitraeformis (Lamarck) Fig. 28j; Pl.5c

Adult whorls sculptured with about 14 ribs, last whorl with 15 to 18 somewhat sinuous ribs. Colour variable, cream with three spiral bands of dark brown blotches and numerous interrupted spiral lines, interior white or cream. Height 44, diameter 20 mm.

Found in sand and sand pockets on reefs on medium to high energy coast and in areas of strong current to 50m depth. It is an active predator on small gastropods, bivalves and chitons.

Superfamily CANCELLARIACEA (= NEMATOGLOSSA)

The Cancellariacea possess a distinctive radula with very elongate central teeth and without lateral and marginal teeth.

Family CANCELLARIIDAE. Nutmegs

Fairly small, ovate-conical, spire moderate to high, whorls cancellate or axially ribbed, aperture elongate-ovate or roundly triangular, excavate below and with a poorly developed siphonal canal; outer lip thickened, folded or dentate within; columella slightly twisted, with two or three strong spiral folds; operculum absent. Feeding habits unknown.

Genus **Sydaphera** Iredale

Spire moderately high, last whorl large, whorls convex, separated by deep sutures and more or less angulate on the shoulder just below the suture; sculpture of rounded broad axial ribs which weaken towards the base.

Sydaphera undulata (Sowerby) Figs 28f,57r

Large for the genus, solid, elongate-ovate, with a relatively high gradate spire which is half the height of the shell, whorls angulate at the shoulder and more or less excavate at the suture; sculptured with about 18 axial ribs on the penultimate whorl, varying on the last whorl, crossed by numerous spiral grooves and lirae. Outer lip lirate within, columella with three strong folds, columellar lip separated from the columella; siphonal fasciole curved and cord-like. Colour cream to brown with a brown broad band below the suture. Height 42, diameter 22 mm.

Sydaphera lactea (Deshayes)

Similar to *S. undulata* but smaller and less strongly sculptured. Cream to fawn-coloured, with an interrupted brown band near the suture. Height 27, diameter 17 mm.

It is found in sand under rocks and rubble in sheltered areas on high energy coasts, in the littoral zone to 5 m depth.

Genus **Nevia** Jousseaume

Spire short, turreted, sutures deeply excavated, somewhat umbilicate, siphonal fasciole cord-like.

Nevia spirata (Lamarck) Fig. 28g

Sutures deeply channelled, with a sharp angle at the margin reflected in the outer lip; early whorls with fine axial ribs which die out on the last whorl, spiral sculpture of fine grooves, columella with three strong folds, outer lip weakly lirate within. Colour cream or fawn with an intermediate band of brown blotches beneath the suture, interior pinkish white. Height 25, diameter 15 mm.

This species is found in sand and sand pockets on reefs on medium energy coast and strong current areas. Nocturnally active, it will prey on small gastropods.

Family MARGINELLIDAE

This is a family of numerous species, both living and fossil, with small, solid, polished, colourful shells with spires of varying height, some immersed, and a large last whorl. As with the cowries and some volutes, the mantle covers most of the shell. The nomenclature of the whole family is difficult, and none are described here. Most of them live on sand banks at low water.

Superfamily CONACEA (= TOXOGLOSSA)

The Conacea or Toxoglossa are the most highly developed of the Neogastropoda. They are predominantly a tropical group comprising three families: the Conidae or poisonous cone shells, which can inflict painful and even fatal stings; the Turridae or turrids, a large family of small fusiform shells inhabiting deeper water, and the Terebridae or augurs living in sand in the littoral zone.

Most of the Conacea have a toxoglossan radula, consisting of a series of hollow, barbed, harpoon-like shafts in the radula sac connected to a poison gland which also opens into the proboscis. With one of the shafts the cone harpoons its prey and injects a powerful neurotoxin to subdue the prey which can then be swallowed whole.

Family TURRIDAE

Genus **Splendrillia** Hedley

Protoconch paucispiral, bluntly rounded, sinus on outer lip moderate to deep, sculptured with prominent axials.

Splendrillia harpularia (Desmoulins) Fig. 67e

Moderately large for the genus, with a smooth protoconch of two fairly high whorls, seven adult whorls with from 15 to 20 oblique axial ribs terminating abruptly at the sinus, below the suture a strong more or less beaded spiral cord, ten spiral lirae on the base and neck; aperture oblique, outer lip with a moderately deep sinus on the shoulder. Height 20, diameter 8 mm.

Family CONIDAE Cones

Medium to large, inverted conical or biconical shells with a low conical or almost flat spire; last whorl very large, gradually narrowing, aperture deep, high and narrow with parallel or nearly parallel margins, columella almost straight, smooth, operculum horny when present, thin, long and narrow with a terminal nucleus.

Genus **Conus** Linnaeus

Mostly heavy, solid to thick-shelled, obconic to concave obconic, last whorl large with a flat or concave ramp above. Aperture almost as high as the last whorl, somewhat excavated or simply truncated below.

Conus (Floraconus) anemone Lamarck Fig. 25a, 66o; Pl.2b

Obconic, spire low, eight adult whorls all spirally lirate, shoulder rounded. Colour variable but commonly white to pink with orange blotches. Height 50, diameter 25 mm. Common on or among rock in the infralittoral fringe.

Conus (Floraconus) compressus Sowerby Fig. 66m,n

A rather small *Conus* with a gradate spire usually about one-third height of shell, adult whorls seven, with an angulate shoulder; sutural ramp with from two to five or six spiral lirae, last whorl with ten spiral grooves on the base; aperture long, narrow, oblique. Height 33, height of spire 11, diameter 15 mm.

Subclass OPISTHOBRANCHIA

Opisthobranchs of southern Australia are the subject of present study and their nomenclature is being revised. That used here is therefore tentative.

Family ATYIDAE

Genus **Haminoea** Turton

Subgenus Liloa Pilsbry

Haminoea (Liloa) brevis (Quoy & Gaimard) Fig. 68r

Small, thin, with an ovately cylindrical shell, truncated at both ends, spire concealed, apex sunken in a broad funnel-shaped depression, last whorl completely enveloping the rest of the shell, smooth but for 12 to 20 spiral striae anteriorly and numerous microscopic growth striae; aperture wide, slightly expanding anteriorly, outer lip arched above the whorl posteriorly. Length 12, diameter 6.6 mm.

Family SCAPHANDRIDAE

Genus **Cylichna** Loven

Cylichna arachis (Quoy & Gaimard)

Shell rolled in an elongate cylinder, the posterior end sunken with a deep adapical umbilicus, sculptured with microscopic spiral striae; aperture long, narrow, widening anteriorly, outer lip turned slightly inwards, curved a little above the shell posteriorly and below the shell in a broad curve anteriorly. Height 33, diameter 14 mm.

In life the shell is covered with a brown epidermis and looks like a peanut.

Family BULLIDAE

Bulla botanica Hedley Fig. 67h; Pl.10q. Bubble shell

Shell involute, thin, large, bubble-like, with á sunken spire and long, wide aperture which is gently curved above the shell posteriorly and expanding into a moderate curve anteriorly. Colour mottled brown. Height 62, diameter 35 mm.

Lives in sandy muds and in weed on tidal flats and in estuaries.

Subclass PULMONATA

The pulmonates are gastropods which can breathe air. They live not only in marine environments but also in freshwater and on land. They include the air-

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PLATE 4 Bivalves of rocky coasts: a-c *Spondylus tenellus;* d,e *Anomia trigonopsis;* f-i *Chlamys (Chlamys) asperrima asperrima;* j. *Chlamys (Chlamys) aktinos* (Trans. 24537)

PLATE 4

breathing snails, air-breathing limpets and slugs. They usually have a well developed shell, but it may be lost. They have no ctenidium or true gill, and with few exceptions the mantle cavity acts as a closed lung. This function of the pallial cavity permits both aquatic and air breathing, so that nearly all of the lower pulmonates are amphibious. All the pulmonates are *hermaphroditic*, the primitive Ellobiidae being *protandrous.*

Most of the pulmonates are herbivorous, the aquatic Basommatophora grazing on algae or fine deposits with a powerful, broad, multiseriate (many-toothed) radula; some of the land pulmonates are carnivorous, feeding on other snails and slugs and earthworms. Unlike the prosobranchs, they have a single median dorsal jaw; only in the ellobiids is there any trace of the style sac, and nearly all have a gizzard for moving the stomach contents; the faeces are stored in the long double-spiral intestine.

Together with the opisthobranchs, the pulmonates differ from the prosobranchs in the nature of the nervous system. In the prosobranchs it is *streptoneurous*, associated with torsion, in which the circuit of nerve cords of the visceral loop cross in a figure 8; in the opisthobranchs and pulmonates *(Euthyneura)* the nerve cords of the visceral loop do not cross, the opisthobranchs by detorsion and the pulmonates by internal rearrangement of the nervous system.

In southern Australia marine pulmonates will be found on coastal margins mostly on tidal mud flats and on rocks.

Order BASOMMATOPHORA

Shell always present, spiral, cap- or cup-shaped, completely admitting the animal, with one exception, aperture entire, operculum absent in all but the Amphibolidae. Eyes when present at the base of the retracting but not invaginating tentacles, which are sometimes absent; genital openings mostly separate. The Basommatophora are almost exclusively inhabitants of freshwater or the marine littoral zone.

Superfamily ELLOBIACEA

Shell spiral, mostly dextral, seldom sinistral; aperture usually constricted by teeth; no operculum. Eyes at the base of the tentacles. Predominantly inhabitants of the marine littoral zone.

Family ELLOBIIDAE. Ear shells

Shell large to very small, solid, ovate to ovate-conical to cylindrical, covered with an epidermis, spire low to moderately high, whorls smooth or sculptured,

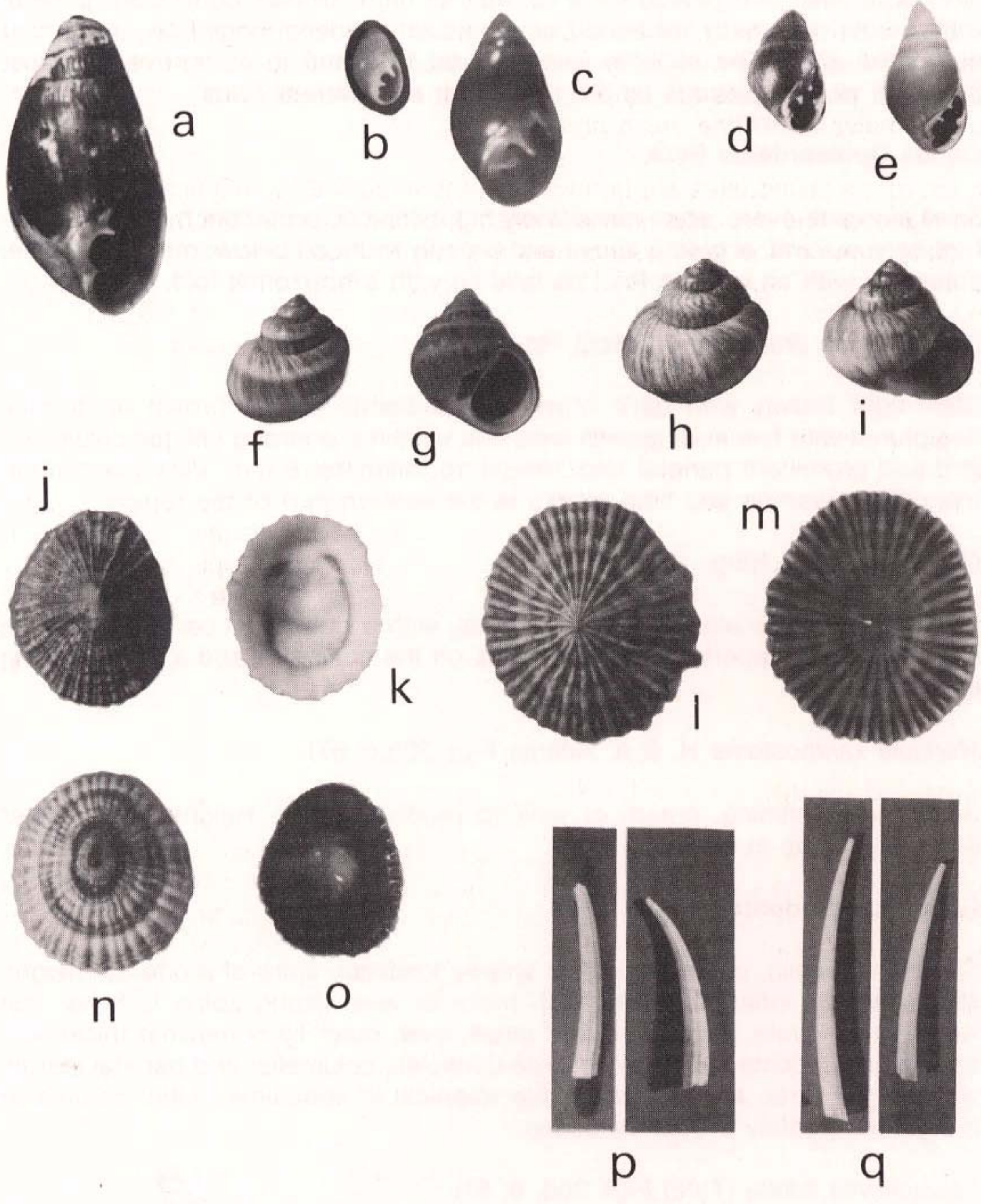

Fig. 30 a. *Ophicardelus ornatus*; b,c. *Marinula xanthostoma* b.x 1, c. x 2; d,e. *Laemodonta ciliata* x 2; f,g. *Salinator fragilis*; h,i. *Salinator solidus*; j,k. *Siphonaria (Hubendickula) baconi*; l,m. *Siphonaria (Hubendickula) diemenensis*; n,o.*Liriola (Pachysiphonaria) tasmanica* p. *Dentalium (Paradentalium) bednalli;* q. *Antalis hyperhemileuron.*
x 1 unless otherwise stated.

the inner walls, with one exception, always more or less resorbed; aperture with columellar and palatal folds as well as more or less denticulate parietal folds; outer lip mostly thickened or denticulate. Animal completely retracting within the shell. The ellobiids live on tidal flats and in mangrove swamps. They are all conspicuous by the columellar and parietal folds.

Genus **Ophicardelus** Beck

Shell elongate-ovate, spire moderately high, conical, protoconch eroded, aperture narrow, oval, angulate above and broadly rounded below; outer lip simple, columella with an oblique fold, parietal lip with a horizontal fold.

Ophicardelus ornatus (Ferussac) Fig. 30a

Shell light brown with dark brown spiral bands and a brown epidermis. Sculptured with fine axial growth lines and wrinkles; a strong oblique columellar fold and prominent parietal fold. Height 15, diameter 8 mm. Very common in mangrove swamps and tidal creeks in the eastern part of the region.

Genus **Marinula** King

Shell more or less elongate ovate-conical, with a rather low conical spire and large last whorl; aperture with two folds on the columella and a larger strong parietal fold.

Marinula xanthostoma H. & A. Adams Figs 30b,c; 67f

Small, solid, shining, cream or pink to reddish yellow. Height 10, diameter 6 mm. Common in sheltered bays.

Genus **Laemodonta** Philippi

Shell small, solid, ovate-conical to shortly fusiform, spire of moderate height, sharp, whorls inflated, mostly with more or less strong spiral furrows; last whorl large, ovate, aperture rather small, oval, outer lip somewhat thickened, sometimes varicate, with two or three denticles, columellar and parietal margin with two or three folds of which the abapical is sometimes bifid; columellar margin moderately broad, calloused.

Laemodonta ciliata (Tate) Figs 30d, e; 67i

Brown and black, shining, with a light band near the suture; sculptured with spiral striae. Height 7, diameter 4 mm. The species is distinguished by the strong denticles on the outer lip. It lives on samphire flats associated with *Salinator fragilis*.

PLATE 5 Molluscs of rocky coasts: a,b *Pterynotus triformis;* c. *Lyria mitraeformis;* d. *Cominella lineolata;* e,f *Polinices incei;* g. *Sinum (Ectosinum) zonale;* h. *Hipponix (Sabia) conicus;* i,j *Cypraea (Notocypraea) piperita;* k,l *Ellatrivia merces;* m,n *Cardita crassicosta;* o,p *Barbatia pistachia* (Trans. 24538)

PLATE 5

Superfamily AMPHIBOLACEA

Shell medium size to small, dextral, rounded; spire rather low, conical, whorls swollen; last whorl large, more or less rounded, often umbilicate, aperture rather wide, operculum horny, oval, a rapidly increasing spiral with the nucleus in the lower half. Mantle cavity filled with water; no ctenidium.

Family AMPHIBOLIDAE

Unselective deposit feeders; they swallow mud which is comminuted by the gizzard. They live in salt marshes, samphire swamps or in brackish water near river mouths, on the surface or partly buried in sand.

Genus **Salinator** Hedley

Shell small, thin, roundly conical, spire low, whorls rounded, with fine axial bands, last whorl large, ventricose, aperture rather wide, oval, outer lip sharp; columella concave, columellar lip not calloused; operculum with relatively large nucleus.

Salinator fragilis (Lamarck) Figs 30f,g

Shell globose-conical, umbilicate, thin, spire less than half height of shell, suture deeply impressed, adult whorls sculptured with irregular growth striae; aperture oblique, almost half circle, columellar lip nearly straight, oblique, parietal lip thin, attached, umbilicus deep. Height 18, diameter 15 mm. Colour cream to light brown with a brown spiral band. Lives in great numbers on samphire flats such as in Gulf St Vincent, back dune swamps as at the Coorong and in estuaries.

Salinator solidus (von Martens) (Figs 30h,i; Pl.11a) is a relatively thick, solid shell with a higher spire, numerous waving axial brown markings and a thick strong operculum with a conspicuous projecting spiral rib on its inner face. Its habitat is similar to that of *S. fragilis*.

Superfamily SIPHONARIACEA

Shell bowl- to cap-shaped, with externally a more or less double ridge running obliquely forward on the right, which corresponds to an internal siphonal groove and sinus; internally a horseshoe-shaped adductor muscle impression, at the right end of which the pulmonary groove passes.

Family SIPHONARIIDAE. Pulmonate limpets, Siphons

Patelliform, depressed conical, elliptical or oval in outline, apex blunt, almost central or set a little posteriorly; surface radially ribbed, with a flat radial ridge from the apex to the siphonal sinus on the right; more or less shining and coloured within; a horseshoe-shaped muscle scar with the pulmonary groove on the anterior right side. Buccal mass and radula very powerful, radula very long.

Like the true limpets, the pulmonate limpets or siphons live attached to rocks, grazing on algae, in the intertidal zone.

Genus **Siphonaria** Sowerby

Upper side with a strong double ridge on the anterior right side of the shell corresponding to the siphonal groove.

Siphonaria (Hubendickula) diemenensis Quoy & Gaimard Figs 30l,m; Pl.1t

Relatively high, conspicuously sculptured with about 40 strong, compact, rounded, white radial ribs separated by dark brown interspaces and concentric dark brown colour bands; the alternation of white ribs and brown interspaces is repeated in the outer part of the interior, with the inner part towards the apex orange. Apex central, inclined to the posterior. Animal citron-yellow speckled with yellow. Length 28, breadth 24 mm. Common on jetty piles and rocks in the upper and mid littoral zones.

S. (H.) baconi Reeve Figs 30j,k; 57a; 67k,l

A relatively flat usually much eroded species with about 15 to 25 primary radial ribs and one to four finer riblets intercalated between each pair; cream to light greyish brown in colour, white inside, adductor scar light brown; siphonal groove conspicuous. Length 23, breadth 18 mm.

Jenkins (1983) considers *S. baconi* to be a synonym of *S. zelandica* Quoy & Gaimard.

Common on intertidal rock shelves in areas of medium to high energy, usually at a lower level than *S. (H.) diemenensis*.

Genus **Liriola** Dall

Small to moderately large, thin, bowl-shaped, irregularly elongate-ovate in outline, apex posterior and directed to the left; sculptured with flat axial ribs with a double rib corresponding to the siphonal groove, or without definite sculpture; interior with horseshoe-shaped muscle scar and siphonal groove as in *Siphonaria*.

Liriola (Pachysiphonaria) tasmanica (Tenison Woods) Figs 30n,o

Thin but solid, irregularly oval, conical, high, apex brown, directed posteriorly and to the left, surface sculptured with from 40 to 50 roundly flattened radial ribs crossed by fine concentric growth striae; frequently corroded, shell margin dentate; colour bluish-white zoned with concentric brown bands, interior shining, chocolate-brown, spatula and siphonal canal white. Length 23, breadth 20 mm. Animal brown, foot yellowish.

The species is found in holes and crevices in rocks in the upper littoral zone on medium to high energy coasts.

The shell is often eroded.

Class SCAPHOPODA. Tusk shells

The scaphopods, or tusk shells, are a small class of marine burrowing molluscs with an external, long, tapering, tubular shell open at both ends. The shell is usually somewhat curved like a tusk. In life (Fig. 31a) the animal lives with the broad end of the shell, containing the head and foot, buried in a muddy or sandy substrate from which the shell projects obliquely, only the narrower apical end projecting into the water. All scaphopods are benthonic. They feed on detritus or microscopic animals such as foraminifera.

Like the shell, the mantle (Fig. 31b) is tubular, wrapped completely around the body, with the pallial cavity running through the shell on the lower side. The larger anterior mantle opening is contracted by a muscular thickening of the mantle, allowing the long conical foot to be extended into the substrate through the anterior mantle opening, drawing the animal downwards. The head has a snout and mouth surrounded by bunches of ciliated tentacles, or *captacula*, which capture foraminifera or other small particles; the *radula* is large and the stomach simple. Organic waste and genital products pass through the smaller posterior opening through which both inward and outward ciliary currents pass. There are no gills, and respiration takes place through folds in the mantle lining. The heart is rudimentary, being in the form of a contractile region near the anus, which propels the blood circulating in a system of rudimentary sinuses. There are paired digestive diverticula arising from the simple stomach; the anus is ventral, with a pair of small kidney openings on either side.

The sexes are separate; there is a large gonad which discharges its gametes through the right renal organ.

Scaphopods are classified in two main divisions. Until recently these were mostly given the rank of families; the DENTALIIDAE, with a regularly tapering shell and conical foot with an encircling sheath, and the SIPHONODENTALI-

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PLATE 6 Bivalves of open ocean beaches: a,b *Donax (Plebidonax) deltoides;* c,d *Tellina (Eurytellina) albinella;* e,f *Bassina pachyphylla;* g,h *Mactra rufescens;* i-l *Mactra australis* (Trans. 24539)

PLATE 6

IDAE, small, mostly smooth shells tapering posteriorly to the apex and commonly contracted anteriorly towards the mouth; the foot is expanded distally in a symmetrical disk and may be simple or vermiform.

Several workers have recently modified this classification and the nomenclature of the higher categories is at present unstable pending more detailed studies of the scaphopod anatomy. In general, a division into two orders: DENTALIIDA in place of Dentaliidae, and GADILIDA in place of Siphonodentaliidae, reflects current usage.

The Dentaliida are represented by at least eleven small species living in southern Australian waters. Most of them have been dredged from depths of forty metres or more and are seldom collected. They are not uncommon as fossils in the Tertiary.

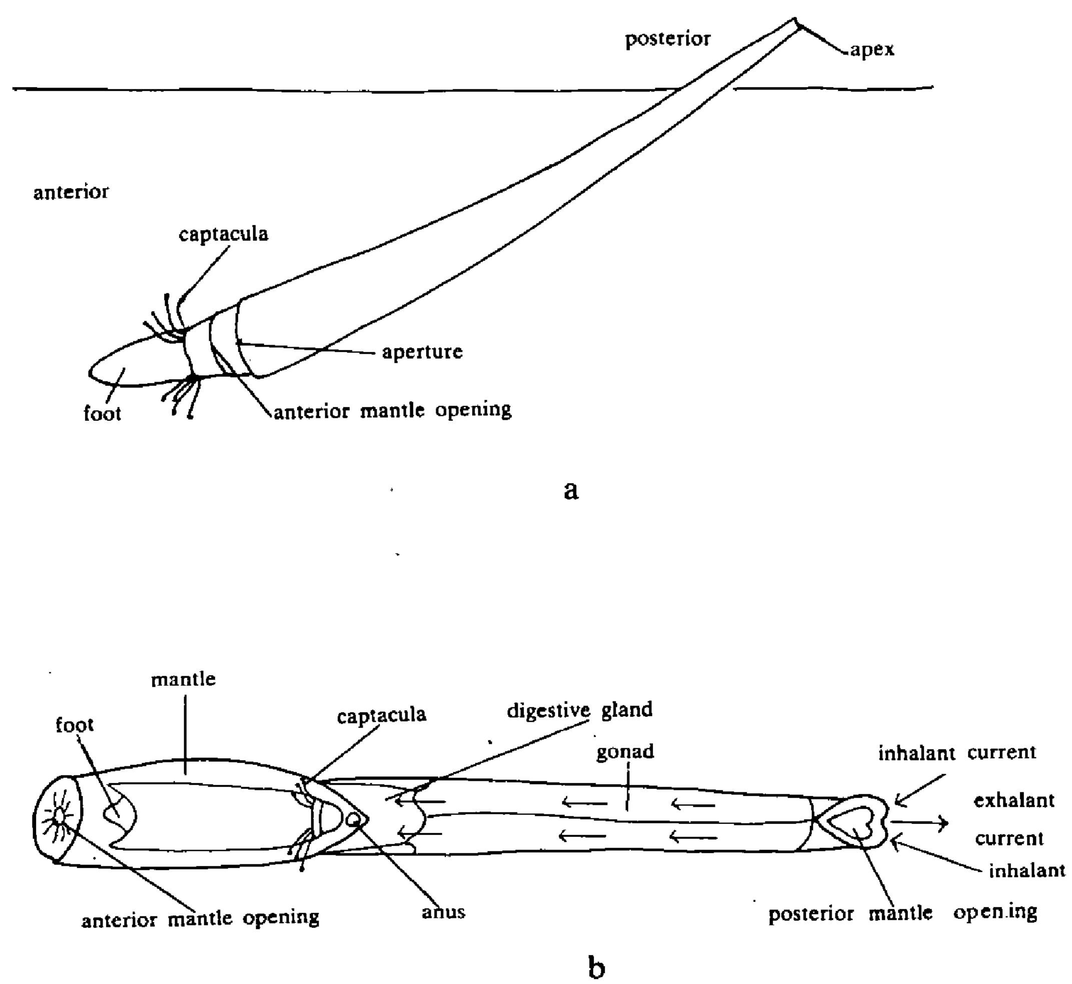

Fig. 31 Scaphopod: a. in living position with foot extended; b. principal soft parts.

Genus **Dentalium** Linnaeus

Small more or less curved, with strong longitudinal ribs, transverse section polygonal. In the subgenus *Paradentalium* the primary ribs are weaker, with secondary ribs rising by intercalation between them. The aperture is rounded, modified by the primary ribs.

Dentalium (Paradentalium) bednalli Pilsbry & Sharp Fig. 30p

Shell curved, particularly towards the apex, with about eight, but varying in number, primary ribs, secondary ribs rising in the interspaces and increasing in strength towards the aperture. Length 23 mm. Dredged in Gulf St Vincent at depths 30-66 m.

Dentalium (Paradentalium) flindersi Cotton & Ludbrook Fig. 63d

Shell small, curved towards the apex, with twelve longitudinal ribs separated by deep concave interspaces wider than the ribs. Length 21, width 2.9 mm.

Dentalium (Paradentalium) tasmaniense Tenison Woods

Very small, with eight longitudinal ribs. Length 10.5, diameter at aperture 1.5 mm.

Genus **Antalis** H. & A. Adams

Small to medium, more or less curved, shells sculptured with fine longitudinal riblets near the apex and becoming obsolete towards the aperture; aperture rounded, apex commonly with a V-shaped notch or terminal pipe.

Antalis hemileuron (Verco) Figs 63b,c

Shell of medium length, gently curved, more so towards the apex, with about 10 fine longitudinal ribs in the posterior half, smooth or nearly so towards the aperture. Length 37, diameter at aperture 3 mm.

Antalis hyperhemileuron Verco Figs 30q; 63a

Slender, curved, microscopically finely ribbed near the apex, smooth towards the aperture. Length 30 mm. Dredged southwestern Australia from King George Sound to Fremantle 20-70 m.

The Gadilida include the genus *Cadulus* of which several species belonging to several subgenera have been recorded from southern Australia. One at least is not a mollusc and others are mainly very small shells less than 10 mm in length, obtained rarely by dredging.

Class BIVALVIA (bivalves)

The Bivalvia ('two valves') have been known by other names, including Pelecypoda ('axe-foot') and Lamellibranchia ('plate-gills'), but, although other forms have two valves, the Linnean name Bivalvia is to be preferred because it has priority over other names and is more generally descriptive. All Bivalvia have two valves but not all have an axe-like foot or plate-like gills.

The Bivalvia include the scallops, mussels, cockles, oysters and clams, all major sources of food, as well as the destructive shipworms. They are bilaterally symmetrical, laterally compressed aquatic molluscs. None can breathe or feed except in water; about one-third live in fresh water, the rest are marine. They are nearly all sedentary but many of them are well adapted for burrowing in sand or mud and some like the shipworms can bore into rocks and wood; they are the predominant shells of sandy beaches and constitute the bulk of the infauna (i.e. species living in the substrate), but many are epifaunal (i.e. living on the substrate).

Soft parts (Fig. 32)

The vital organs are surrounded by a *mantle* which secretes and lines the shell. The mantle edge has three lobes - the outer secretes the calcareous layer of the shell, the middle is sensory and the inner lobe or velum controls the flow of water. The *mantle cavity* has the important functions of acting as a respiratory chamber, and a chamber through which all food passes and through which waste and genital products pass before being discharged. Water is drawn into the mantle cavity by ciliary activity on the ctenidia as an inhalant current and expelled as an exhalant current, usually through inhalant (or incurrent) and exhalant (or excurrent) siphons situated posteriorly. The siphons can be retracted within the shell by means of *siphonal retractor muscles.* In deep burrowing forms the siphons can be considerably elongated.

The well developed foot is usually used not for creeping but for burrowing and rhythmic locomotion by means of alternate lengthening and shortening. Associated with the foot in many bivalves is the *byssus*, a bundle of hair-like threads by which the mollusc can attach itself to rocks, jetty piles, seaweed and the like.

Almost all bivalves are ciliary feeders, either infaunal suspension feeders, epifaunal suspension feeders or surface deposit feeders. They live on suspended material or on organic matter deposited in mud and sand. The food particles pass in with the current through the inhalant siphon and are sorted out by the gills or ctenidia which then pass it to the *labial palps*, lying in front of the gills, for further sorting. The palps then pass on the food to the mouth. Bivalves have the most complex and elaborate gills with two rows of filaments which are one of their most distinguishing features; they have a respiratory function and a highly efficient system of cilia for collecting, sorting and straining food.

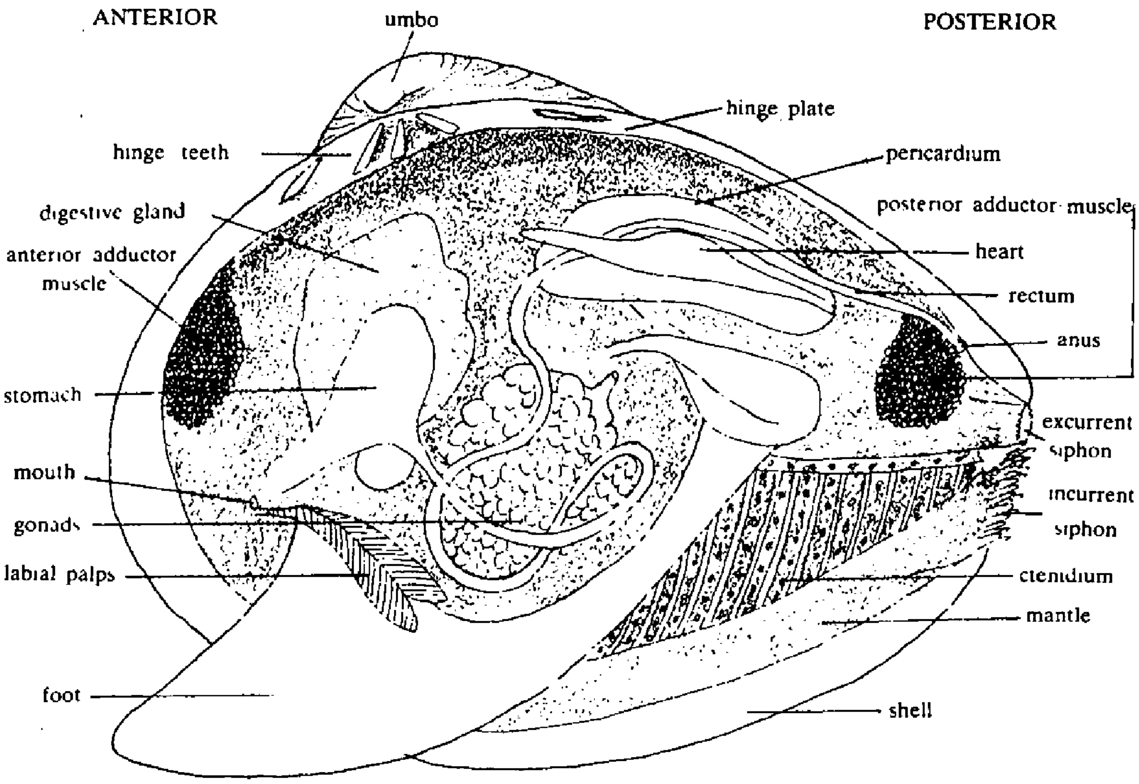

Fig. 32 **Generalised bivalve, with left valve removed to show principal soft parts.**

The mouth is a small opening at the anterior end of the animal above the front of the foot. From the mouth a short *oesophagus* leads to the *stomach* into which ducts from the *digestive gland* open. The function of the stomach is to sort out particles passed on by the labial palps and to pass on indigestible matter to the intestine. This is done by rotation of the *crystalline style*, similar to that of the gastropods. The digestive gland surrounding the stomach is the main organ of digestion. The paired digestive glands consist of numerous tubules (*diverticula*) which communicate with the stomach by a system of ducts. The main ducts opening into the intestinal groove are ciliated. There are differing opinions on the functions of the diverticula, which vary with species, but they appear to be organs of both absorption and secretion, with a two-way system of circulation by means of the ciliated ducts. Fluid and possibly also fine particles are conveyed from the stomach to the tubules, while waste materials are conveyed by an exhalant current in the opposite direction.

The faecal matter passes through the intestine to the anus where it is discharged as faecal pellets.

The Bivalvia have a *circulatory system* with a heart consisting of a *ventricle* and two *auricles, arteries, veins* and *kidneys*. The blood is clear and transparent, although a few such as *Anadara trapezia*, the Sydney blood cockle, have red blood containing two intracellular haemoglobins (Dixon 1976).

The *nervous system* consists of three pairs of *ganglia* - the *cerebro-pleural ganglia*, the *pedal ganglia* and the *visceral ganglia*; in the absence of the head and eyes many bivalves have a pair of *otocysts* in the foot; *osphradia* or sensory patches are present in the wall of the mantle cavity in some primitive bivalves and *sensory tentacles* along the edge of the mantle in some, particularly the scallops (Fig. 39).

Bivalves have a simple *reproductive system*, consisting of *gonads* placed symmetrically on the two sides of the *visceral mass*; most are unisexual, but some are bisexual or have a reversal of sex with age, or alternative seasonally between male and female. Fertilisation takes place either in the water or in the mantle cavity.

The *muscles* are important features of bivalves in that some are attached to the shell on which they leave characteristic scars (Fig. 33). The *anterior* and *posterior adductor* muscles draw the valves together; *dimyarian* bivalves have two adductor muscles; if they are nearly equal in size they are said to be *isomyarian* or *homomyarian; anisomyarian* bivalves have the anterior adductor reduced (*heteromyarian*) or absent (*monomyarian*). The adductors consist of bundles of muscle fibres, attached at the adductor scar. The muscles of the mantle are the *pallial muscles*. They consist of radially directed fibres, usually attached to the interior of the shell near the margin along a line called the *pallial line*. The pallial muscles withdraw the mantle edge within the valve before it closes. The siphons, when present, are withdrawn by the *siphonal retractor muscles* attached along the embayment in the pallial line called the *pallial sinus*.

If the siphons are large, the pallial sinus is usually large, if they are small or absent, there is no sinus and the pallial line is said to be *entire*.

The foot is retracted by the *anterior pedal retractor*, usually attached on the posterior side of the anterior adductor, and the *posterior pedal retractor* muscle usually attached on the dorsal side of the posterior adductor. In bivalves with a byssus, the posterior retractor is joined to the byssus which it retracts as well as the foot. There may be also a *pedal protractor* muscle for extending the foot and, in some families, a *pedal elevator* muscle attached in the umbonal cavity.

Important features of soft and hard parts, some of which have been used in classifying bivalves, are tabulated in Table 2..

Hard parts

The shell consists of two valves which open and close on a *hinge* on the *dorsal margin* by means of an elastic *ligament*. The opposite margin is the *ventral margin*, which usually opens widely and the two end margins are the *anterior* and *posterior*. If the two valves are equal, the shell is *equivalve*, if unequal, *inequivalve*; if the two sides of the valve are equal, the shell is

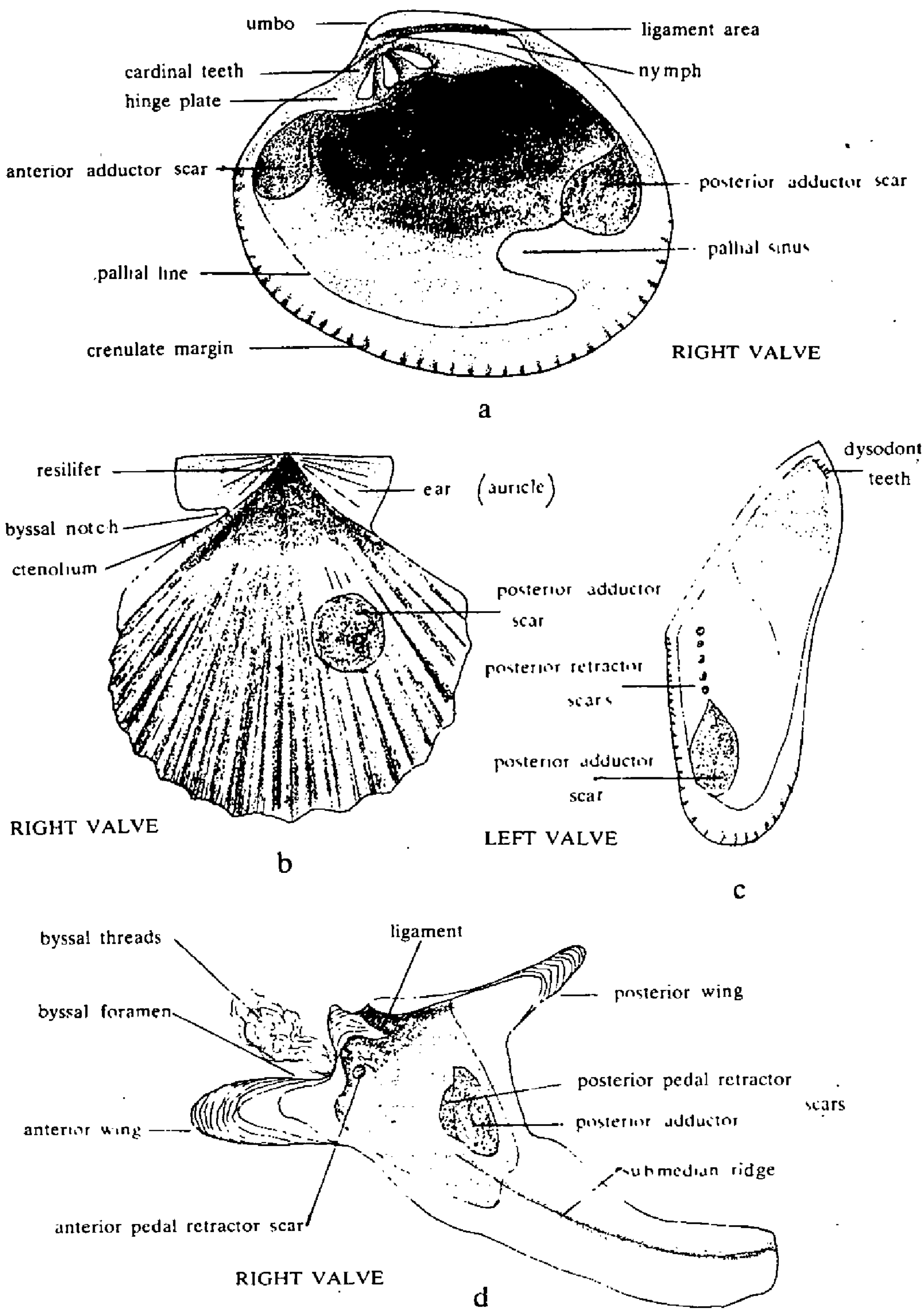

Fig. 33 Internal features of bivalve shells showing muscle scars: a. Dimyarian—Veneridae; b. Monomyarian—Pectinidae; c. Monomyarian—Mytilidae; d. Monomyarian—Malleidae.

SOME CHARACTERISTICS USED IN

HARD PARTS

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
PALAEOTAXODONTA																					
Nuculidae	1				5		7						13	14						20	
Nuculanidae	1				5		7	8			11					16					21
CRYPTODONTA																					
Solemyidae		2					7	8		10						16	17		19		
PTERIOMORPHA																					
Arcidae	1				5				9	10				14					19		
Limopsidae	1				5									14					19		
Glycymerididae	1								9					14					19		
Philobryidae	1						7							14					19		
Mytilidae										10			13						19	20	
Pinnidae		2					7						13					18	19		
Pteriidae		2	3										13								
Isognomonidae		2	3					8					13							20	
Malleidae		2					7	8					13								
Pectinidae		2	3		5		7		9				13	14	15						
Spondylidae		2	3		5		7		9								17	18			
Dimyidae		2		4	5		7														
Anomiidae		2			5														19		
Limidae	1		3		5										15			18		20	
Ostreidae		2			5										15			18		20	
PALAEOHETERODONTA																					
Trigoniidae		2						8		10											
HETERODONTA																					
Lucinidae		2				6	7	8		10				14					19	20	
Thyasiridae		2			5		7	8		10				14					19	20	
Ungulinidae		2					7	8		10				14						20	
Chamidae		2								10				14						20	
Erycinidae		2			5		7							14					19	20	
Kelliidae		2			5		7							14					19	20	
Leptonidae		2			5		7							14					19	20	
Montacutidae		2			5		7							14					19	20	
Cyamiidae		2			5		7							14					19	20	
Carditidae		2						8						14					19	20	
Condylocardiidae		2			5		7							14					19	20	
Crassatellidae		2			5		7							14					19	20	
Cardiidae		2						8		10				14							21
Mactridae		2			5		7							14							21
Mesodesmatidae		2			5		7							14							21
Solenidae		2				6		8		10	11			14					19		21
Tellinidae		2				6		8		10				14							21
Donacidae		2				6		8		10				14					19		21
Psammobiidae		2				6		8		10				14					19		21
Semelidae		2			5		7	8		10				14					19		21
Veneridae		2				6		8		10				14					19		21
Petricolidae		2				6		8		10				14					19		21
Corbulidae		2			5	6		8			11			14						20	
Gastrochaenidae		2e						8						14					19		
Hiatellidae		2												14							21
Pholadidae					5		7							14					19		
Teredinidae					5		7							14							
ANOMALODESMATA																					
Pholadomyidae		2e			5			8		10			13						19		21
Pandoridae		2			5								13							20	
Cleidothaeridae		2											13								
Laternulidae		e									11		13						19		21
Myochamidae		e			5			8					13								21
Periplomatidae		e			5								13								21
Thraciidae		e			5			8			11										21
Poromyidae		2			5			8			11		13								21
Cuspidariidae		2e			5			8			11		13								21
Verticordiidae		2						8					13								
Clavagellidae								8					13								

CLASSIFICATION OF BIVALVE FAMILIES

SOFT PARTS

	22	23	24	25	26	27	28	29	30	31	32	33	34
PALAEOTAXODONTA													
Nuculidae		23				27	28				32		
Nuculanidae		23				27	28						
CRYPTODONTA													
Solemyidae		23				27	28						
PTERIOMORPHA													
Arcidae	22	23						29				33	
Limopsidae	22	23						29				33	
Glycymerididae	22	23						29				33	
Philobryidae	22	23	24					29				33	
Mytilidae	22			25	26			29			32		
Pinnidae	22			25					30			33	
Pteriidae	22		24	25				29				33	
Isognomnidae	22		24										
Malleidae	22	23	24					29					
Pectinidae	22	23	24					29				33	
Spondylidae			24					29				33	
Dimyidae			24					29				33	
Anomiidae	22y		24					29				33	
Limidae	22		24									33	
Ostreidae		23	24						30			33	
PALAEOHETERODONTA													
Trigoniidae		23						29			32		
HETERODONTA													
Lucinidae		23				27			30		32		
Thyasiridae		23				27			30		32		
Ungulinidae		23				27			30		32		
Chamidae		23				27			30		32		
Erycinidae	22					27			30		32		
Kelliidae	22					27			30		32		
Leptonidae	22					27			30		32		
Montacutidae	22					27			30		32		
Cyamiidae	22					27			30		32		
Carditidae	22					27			30		32		
Condylocardiidae	22					27			30		32		
Crassatellidae						27			30		32		
Cardiidae						27			30		32		
Mactridae						27			30		32		
Mesodesmatidae						27			30		32		
Solenidae		23				27			30		32		
Tellinidae		23				27			30		32		
Donacidae		23				27			30		32		
Psammobiidae		23				27			30		32		
Semelidae		23				27			30		32		
Veneridae		23				27			30		32		
Petricolidae		23				27			30		32		
Corbulidae		23				27			30		32		
Gastrochaenidae		23				27			30				34
Hiatellidae		23				27			30				34
Pholadidae					26				30		32		34
Teredinidae					26				30		32		34
ANOMALODESMATA													
Pholadomyidae						27			30	31	32		
Pandoridae									30		32		34
Cleidothaeridae									30		32		
Laternulidae									30		32		
Myochamidae									30		32		
Periplomatidae					26				30		32		
Thraciidae					26				30		32		
Poromyidae										31			
Cuspidariidae				25						31			
Verticordiidae										31			
Clavagellidae									30		32		34

KEY TO NUMBERS

Hinge
1. Taxodont or taxodont type
2. Not taxodont; e. edentulous
3. Drawn out into ears
4. Not drawn out into ears
5. Resilifer present
6. Resilifer not present

Ligament
7. Internal
8. External
9. Amphidetic
10. Opisthodetic

Shell structure
11. Drawn out posteriorly
12. Not drawn out posteriorly
13. Nacreous
14. Cross lamellar
15. Foliate
16. Homogeneous
17. Aragonite
18. Calcite
19. Equivalve
20. No pallial sinus
21. Pallial sinus

Byssus
22. Byssiferous
23. Non-byssiferous

Adductor muscles
24. Monomyarian
25. Dimyarian
26. Anisomyarian
27. Isomyarian

Gills
28. Protobranch
29. Filibranch
30. Eulamellibranch
31. Septibranch
32. Cilia type 1
33. Cilia type 2

34. Burrowing
y. in young stages

equilateral, if unequal the shell is *inequilateral*. The two valves are the *right valve* (RV) and the *left valve* (LV), and it is important to be able to distinguish between the two. Hold the shell upright with the dorsal side, hinge and beaks uppermost and the external ligament or the pallial sinus towards you, then the posterior margin is towards you and the anterior margin away from you, the right valve is on the right hand side and the left valve on the left hand side.

The larval shell from which the valves grow is the *prodissoconch* situated at the angle called the *beak* and the convex area surrounding the beak is the *umbo*. If the umbones point anteriorly they are said to be *prosogyrate*, if posteriorly they are *opisthogyrate*, if they point straight towards the other valve they are *orthogyrate*. In front of the umbones there may be a heart-shaped more or less depressed area called the *lunule* and behind the umbones a similar lozenge-shaped area called the *escutcheon*. Both correspond to the external trace of the growing hinge structures.

The hinge is a complete structure, consisting of *hinge teeth*, which interlock so that the valves can be tightly closed, situated on a *hinge plate*. Those beneath the beaks and tending to radiate are the *cardinal teeth* and those oriented longitudinally close to the dorsal margin some way from the beaks are the *lateral teeth*. A nomenclature sometimes used for describing the hinge teeth of some families is included in Figure 34.

The types of hinge based on the shape and arrangement of the teeth have been used to classify the Bivalvia, the main types being

- *taxodont:* with a series of straight or chevron-shaped teeth and alternating sockets: e.g. Nuculidae, Glycymerididae.
- *heterodont:* with distinctly different cardinal and lateral teeth: Veneridae, Tellinidae.
- *isodont:* with two equal teeth in each valve on either side of a resilium pit fitting tightly into corresponding sockets in the other valve: Spondylidae.
- *schizodont:* median tooth of left valve broad and bifid: Trigoniidae. Little value in classification.
- *dysodont:* having small denticles close to the beak. Also of little value.

Classification by means of the hinge alone is not satisfactory, and in general hinges are considered taxodont or not taxodont.

The hinge plate also serves as attachment for the horny *ligament*. The ligament may be *external*, attached at the *nymphs* which extend behind the beaks and at the bottom of the escutcheon, or occupying the triangular

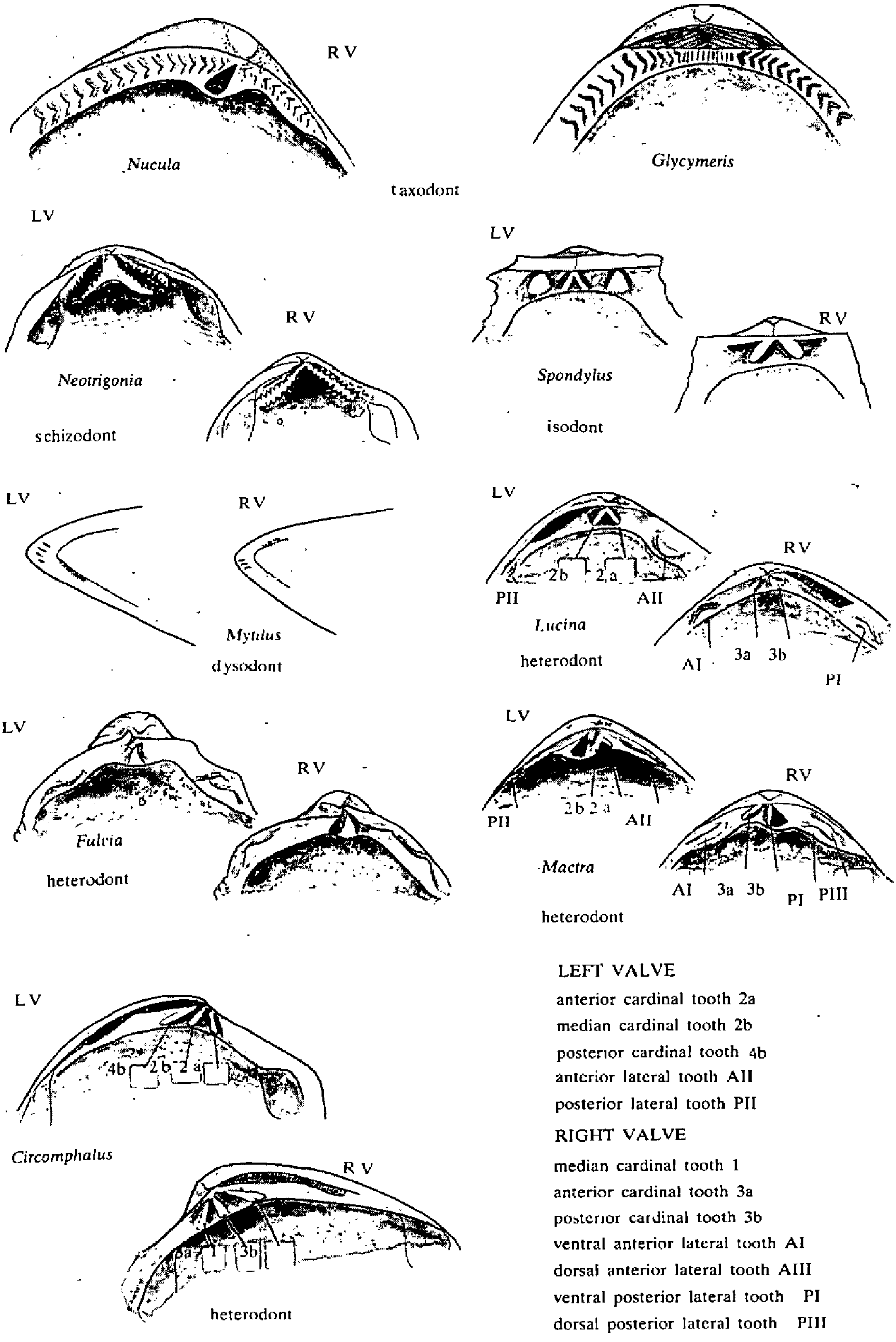

Fig. 34 **Bivalve hinges, including numerical system sometimes used for heterodont hinge teeth.**

cardinal area between the beak and the hinge margin and keeping the beaks apart; it may be *internal*, occupying a pit or depression in the hinge plate under the beak or in the form of a resilium attached to a process called the *resilifer* or *chondrophore* projecting below the beak.

The ligament itself may be *amphidetic*, extending on both sides of the beaks, *opisthodetic*, or located only posteriorly to the beaks; *alivincular*, or located between cardinal areas of the valve with a lamellar layer both anterior and posterior to a fibrous layer; *parivincular*, longitudinally elongated posterior to the beaks; *or duplivincular*, with the lamellar component repeated as a series of bands, each with its two edges inserted in narrow grooves in the cardinal areas.

The shell structure and mineralogy of the Bivalvia are discussed by Taylor et al (1969). No known bivalves have a shell wholly of calcite.

CLASSIFICATION OF THE BIVALVIA

The classification outlined here is that used in the Treatise on Invertebrate Paleontology, part N, Mollusca 6, and description of the major groupings have been freely taken from the Treatise.

The Bivalvia are divided into six subclasses:

1. *Palaeotaxodonta*, comprising the nuculoids which have a primitive taxodont hinge and protobranch ctenidia. They are all soft-bottom detritus feeders. The shell is wholly aragonitic.

2. *Cryptodonta*, with few living representatives, with poorly developed teeth, the protobranch ctenidia being used for feeding and respiration, foot adapted for burrowing.

3. *Pteriomorpha*, comprising among living bivalves the anisomyarians and the arcoids. Many have a duplivincular ligament. Some bore into firm substrates and many retain the byssus through life.

4. *Palaeoheterodonta*, including the freshwater unionaceans and the trigoniaceans. They have free or incompletely fused mantle margins, an opisthodetic parivincular ligament and wholly aragonitic shells; posterior lateral teeth begin at the beaks below the ligament.

5. *Heterodonta*, nestling or burrowing bivalves having non-nacreous shells and more-or-less fused, siphonate, mantle margins. Posterior lateral hinge teeth originate some distance behind the beaks and ligament. Ctenidia eulamellibranch. Siphons adapted for depth below the surface.

6. *Anomalodesmata*, siphonate burrowing forms with prismatic, nacreous shells, an internal resilium, chondrophores and lithodesma. Hinge plate and teeth weak or lacking.

Subclass PALAEOTAXODONTA

Order NUCULOIDA

Superfamily NUCULACEA

Equivalve, hinge taxodont, isomyarian, posterior side truncate, no pallial sinus, resilifer present or absent. Gills protobranchiate, foot large, grooved; not byssiferous. Shell with an outer prismatic and inner and middle nacreous layers.

Family NUCULIDAE. Nut shells

Shell solid, nacreous, beaks opisthogyrate, resilifer present, ligament internal.

Genus **Nucula** Lamarck

Ovate, with polished periostracum.

A number of small species of *Nucula* are obtained mostly by dredging in shallow to deep water. They live offshore, burrowing in soft mud and sand.

Nucula pusilla Angas Figs 80a-d

Shell solid, fairly small, quadrately ovate, with a slightly curved dorsal margin, posterior margin roundly truncated, anterior margin gently rounded; hinge arched, chonodrophore short, directed anteriorly; 10 anterior and four posterior V-shaped teeth; inner margin finely denticulate, surface smooth or with fine concentric ribs on anterior and posterior areas and near the ventral margin; fine radial structure in the middle of the valve. Length 3.75, height 3.22 mm.

The species has been known also as *Nucula micans, Nucula hedleyi* and *Pronucula concentrica* (Bergmans 1978)
Nucula (Leionucula) obliqua Lamarck.

Hinge line angular, chondrophore oblique, with seven anterior and 12 to 15 posterior teeth. Dredged in the eastern part of southern Australia. Length 15, height 10 mm.

A surface deposit feeder.

Superfamily NUCULANACEA

Equivalve, hinge taxodont, isomyarian, elongate posteriorly, pallial sinus usually present. Gills protobranchiate, foot large, grooved; not byssiferous. Shell with inner and outer homogeneous layers.

Family NUCULANIDAE

Shell not nacreous, resilifer present, ligament partly internal.

Genus **Nuculana** Link

Posterior end produced, ligament pit narrow, oblique, sculpture concentric.

Nuculana (Scaeoleda) crassa illepida Iredale Figs 35a,b

Large, solid, strongly concentrically lirate, rostrate with a well defined posterior rostral area bordered by a ridge running from the umbo to the posterior ventral margin. Periostracum glossy, greenish grey. The South Australian subspecies *illepida* has a shorter rostrum and is deeper than typical *crassa*. Length 30, height 20 mm. Dredged from offshore, but cast up on the beach at Encounter Bay.

Subclass CRYPTODONTA

Order SOLEMYOIDEA

Superfamily SOLEMYACEA

Equivalve, gaping, edentulous, anisomyarian, anterior side longer than the posterior, escutcheon sometimes present, dimyarian, pallial line obscure. Animal protobranchiate, foot large, adapted for burrowing. Shell aragonitic with an outer prismatic layer and inner homogeneous layer.

Family SOLEMYIDAE. Date shells

The only family.

Genus **Solemya** Lamarck

Elongate, subrectangular, umbones near the posterior margin. level with the

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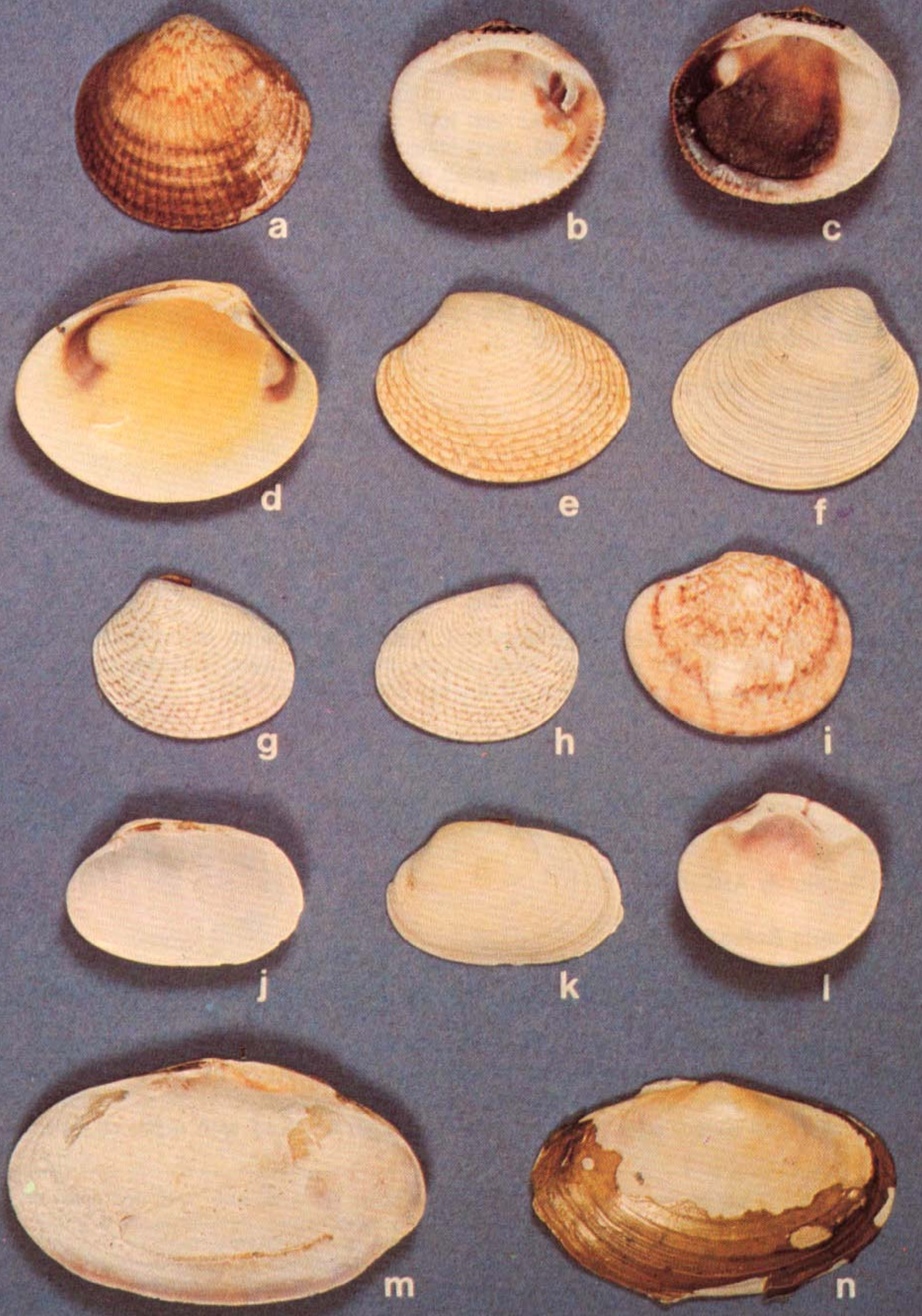
PLATE 7 Bivalves of sandy beaches: a-c *Glycymeris (Tucetilla) striatularis;* d,e *Katelysia rhytiphora;* f *Katelysia scalarina;* g,h *Tawera gallinula;* i,l *Sunetta aliciae;* j,k *Venerupis galactites;* m,n *Sanguinolaria (Soletellina) biradiata* (Trans. 24540)

PLATE 7



hinge margin, valves narrowly gaping at both ends, ligament posterior to beaks; adductor scars unequal—posterior small, anterior larger with a characteristic continuation in the form of a narrow band extending vertically from the postero-ventral corner to the dorsal margin; this band marks the attachment of muscles of the visceral mass and foot; pallial line indistinct, entire; periostracum conspicuous, polished, consisting of radiating sectors which form a frill around the shell which splits when the animal dies.

Solemya australis Lamarck Figs 35e,f

Periostracum brown, interior of shell brownish to greyish white, length 57, height 26 mm. Common along the southern coast where it burrows in mud or sand in the sublittoral zone.

Subclass PTERIOMORPHA

Order ARCOIDA

Superfamily ARCACEA

Equivalve, trapezoidal, hinge taxodont, radially sculptured, isomyarian, dorsal margin with a flat cardinal area above the hinge axis; microstructure of aragonitic shell crossed lamellar. Animal with filibranch gills.

Family ARCIDAE. Arks

Dental series nearly straight, of numerous small, transverse, straight or chevron-shaped teeth diminishing in size towards the middle, ligament duplivincular.

Subfamily ARCINAE

Genus **Barbatia** Gray

Elongate, ovoid, inequilateral, ends rounded or subangular, radially ribbed.

Barbatia pistachia (Lamarck) Figs 35g,h; 69e,f; Pl.5o,p

A shallow sinus at the ventral margin for emergence of byssus. Sculptured with radial riblets and fine concentric grooves; covered with a brown perios-

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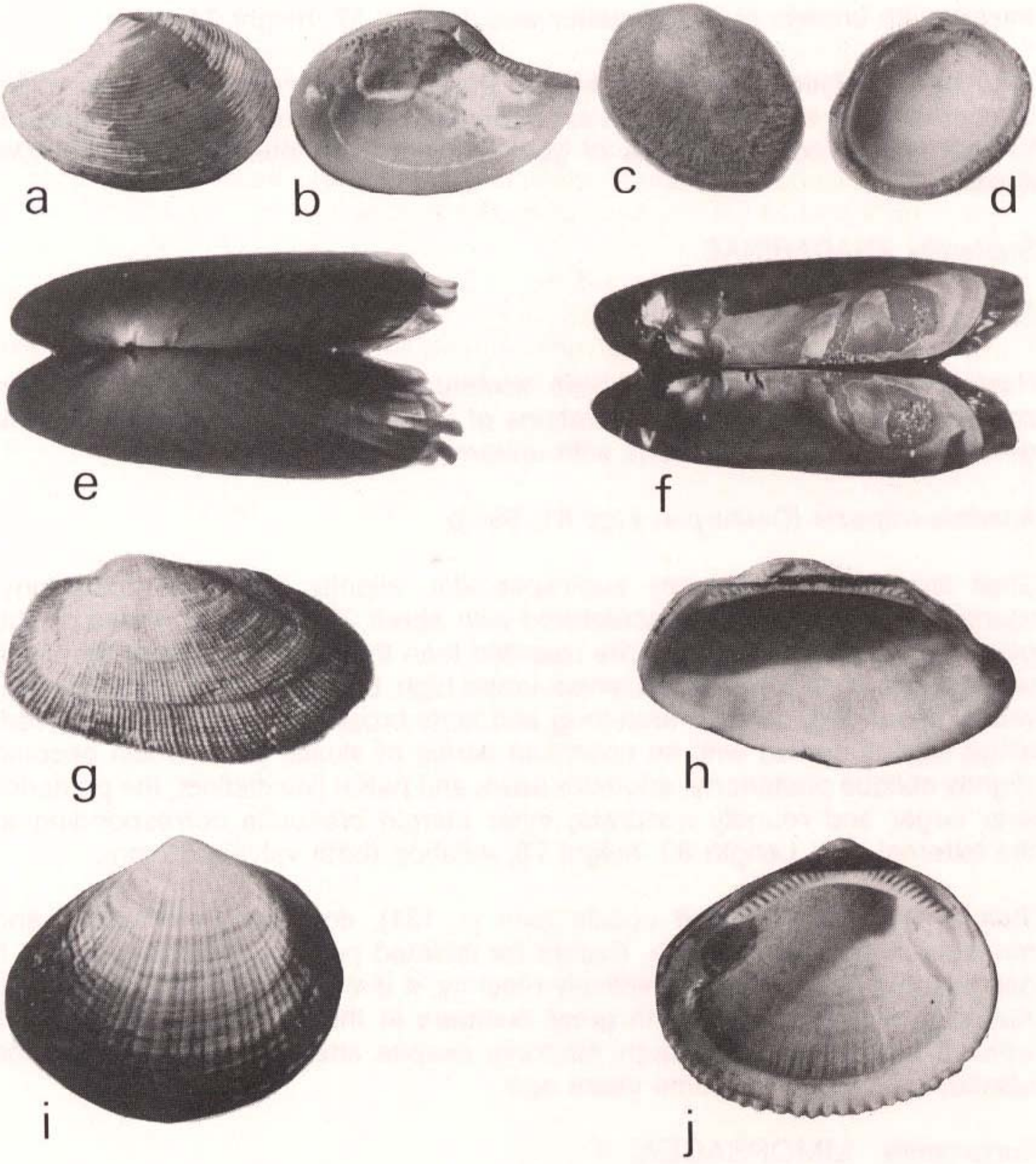
Fig. 35 a,b. *Nuculana (Scaeoleda) crassa illepida* RV a. exterior with periostracum, b. interior; c,d *Limopsis tenisoni* LV c. exterior with periostracum, d. interior; e,f. *Solemya australis* both valves with periostracum e. exterior, f. interior; g,h. *Barbatia pistachia* LV g. exterior, h. interior; i,j. *Glycymeris (Tucetilla) radians* i. RV exterior, j. LV interior; k,l. *Glycymeris (Tucetilla) striatularis* LV k. exterior, l. interior. x 1.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tracum with bristles at the posterior end. Length 57, height 34 mm.

A suspension feeder found attached by the byssus in crevices or under rocks or overhangs in association with sponges and bryozoans on reefs on medium to high energy coast or areas of good current from intertidal pools to 30m depth.

Subfamily ANADARINAE

Genus **Anadara** Gray

Heavy, solid, subtrapezoidal shells sculptured with strong radial ribs and corresponding interlocking crenulations of the shell margins; ligament amphidetic, dental series continuous with uniformly graded teeth.

Anadara trapezia (Deshayes) Figs 61, 69a,b

Shell large, thick, obliquely subtrapezoidal, slightly produced posteriorly, rounded anteriorly, surface sculptured with about 26 radial ribs, those on the posterior area broader and more rounded than those on the rest of the shell, weakly granulose towards the umbo; umbo high, beaks incurved, prosogyrate, widely separated, cardinal area long and fairly broad, conspicuously grooved, hinge slightly curved with an unbroken series of similar teeth which become slightly oblique posteriorly; adductor scars and pallial line distinct, the posterior scar larger and roundly quadrate; inner margin crenulate corresponding to the external ribs. Length 80, height 78, inflation (both valves) 66 mm.

This is the Sydney blood cockle (see p. 131), common in estuaries and mudflats in eastern Australia. Except for isolated pockets in Victoria where it has become nearly extinct relatively recently, it is no longer living in southern Australia. However, it lived in great numbers in the Late Pleistocene, since when it has died out in South Australia despite attempts to reestablish the species near Adelaide some years ago.

Superfamily LIMOPSACEA

Equivalve, orbicular to obliquely ovoid, hinge taxodont, smooth or radially sculptured, isomyarian, central triangular resilifer and smooth cardinal area. Shell aragonitic with outer crossed-lamellar and inner complex crossed-lamellar layer.

PLATE 8 Molluscs of the sublittoral zone, recovered by Department of Mines and Energy during calcium carbonate investigation 13 km offshore from Outer Harbor, depth 27 m: a. *Glycymeris (Tucetilla) radians;* b. *Fulvia tenuicostata;* c. *Dosinia (Kereia) victoriae;* d,e *Circe weedingi;* f. *Chlamys (Equichlamys) bifrons;* g. *Circomphalus disjecta;* h,i *Placamen flindersi;* j. *Polinices conicus;* k. *Astraea (Bellastraea) squamifera;* l. *Cassis (Hypocassis) fimbriata (juvenile);* m. *Gazameda iredalei* (Trans. 24541)

PLATE 8

Family LIMOPSIDAE. False dog cockles

Ligament confined to triangular resilifer, dentition in two more or less symmetrical series.

The functional morphology and evolution of living Limopsidae was reviewed by Oliver (1981) who illustrated the gross anatomy of southern Australian species.

Genus **Limopsis** Sassi

Orbicular, usually with a slight forward obliquity; periostracum sometimes hairy.

Limopsis tenisoni Tenison Woods Figs 35c,d

With about 36 radiating ribs and fine closely set concentric striae; hinge arched with 10 to 12 teeth each side of the umbones. Length 30, height 30 mm.

Found in fine sand and silt in areas of good current flow, from 5 to 30m depth.

Family GLYCYMERIDIDAE. Dog cockles

Heavy shells with submedian beaks, cardinal area broad, with one or more chevron grooves; dental series strongly arched, with strong transverse chevron-shaped teeth, radial and small below the beaks.

Genus **Glycymeris** Da Costa

Subcircular to subquadrate, beaks orthogyrate to opisthogyrate, ligament amphidetic.

Glycymeris (Tucetilla) mayi (Cotton) Fig. 69c,d

Rather small, inflated, slightly produced posteriorly, with 20 primary riblets and numerous secondary riblets; hinge with about 10 teeth on each side; inner ventral margin with about 50 fine denticles. Length 18, height 16 mm.

Glycymeris (Tucetilla) radians (Lamarck) Figs 35i,j; 58f; Pl.8a

Produced posteriorly, with 30 to 35 radial ribs which are radially striated.

Common, found in clean sand particularly in association with the seagrasses *Posidonia* and *Amphibolis* in areas of good water movement from 2 to 30 m deep.

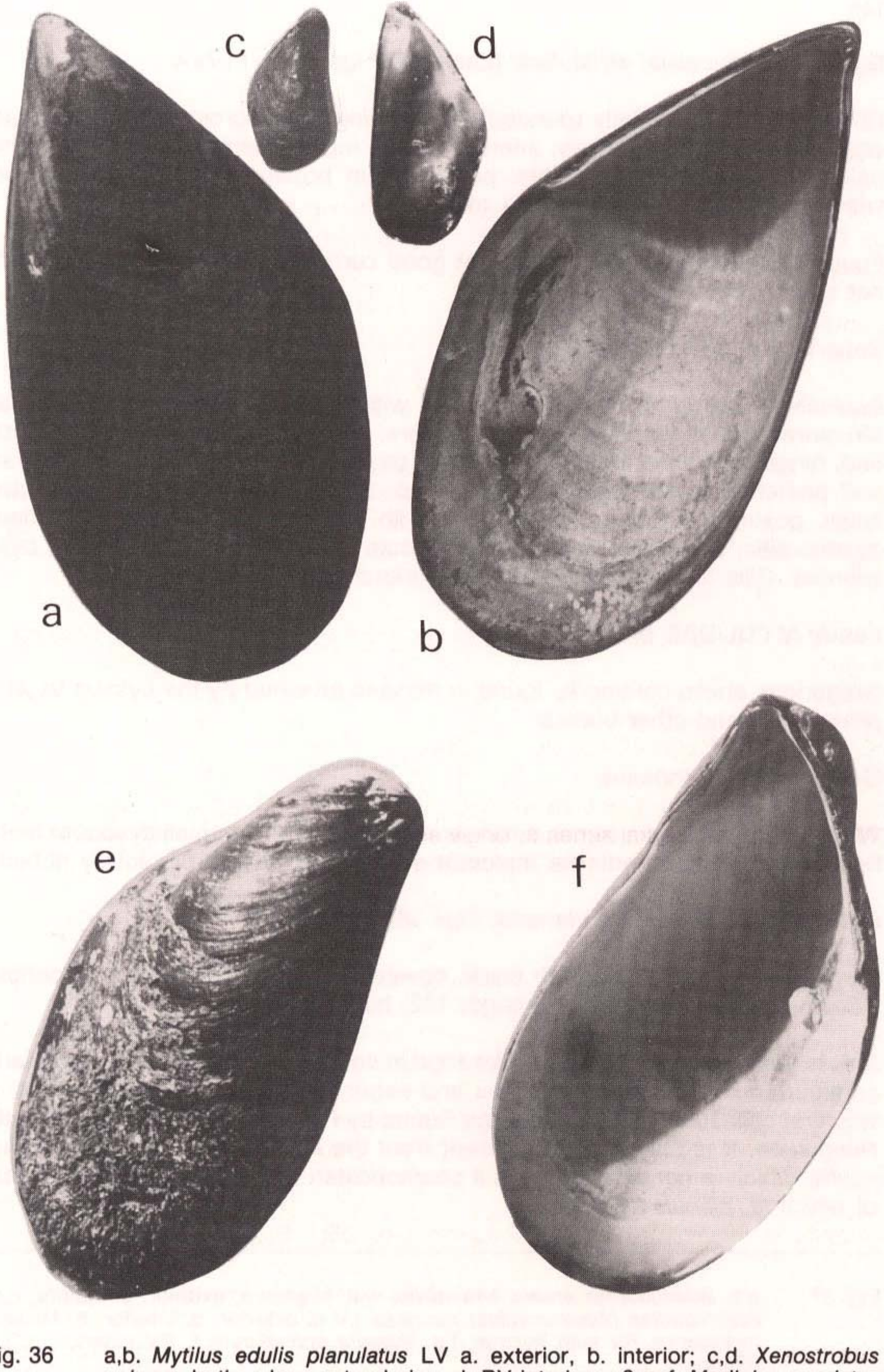


Fig. 36 a,b. *Mytilus edulis planulatus* LV a. exterior, b. interior; c,d. *Xenostrobus pulex* c. both valves natural size, d. RV interior x 2; e,f. *Modiolus areolatus* RV e. exterior with periostracum, f. interior. x1.

Glycymeris (Tucetilla) striatularis (Lamarck) Figs 35k,l; Pl.7a-c

Roundly ovate, with flatly rounded ribs carrying fine microscopic radial striae and concentric growth lines; interior ventral margin dentate; area within the pallial line finely radially striate; periostracum brown, interior white stained with brown. Length 45, height 41 mm.

Found in fine sand or silt in areas of good current flow 5 to 30 m deep. It is not so common as *G. (T.) radians*.

Superfamily MYTILACEA

Equivalve, shell either wholly aragonitic with nacreous and crossed-lamellar structures or finely prismatic calcitic layers, beaks prosogyrate, near anterior end, hinge smooth or dysodont, surface usually divided into anterior, median and posterior areas; variously sculptured, heteromyarian, anterior adductor small, posterior large and continuous with the posterior retractor; ligament opisthodetic, pallial line entire; periostracum strong, commonly hirsute; byssiferous. Gills filibranchiate or eulamellibranchiate.

Family MYTILIDAE Mussels

Gregarious shells commonly found in masses attached by the byssus to jetty piles, rocks and other bodies.

Genus **Mytilus** Linnaeus

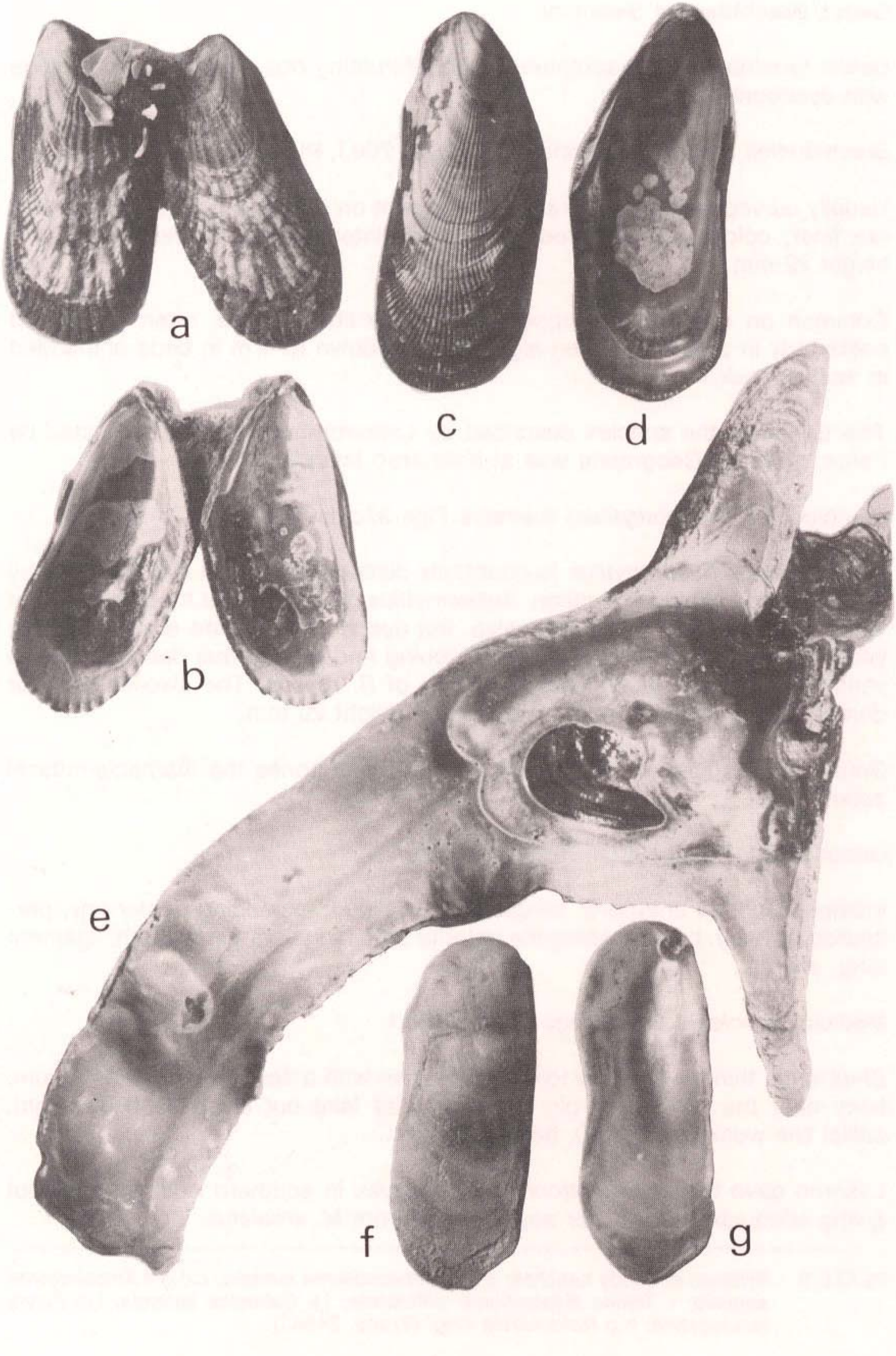
Wedge-shaped, beaks terminal, lunule with folds forming small dysodont teeth behind the ligament; anterior adductor scar small, smooth or radially ribbed.

Mytilus edulis planulatus Lamarck Figs 36a,b; Pl.3d

Large, dark brown to purplish black, covered with a dark olive-brown periostracum, interior bluish white. Length 102, height 50 mm.

This is the common mussel sold for food in southern Australia; it is particularly common in harbours on jetty piles and exposed rocks in the littoral zone. It was first collected from King George Sound by Peron from the French corvette *Géographe*. It is only slightly different from the Northern Hemisphere *Mytilus edulis*, which is considered to be a cosmopolitan species with local varieties, of which *M. planulatus* is one.

Fig. 37 a,b. *Brachidontes erosus* two valves with byssus a. exterior, b. interior; c,d. *Brachidontes (Austromytilus) rostratus* LV c. exterior, d. interior; e. *Malleus meridianus* RV with byssus; f,g. *Vulsella spongiarum* f. RV exterior, g. LV interior. x 1.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Genus **Brachidontes** Swainson

Beaks terminal, radially sculptured with bifurcating ribs, ligament short, hinge with dysodont teeth.

Brachidontes erosus (Lamarck) Figs 37a,b; 70e,f; Pl.3b,c

Usually curved, with coarse radial ribs except on the anterior area where they are finer; colour brown tinted with green, interior dark purple. Length 70, height 22 mm.

Common on rocks in the upper and middle littoral zone, often embedded posteriorly in a spongy green alga and also down to 4 m in beds embedded in mud or rock.

This is one of the species described by Lamarck from material collected by Peron while the *Géographe* was at Kangaroo Island.

Brachidontes (Austromytilus) rostratus Figs 37c,d; 70a-d

The subgenus *Austromytilus* is doubtfully distinguished from *Brachidontes* by the difference in hinge dentition. *Austromytilus* may have one tooth in the right valve and two teeth in the left valve, but dysodont teeth are also present in young specimens. Both the external ribbing and the internal dentition on the ventral margin are much finer than that of *B. erosus*. The swollen anterior dorsal area is almost smooth. Length 36, height 20 mm.

Dominant on rocks in the upper and mid littoral zones the 'barnacle-mussel zone'.

Genus **Modiolus** Lamarck. Horse mussels

Inflated, rounded anteriorly, inequilateral, oblique, expanding posteriorly, periostracum hairy, beaks behind the anterior end, hinge margin smooth, ligament long, internal.

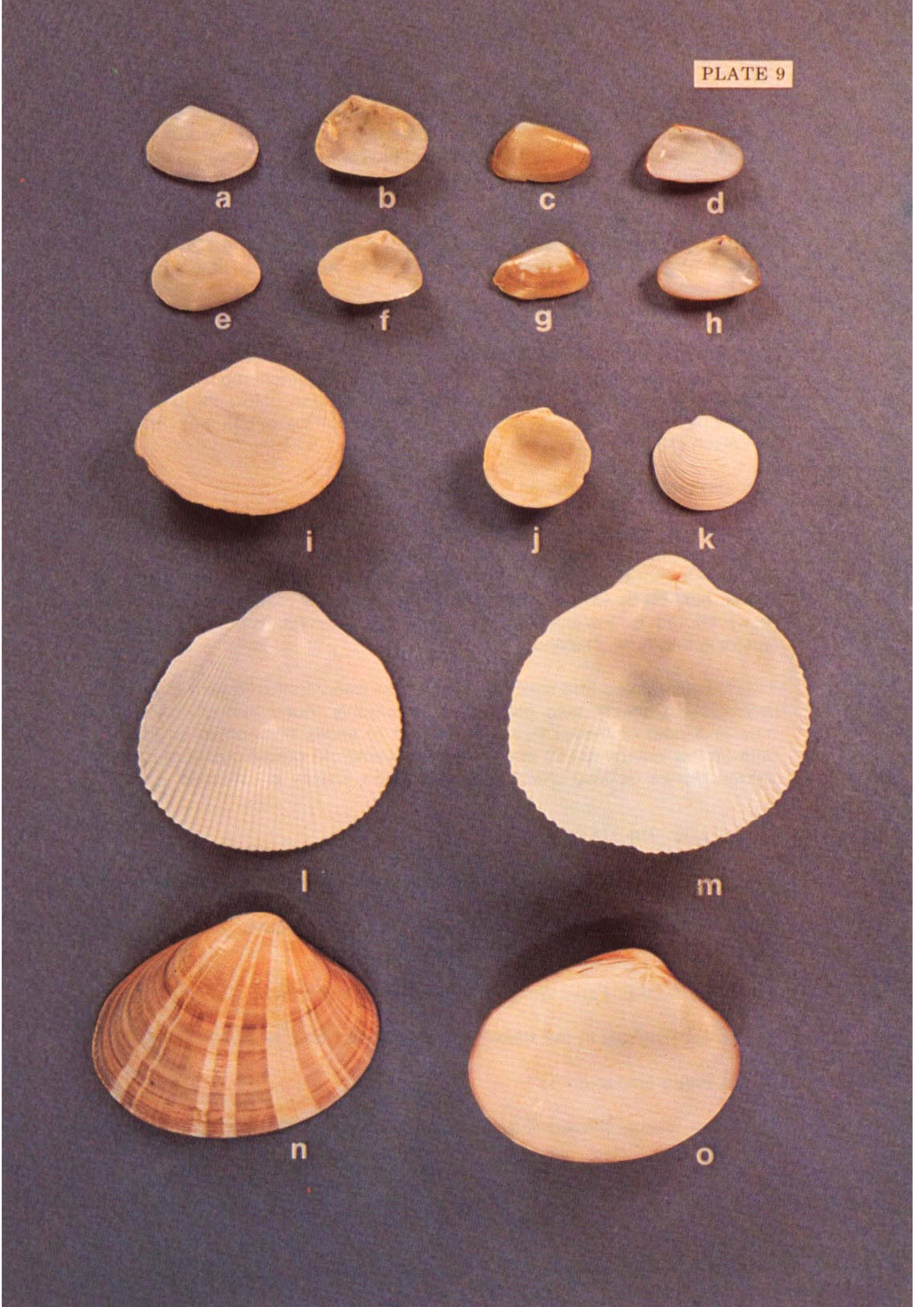
Modiolus areolatus Gould Figs 36e,f; Pl.3e,f

Shell large, thin, pale yellow to reddish brown with a dark brown periostracum, hairy near the ventral margin; muscle scars faint but clear in oblique light, pallial line weak. Length 40, height 80 mm.

Laseron gave the name *cottoni* to the species in southern Australia, without giving adequate reasons for separating it from *M. areolatus*.

PLATE 9 Bivalves of sandy beaches: a,b,e,f *Amesodesma cuneata;* c,d,g,h *Amesodesma angusta;* i. *Tellina (Macomona) deltoidalis;* j,k *Callucina lacteola;* l,m *Fulvia tenuicostata;* n,o *Notocallista kingi* (Trans. 24542)

PLATE 9



The species is found in a range of habitats of which the main one is that of being individually buried in medium to coarse sand with the byssus attached to sand grains as an anchorage, in association with the seagrasses *Posidonia* and *Amphibolis* in areas of good water movement 2 to 20 m deep. It also attaches by the byssus to pebbles, rubble and rocks without being buried in sand from 5 to 20 m depth on reefs in areas of good water movement; it can be attached to rock by the byssus in large, dense beds from 1 to 3 m deep in areas of good current flow sheltered from strong wave action.

Genus **Xenostrobus** Wilson

Shell elongate, subcylindrical, with a prominent umbonal keel, exterior smooth with radial striae; umbones terminal or subterminal, ligament moderately strong; hinge line edentulous except for a peg-like projection below the umbo; periostracum thin, smooth and shiny. The anatomy of the genus was described by Wilson (1967).

Xenostrobus pulex (Lamarck) Figs 36c,d; Pl.3g

Rather small, subarcuate in outline, umbones terminal, umbonal angle approximately 42°, incurrent aperture bordered by short branched papillae, posterior byssal retractors a single bundle, posterior pedal retractors usually single. Colour blue-black. Maximum length 25 mm. A marine mat-forming species on rocky shores of low-medium to high energy coasts throughout southern Australia and New Zealand.

Two closely related and similar species have been confused with *X. pulex: X. inconstans* (Dunker), also gregarious, commonly found buried in sand and mud in a nest of byssal threads attached to shells or pebbles on intertidal flats on low energy coast, and *X. securis* (Lamarck) gregarious in masses on timber, stones or dead shells in waters of low salinity in estuaries.

Superfamily PINNACEA

Mostly equivalve, beaks at anterior end of long hinge margin, posterior margin gaping, dimyarian, hinge without teeth, ligament extending along the whole length of the hinge margin, byssiferous. Shell with an outer prismatic calcitic layer and middle and inner nacreous layers.

Family PINNIDAE. Fan-, Wing-, or Pen-shells; Razor fish

The family Pinnidae in the Indo-Pacific was described by Rosewater (1961).

Genus **Pinna** Linnaeus

Equivalve, wedge-shaped, internal nacreous layer divided into two parts by a longitudinal sulcus.

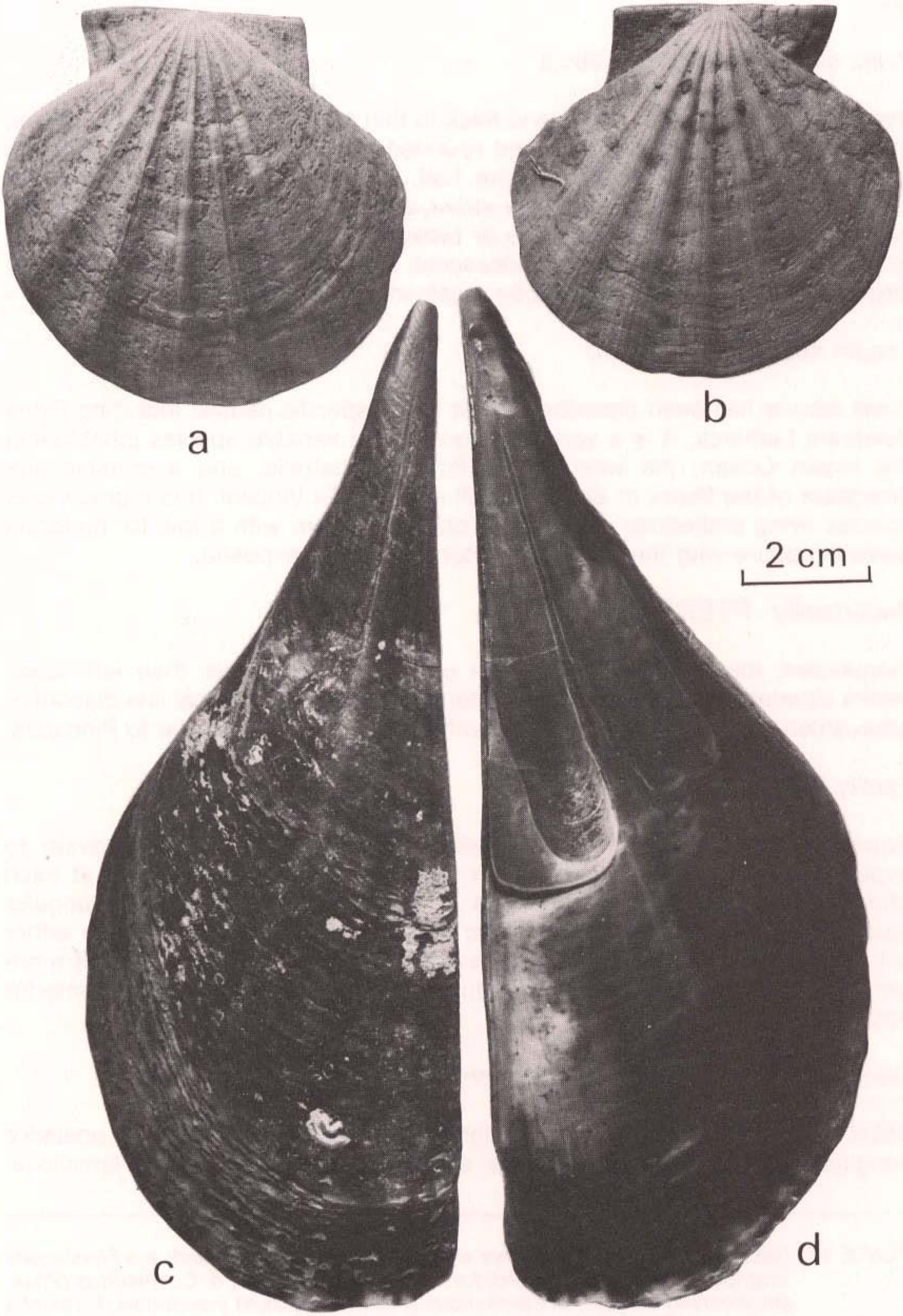


Fig. 38 a,b. *Chlamys (Equichlamys) bifrons* a. LV, b. RV; c,d. *Pinna bicolor* LV c. exterior, d. interior x 2/3

Pinna bicolor Gmelin Figs 38c,d

Very large, varying from heavy and thick to thin and brittle in small specimens, triangular, attenuated anteriorly and rounded posteriorly, moderately inflated, longitudinally carinate in the anterior half, sculptured with 8 to 17 irregular radial ribs and concentric growth striae and folds. Dorsal margin straight, ventral margin straight to concave or broadly sinuous. Colour horn-coloured to purplish brown, nacreous area iridescent. Anterior adductor scar moderately large, on ventral half of dorsal lobe, ligament moderately thick.

Length 400, width 150 mm.

Pinna bicolor has been described under many specific names, including *Pinna dolabrata* Lamarck; it is a very widespread and variable species inhabitating the Indian Ocean, the western Pacific and Australia, and a conspicuous inhabitant of the floors of Spencer Gulf and Gulf St Vincent. It is a gregarious species living embedded apex down on soft bottom with a low to moderate wave exposure with the sharp posterior shell ends exposed.

Superfamily PTERIACEA

Inequivalve, inequilateral, right valve usually less concave than left valve, beaks situated anteriorly, ligament external, opisthodetic, pallial line discontinuous anteriorly; byssal notch in right valve. Shell structure similar to Pinnacea.

Family PTERIIDAE. Pearl oysters

Equivalve or inequivalve with left valve more inflated, obliquely ovate to suborbicular, hinge line straight with triangular wing-like projection at each end, anterior wing smaller; umbones at anterior end; an obtusely triangular ligament pit directed posteriorly from the beak in both valves; hinge either without teeth or with very short transverse teeth near the beak; adults monomyarian with anterior adductor reduced, pallial line discontinuous, interior nacreous.

Genus **Pinctada** Röding. Pearl oysters

Thick shelled, subquadrate, slightly higher than long, nearly equivalve, posterior wing not clearly defined and posterior sinus weak or absent, surface lamellose.

PLATE 10 Gastropods of sheltered bays with sandy beaches or weed: a.a *Phasianella ventricosa;* b.a *Polinices sordidus;* c. *Polinices conicus;* d. *Cantharidus (Phasianotrochus) eximius;* e. *Cantharidus (Phasianotrochus) irisodontes;* f. *Thalotia conica;* g. *Thalotia (Prothalotia) ramburi; Bankivia fasciata;* i. *Cymatiella gaimardi;* j. *Bembicium melanostoma;* k. *Bedeva paivae;* l. *Mitra (Eumitra) glabra;* m. *Mitrella (Dentimitrella) lincolnensis;* n. *Mitrella (Dentimitrella) semiconvexa;* o. *Phalium (Semicassis) semigranosum;* p. *Phasianella australis;* q. *Bulla botanica* (Trans. 24543)


PLATE 10
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Pinctada carchariarum Jameson Figs 62; 70g-i

Shell small for the genus, higher than long, subequivalve with the LV slightly more inflated than the right, inequilateral with the beak near the anterior margin, dorsal margin straight, anterior wing well defined, subtriangular, fairly large with a small byssal notch beneath it, posterior wing not clearly distinguished in the adult but having a broad sinuation below it in the juvenile, posterior margin almost straight and at right angles to the dorsal margin, ventral margin roundly curved, hinge long, straight, with a long shallow cardinal area behind the beak, teeth weak or absent, when present an elongate lamina behind and in front of the beak; interior nacreous within the pallial line, posterior adductor impression large. Living specimen length 53, height 60 mm, a large Pleistocene specimen from St Kilda S.A. has length 62, height 76 mm.

This is the Shark Bay Pearl Oyster which lives as far south as Albany and is present in the Late Pleistocene Glanville Formation of South Australia from Ceduna to Port Adelaide.

Genus **Electroma** Stoliczka

Thin-shelled, inequivalve, posterior wing small to lacking.

Electroma georgiana (Quoy & Gaimard). Butterfly shell.

Semi-transparent, creamy white, with or without coloured rays. Length 40, height 26 mm.

Lives attached by the byssus to seaweed with which it is cast up on beaches after storms.

Family MALLEIDAE. Hammer oysters

Subequivalve or inequivalve, with or without byssus, valve margins gaping or notched; a triangular internal to external ligamental area partly or wholly occupied by median triangular pit; adults monomyarian, inner shell layer nacreous.

Genus **Malleus** Lamarck

Hammer-shaped, body of shell elongated dorso-ventrally, posterior and anterior wings varying, body of shell waving, lamellose, ligamental pit deep, oblique, with lower margin projecting; byssal notch narrow; nacreous interior of shell reduced in area, long ventral part with a submedian ridge; posterior adductor and posterior pedal retractor confluent, large.

Malleus meridianus Cotton Fig. 37e; Pl.3a

Horn-coloured, nacreous area bluish grey with black muscle scars. Length across auricles 120, height 150 mm.

Lives rarely on sandy beaches fixed in the sand by the byssus, and mostly on rocks, jetty pilings, shells of *Pinna* in large colonies, often several deep.

Genus **Vulsella** Röding

Shell elongated dorso-ventrally, subequivalve, linguiform, compressed, gaping, posterior muscle scars moderately large, scarcely impressed; surface lamellose, sometimes radially ribbed; ligament pit strongly convex and protruding; not byssiferous.

Vulsella spongiarum Lamarck. Sponge finger Figs 37f,g

Translucent, thin, shape variable but commonly elongated with nearly parallel sides, dorsal and ventral margins rounded; ligament pit large, anterior, surface with concentric growth lamellae and fine irregular, waving radial riblets producing a squamulose surface; interior pearly; horn-coloured. Length 16, height 45 mm.

Lives in sponges, sometimes in considerable numbers, on reefs on low-medium to high energy coasts 2 to 30 m deep.

Superfamily PECTINACEA

Equivalve or inequivalve, subequilateral, with wing-like extensions of the hinge margin (ears or auricles); right valve underneath when at rest, byssal notch mostly below right anterior auricle, sculpture radial; monomyarian, ligament area alivincular, internal. Shell mostly of foliated calcite.

Family PECTINIDAE Scallops, Fan shells

Orbicular to oval, one valve usually more inflated than the other; umbones central with ears on either side, the anterior of the RV with a byssal notch below it; hinge line straight, ligament amphidetic, in a triangular resilifer below the umbo; cardinal crura usually present on either side of the ligament pit, surface smooth or with radial ribs and folds; only posterior adductor present, large; attached by the byssus or lying on the bottom; margin of mantle with short filaments and commonly with eyes. The anatomy is illustrated in Figure 39. Certain features of the anatomy vary according to the habitat of the individual species and therefore are not reliable in taxonomic classification. For example, species living in the open have well developed eyes while species such as *Chlamys aktinos*, which lives entirely under rocks, has small

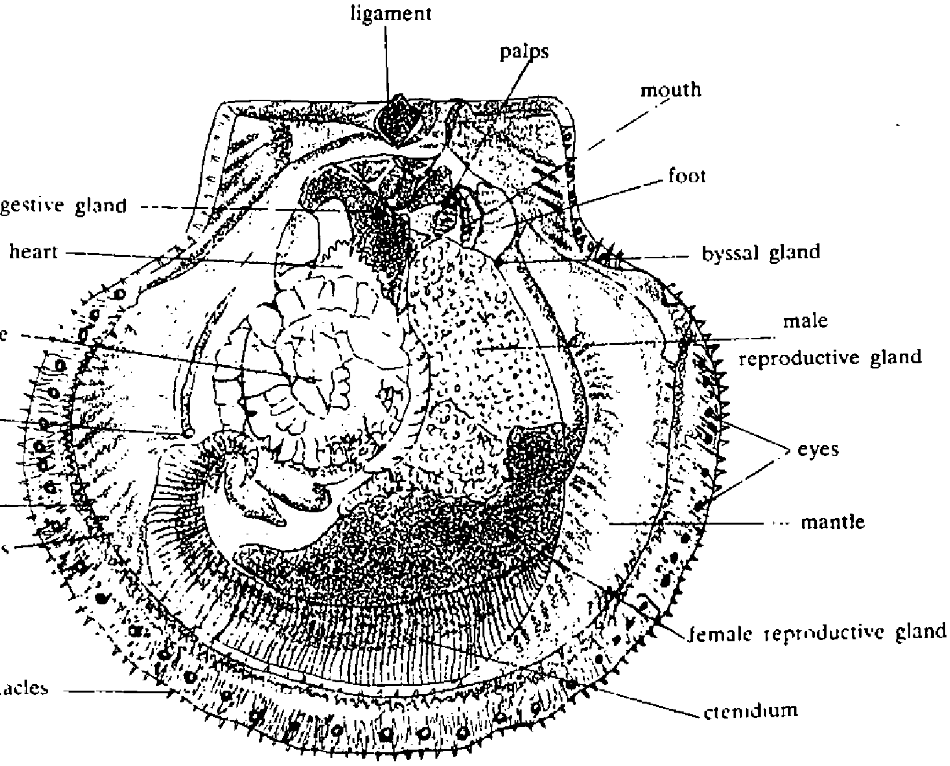

Fig. 39 Anatomy of a scallop (adapted from Rees 1957)

reduced eyes. Some scallops can propel themselves about by vigorously clapping the valves together and expelling jets of water. They are gregarious molluscs, gathered for food.

Genus **Chlamys** Röding

Both valves convex, a large byssal notch below the right anterior auricle, below which there is usually a row of small teeth, or ctenolium; sculpture of fine to coarse scaly radial ribs, margin scalloped.

A number of generic names introduced by Iredale for species of *Chlamys* are regarded as synonyms of *Chlamys (Chlamys)*, i.e. *Chlamys* in the strict sense.

Chlamys (Chlamys) aktinos (Petterd) Pl.4j

Size medium, trigonal-orbicular, depressed, with 14 to 24 irregular imbricated radial ribs surmounted by radial lirae with shagreen sculpture in the interspaces; ears very unequal, the anterior large and radially ribbed, the posterior small

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PLATE 11 Molluscs of tidal inlets, saline flats and marginal salt lakes: a. *Salinator solidus;* b. *Batillaria (Zeacumantus) diemenensis;* c. *Batillaria (Batillariella) estuarina;* d. *Hypotrochus monachus;* e. *Diala lauta;* f. *Eubittium lawleyanum;* g. *Clanculus (Isoclanculus) dunkeri;* h. *Niotha pyrrhus;* i. *Niotha pauperata;* j. *Plicarcularia burchardi;* k. *Katelysia peronii;* l,m *Irus crenatus* (RV and LV); n,o *Anapella cycladea* (RV and LV); p. *Spisula (Notospisula) trigonella* (LV); q. *Laternula creccina* (RV and LV); r. *Spisula (Diaphoromactra) versicolor;* s. *Lutraria rhynchaena* (LV); t. *Coxiella striata* (Trans. 24544)

PLATE II

and truncated; colour variable, pink to reddish-brown, yellow, purplish with small angular patches of white to pink, interior shining white or tinted pink. Length 36, height 42 mm.

Eyes small, reduced.

Lives entirely under rocks from Albany WA to Western Port Bay, Vic. and northern Tas.

The specific name has been frequently misspelt *atkinos.*

Chlamys (Chlamys) asperrima (Lamarck). Fan shell, Prickly scallop Fig. 41a; Pl.4f-i

Nearly equivalve and equilateral, with unequal ears, both valves convex, sculptured with almost 25 scaly radiating ribs flanked by a smaller rib on each side; brightly coloured red, yellow, orange or purple; has large blue eyes. Length 86, height 100 mm.

Attached to firm substrate by byssus, gregarious on reefs, *Pinna,* jetty piles, sponges, frequently covered by sponge, 1 to 100 m deep on low to high energy coast. Swims readily and well when disturbed.

Chlamys (Equichlamys) bifrons (Lamarck). Queen scallop Fig.38a,b; Pl.8f

In the subgenus *Equichlamys* the left valve is more convex than the right which it tightly clasps; sculpture of seven radial ribs or folds, those on the left valve more elevated and narrow than those on the right; primary rib and interspaces surmounted with secondary ribs about six on each rib and interspace, surface shagreened; colour purple and rose, occasionally white, brown or orange; eyes in both valves, brown. Length 105, height 95 mm.

Juveniles are firmly attached to the substrate to about 4 cm in length when they begin the free living stage, lying on the left valve; adults are free living, gregarious, on sand to silty bottom often near reefs on low to medium energy coasts or good current areas from 2 to 30 m deep.

They are good swimmers and a scallop bed of this species is transient, the whole group moving location in a random process that requires investigation.

It is an edible scallop, taken commercially.

Genus **Pecten** Müller

Inequivalve, right valve convex, left valve gently convex, flat or concave, auricles nearly equal, radial ribs broad, flat topped, narrow in LV, wider than interspaces in RV; hinge with cardinal crura extending from each side of

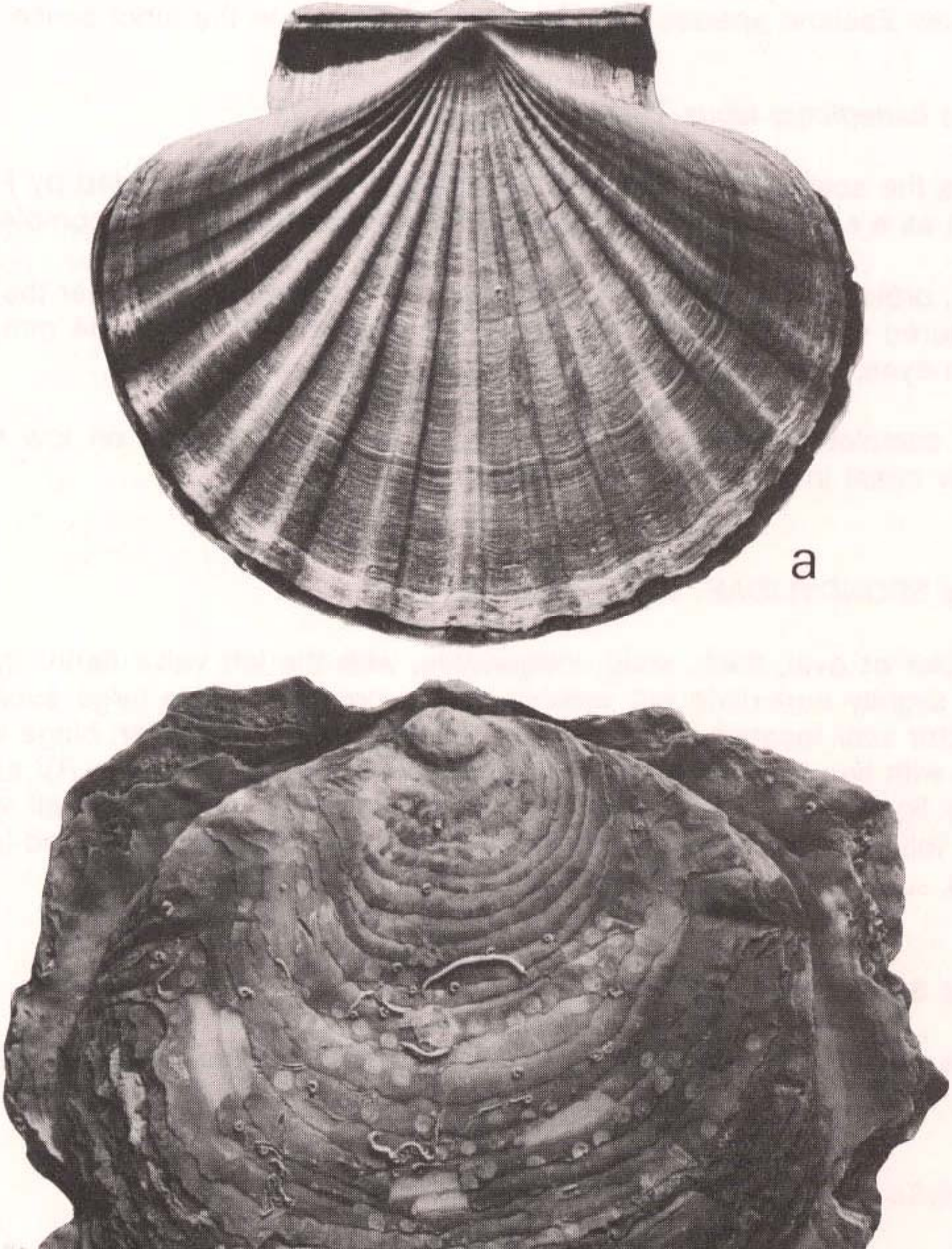


Fig. 40 a. *Pecten benedictus albus* both valves with flat LV on top; b. *Ostrea angasi* both valves with flat RV on top. x 2/3.

ligament pit. The genus *Notovola* Finlay, which has been used for Australian and New Zealand species, is a synonym of *Pecten* in the strict sense.

Pecten benedictus albus Tate. King scallop Fig. 40a

This is the scallop recorded also as *Notovola alba*, but regarded by Fleming (1957) as a subspecies of the wide-ranging *Pecten benedictus* complex.

Large, orbicular, right valve deeply convex, left valve concave near the umbo; sculptured with from 12 to 16 radial ribs. Length 100, height 84 mm. Small brown eyes, well developed only in the left valve.

Lives completely buried in sand with left valve uppermost, on low to high energy coast in water 3 to 30 m deep.

Family SPONDYLIDAE. Thorny oysters

Orbicular or oval, thick, solid, inequivalve, with the left valve flatter than the right, slightly auriculate but without byssal notch; a single large subcircular adductor scar located posteriorly, ligament pit deep, triangular, hinge in adult stage with two isodont cardinal crura in each valve, those in the RV adjacent to the ligament pit. Sculpture of irregular spinose costellae. Shell with an outer foliated calcitic layer and middle and inner aragonitic crossed-lamellar layers.

Genus **Spondylus** Linnaeus

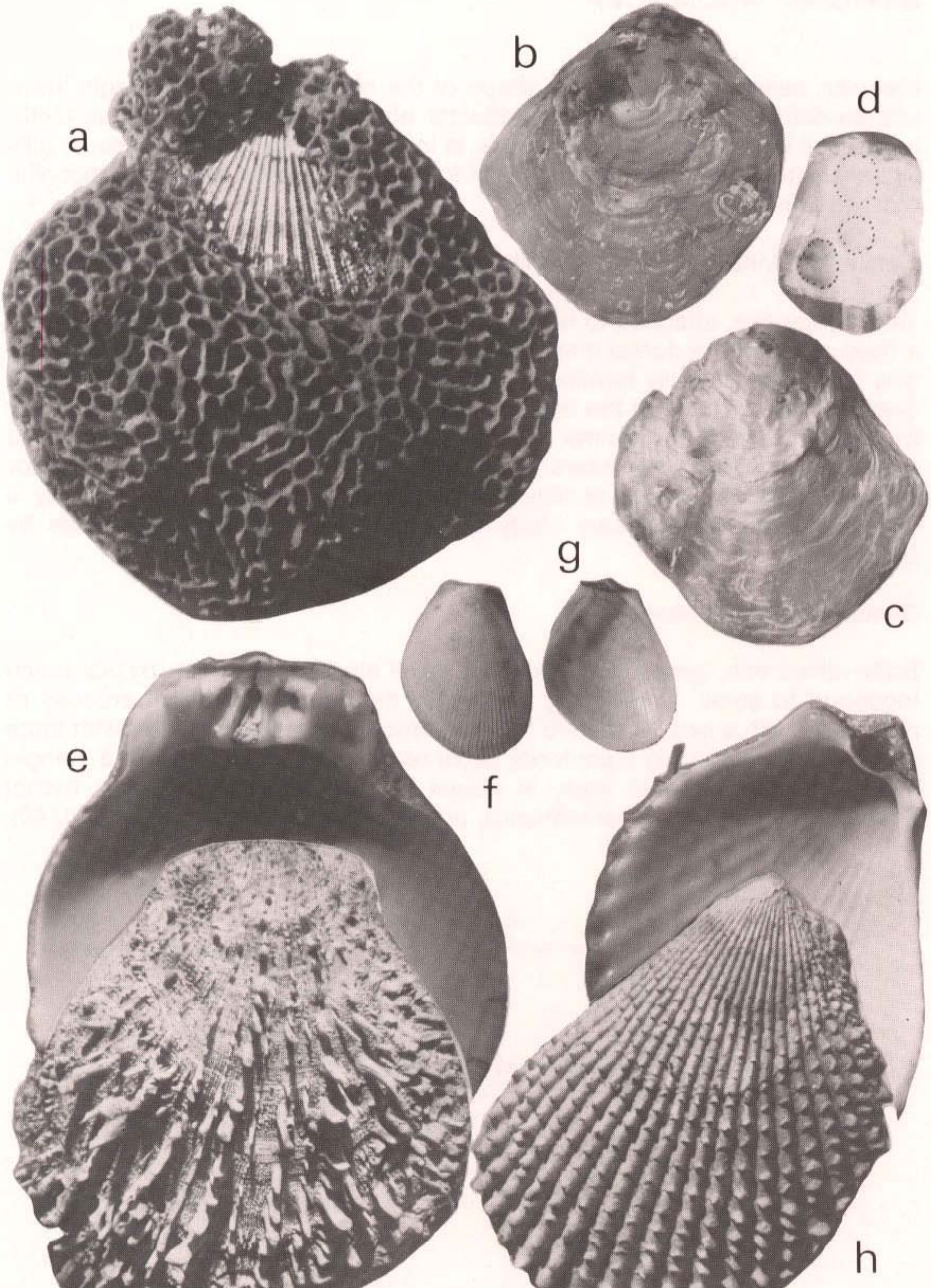
Radial sculpture strong, spiny or foliaceous, cardinal area large, cardinal crura short, heavy.

Spondylus tenellus Reeve Fig. 41e; Pl.4a-c

Large, sculpture of strong radial costellae with long spines, the interspaces with finer crowded spinose costellae; colour scarlet rose. Length (without spines) 54, height 60 mm.

Attached to stones, rocks and dead shells or other solid substrate, usually heavily encrusted with marine growths from 2 to 30 m depth on medium to high energy coasts or good current areas from WA to NSW.

Fig. 41 a. *Chlamys asperrima* with sponge; b,c,d. *Anomia trigonopsis* b. both valves with RV on top, c. LV exterior, d. LV interior with muscle scars outlined in ink; e. *Spondylus tenellus* LV and hinge; f,g. *Limaria orientalis* RV f. exterior, g. interior; h. *Lima lima* LV exterior and LV interior. x 1.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Superfamily ANOMIACEA

Irregular, sessile, assuming the shape of the object on which the right valve lies, monomyarian, with anterior adductor obsolete, hinge lacking true teeth, inner shell layer lustrous, a large hole in lower valve for pluglike byssus; gills filibranchiate. Shell structure largely of foliated calcite with an inner aragonitic crossed-lamellar layer.

Family ANOMIIDAE. Saddle oysters, Jingle shells

Thin, oyster-like, attached to hard substrate by byssus which passes through a deep notch in the dorsal margin of the right valve, the notch or embayment may be closed dorsally forming a foramen or hole, the byssal plug becomes calcified and attached to the left valve by an adductor muscle; a thin white or translucent layer in the central area of each valve in which the adductors and posterior pedal retractor scars are located; a small anterior pedal retractor scar near the end of the resilium in the left valve; resilium supported by a chondrophore. A preliminary study of Australasian anomiids was made by Beu (1967).

Genus **Anomia** Linnaeus

Both valves thin, generally translucent, shell structure lamellar; byssal notch moderate to small, byssal plug welded to the substrate; resilial process of right valve with a saddle-shaped surface directed dorsally; left valve with three muscle scars, including a posterior pedal retractor scar, arranged in a triangle within the central white area, in dorsal to ventral order they are: byssal adductor or retractor, valve adductor, posterior pedal retractor (Figs 41d, 42).

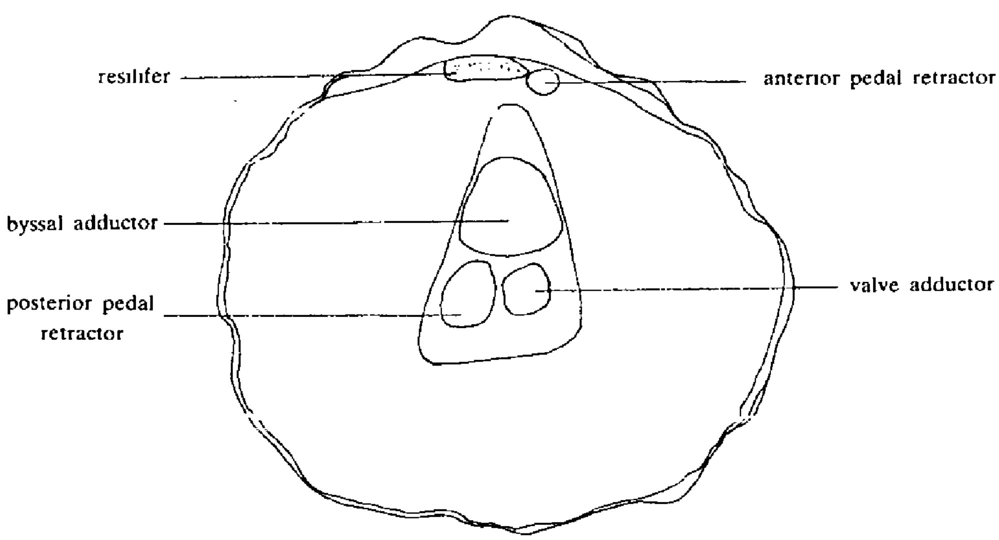


Fig. 42 Muscle scars of *Anomia* LV

Anomia trigonopsis Hutton Figs 41b-d; Pl.4d,e

This is the species previously identified and illustrated in South Australia as *Monia ione* (Gray). The muscle scars and other features are typical of *Anomia.* The species is common to both Australia and New Zealand where it has been described under several names. The sculpture and shape of the valves as well as the relative sizes and position of the muscle scars are very variable. The shell is commonly translucent, and lustrous, particularly the left valve, and pale bluish-green in colour. Very large specimens can attain a length of 90 mm, but most specimens are usually about 45 mm long and 45 mm high.

They attach to any solid substrate, particularly live scallops and *Pinna*, also dead shells, rocks, etc. in the intertidal zone to 100 m depth on low to high energy coasts. The left valve often takes on the form of the host shell, particularly scallops.

Superfamily LIMACEA

Equivalve, ovate, orbicular or subtrigonal, hinge with two unequal or reduced auricles, triangular cardinal area with triangular ligament pit in both valves, hinge without teeth, monomyarian, adductor scars obscure, surface smooth or with radial sculpture.

Family LIMIDAE

Equivalve, ovate to subtrigonal, usually with two small ears, the posterior obtuse, smooth or radially sculptured; umbones well separated, hinge with a triangular cardinal area and shallow triangular ligament pit, edentulous or with weak teeth of the taxodont type; monomyarian, adductor scars obscure.

Genus **Lima** Bruguière

Subtrigonal, hinge margin short, anterior auricle somewhat smaller than posterior, hinge edentulous or with weak denticles near ends of hinge. *Austrolima* Iredale is a synonym.

Lima lima Linnaeus Fig. 41h.

Obliquely trigonal-ovate, inequilateral, moderately convex, hinge with or without weak denticles on the auricles; sculpture of 20 to 40 scaly ribs broader than the interspaces. Length 40, height 52 mm.

This is a cosmopolitan species, described in Australia as *Lima gemina* and *Lima nimbifer* which are indistinguishable from *L. lima.* The number of ribs is variable.

Found in aggregations in association with sponges, either in cavities in large sponges or on sponge-covered rocks and overhangs from 2 to 30 m deep on medium to high energy coasts.

Genus **Limaria** Link

Small to medium, ovate, with small subequal auricles, cardinal area almost equilateral, hinge edentulous.

Limaria orientalis (Adams & Reeve) Figs 41f,g

Obliquely ovate, slightly gaping, with very fine radial ribs, showing internally, ligament broad. Height 20, width 18 mm.

Found in large aggregations in nests made of mucus in fine silty sand and mud, from 5 to 20 m deep on low to medium energy coasts.

Genus **Limatula** Wood

Shell small, elongate-ovate, with small subequal auricles, sculpture of fine radial riblets, except on the auricles, hinge nearly straight, edentulous.

Limatula strangei (Sowerby)

Equilateral, with about 20 sharp, narrow radial ribs, the ribs and interspaces crossed by frequent concentric growth lines; colour white. Height 38, width 22 mm.

Shell details were well illustrated by Buonaiuto (1977).

Superfamily OSTREACEA

Inequivalve, valves thick and solid, sessile, shell mostly of foliated calcite with a prismatic calcitic layer on the upper valve of some species, aragonitic in muscle attachment areas, ligament and prodissoconch; attached by the left valve, monomyarian, ligament alivincular, with resilium in the middle flanked by lamellar ligament.

The Ostreacea have been described in considerable detail by Stenzel (1971).

Family OSTREIDAE. Oysters

Valves subequal to unequal, chomata present or absent, posterior adductor scar reniform or crescentic, nearly central or closer to the ventral margin. Incubatory or non-incubatory. Umbonal cavity deep to shallow or absent.

Genus **Ostrea** Linnaeus

Medium to large, roughly orbicular, RV flattish, covered with long unequal radial ribs or plications and frilled growth scales; adductor scar reniform, chomata present. Incubatory umbonal cavity either absent or shallow beneath the LV hinge plate.

Ostrea angasi Sowerby. Mud oyster, Port Lincoln oyster Figs 40b, 71a.

Large, roundly trigonal to rounded, left or lower valve convex, thick, irregularly radially ribbed with scaly concentric growth lamellae; right valve flat to concave, fitting into the left valve, not radially ribbed but with conspicuous growth lamellae; chomata on the right valve extending for about 20 mm from the hinge area. Length 100, height 120 mm.

The juvenile oysters settle on to some solid object, often a small shell or stone, the adults often free living, but sometimes remain fixed, at depth 2 to 20 m on low to medium energy coasts.

Subclass PALAEOHETERODONTA

Order TRIGONIOIDA

Superfamily TRIGONIACEA

Equivalve, trigonal or variable in shape, posterior slope carinate, sculpture varied, but radial in the only modern genus, ligament external, short, opisthodetic, hinge teeth radiating from beak, adductor scars small, close to hinge teeth, pallial line entire. Shell with an outer prismatic and inner and middle nacreous layers.

Family TRIGONIIDAE

Variable in shape and sculpture, umbones opisthogyrate, area and flank differently sculptured in most genera, median tooth of left valve broad, grooved, posterior left weak, anterior left of moderate strength, right valve with two subequal divergent teeth not borne on a hinge plate, with strong transverse ridges on the sides fitting into the corresponding grooves of the teeth in the left valve; pallial line entire; filibranchiate, non byssiferous. The only living genus of the family is the Australian *Neotrigonia*.

Genus **Neotrigonia** Cossmann

Trigonally ovate, with radial scaly ribs over the whole shell; adductor muscle scars high, the anterior below and anterior to the anterior lateral tooth, buttressed, the posterior below the end of the posterior cardinal. The valves fit very tightly together, the radial ribs on one valve corresponding to the grooves on the other.

Neotrigonia margaritacea (Lamarck) Fig. 43h

Large, robust, equivalve, inequilateral, sculptured with 22 granulated radial ribs. Interior nacreous, teeth large, high. LV with two grooved diverging teeth receiving two similar teeth of the RV. Periostracum brown. Length 48, height 47 mm.

This is the species found in NSW, Vic. and Tas. It is used for jewellery. It has been recorded as capable of leaping by means of its angulated foot.

Neotrigonia bednalli (Verco) Fig. 43i

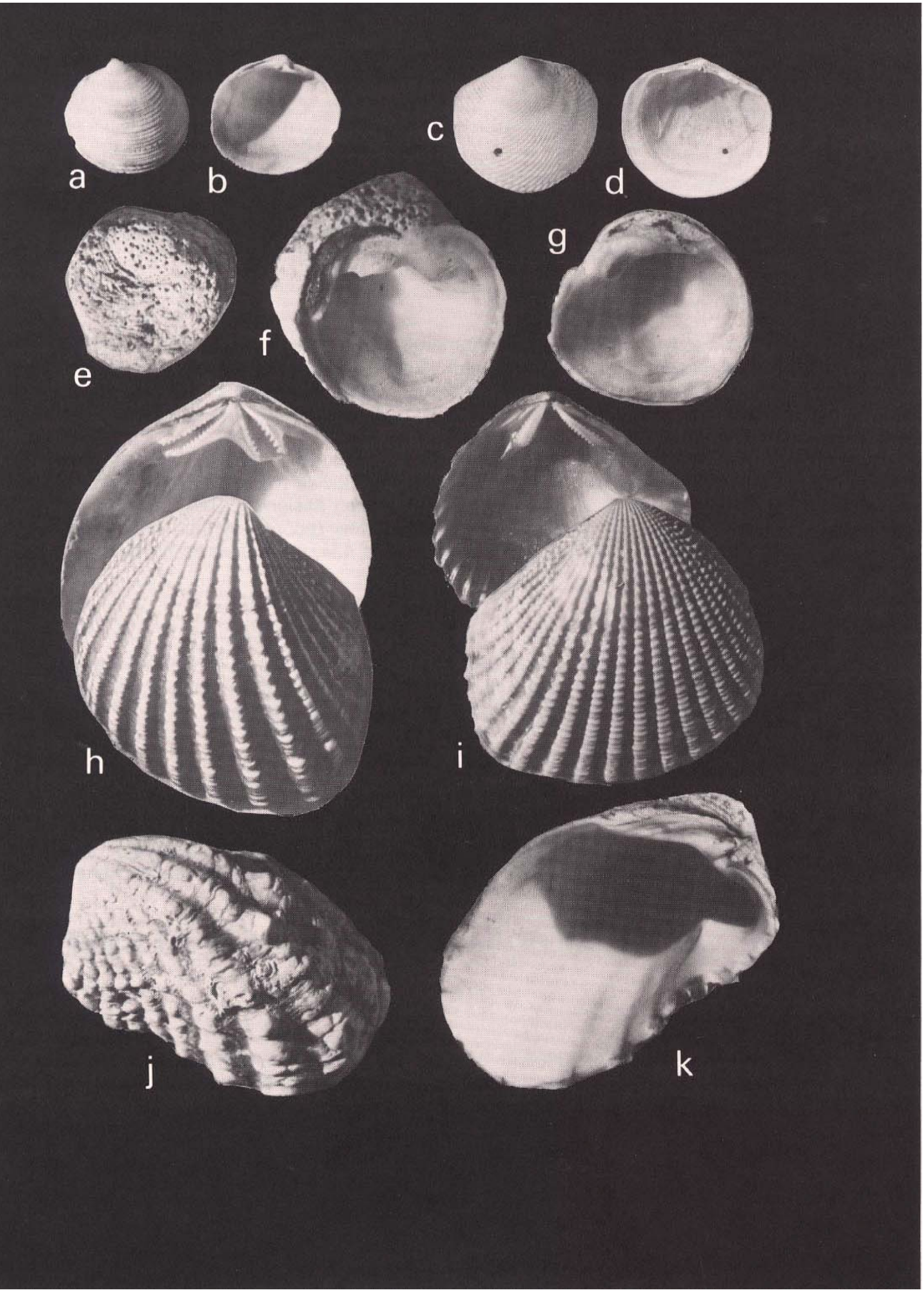
Smaller than *N. margaritacea*, with 26 radial ribs about equal to the interspaces, high, set with rectangular plate-like tubercles, interspaces flat with concentric threads; anterior margin rounded, posterior margin obtuse-angled, posterior-ventral margin straight. Colour variable, in delicate shades from white to pale yellow, pink, mauve and purple; interior nacreous in similar shades. Length 36, height 34 mm.

Dredged from Beachport to King George Sound; common on most Eyre Peninsula beaches.

Subclass HETERODONTA

Heterodont bivalves usually possess siphons and eulamellibranchiate gills; they have a hinge plate with teeth differentiated into cardinals and laterals; shell structure never nacreous.

Fig. 43 a,b. *Wallucina* sp. a. RV exterior, b. LV interior; c,d. *Divalucina cumingi* RV c. exterior, d. interior; e,f,g. *Chama ruderalis* e. RV exterior, f. LV interior, g. RV interior; h. *Neotrigonia margaritacea* RV exterior, LV interior; i. *Neotrigonia bednalli* LV exterior, RV interior; j,k. *Cardita crassicosta* LV j. exterior, k. interior. x 1.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Order VENEROIDA

Superfamily LUCINACEA

Equivalve, mostly suborbicular, smooth or concentrically sculptured, but some with radial sculpture, beaks small, prosogyrate to orthogyrate, lunule more extended on right valve, escutcheon ill-defined; hinge with tooth formula 3a,3b/ 2,4b; isomyarian, pallial line entire.

Family LUCINIDAE

Hinge with two cardinals, ligament marginal to inframarginal, anterior adductor scar elongated and extending ventrally within and separated from the pallial line. The family is widely distributed particularly in the tropics where they are eaten by fishes.

The whole of the family is in need of taxonomic revision in South Australia; the lucinids are represented by a number of species which do not necessarily belong to the genera to which they have been assigned. They have mostly been obtained by dredging and there are few records of their habitats. A species of *Wallucina* is not uncommon (Figs 43a,b). Its specific name needs checking.

Genus **Divalucina** Iredale

Rounded, solid, moderately inflated, sculpture of divaricating imbricating ridges; lunule narrow, long. Hinge with two short cardinals, the posterior bifid, the anterior lateral a tubercle, posterior lateral weak or obsolete.

Divalucina cumingi (Adams & Angas) Figs 43c,d

With distinctive divaricating sculpture. Hinge narrow, RV with a triangular posterior cardinal and small anterior cardinal, anterior lateral a tubercle at the ventral end of the hinge, posterior lateral long,thin; anterior adductor scar long and mostly within the pallial line. Area inside the pallial line thickened. Length 22, height 21 mm.

Lives buried in sand in the sublittoral zone and cast up on the beach after storms.

Genus **Anodontia** Link

Medium to large size, tumid, with a more-or-less defined anterior area, ligament sunken, hinge edentulous, inner margin smooth. Species of the subgenus *Cavatidens* are smaller, with concentric sculpture only and a distinct dorsal area.

Anodontia (Cavatidens) perplexa (Cotton & Godfrey) Figs. 71f-i

Globose, thin, sculptured with fine concentric striae, hinge line narrow, edentulous, ligament long, thin, sunken on cardinal process. Length 25, height 22 mm.

Genus **Wallucina** Iredale

Roundly inflated, sculptured with concentric and radial lines, hinge LV with cardinals 2 and 4b and lateral PII, RV with 3b, AIII and PIII, inner margin finely crenulate.

Wallucina assimilis (Angas) Figs. 71l,m

Rather small, triangularly orbicular, sculptured with concentric riblets and microscopic radial striae. Length 8.5, height 8.25 mm.

Genus **Callucina** Dall

Shell medium to large, suborbicular, sculpture concentric, inner margin finely crenulate; hinge LV with 2, 4b, AII, AIV and PII; RV with 3b, AIII and PIII.

Callucina lacteola (Tate) Figs 71b-e; Pl.9j,k

Suborbicular, solid, sculptured with thin concentric lamellae about 1 mm apart, interspaces finely striated. Length 30, height 29 mm.

The families THYASIRIDAE and UNGULINIDAE are not a common element of the fauna. They are mostly small, white, thin bivalves obtained by dredging but sometimes, like the lucinids, cast up on beaches.

Superfamily CHAMACEA

Inequivalve, with rough concentric or radial sculpture or both; one valve cemented to substrate, beaks prosogyrate, ligament parivincular, hinge degenerate with at least one large cardinal tooth in either valve; isomyarian with two large subequal muscle scars, pallial line entire.

Family CHAMIDAE.

The only family living, mainly in warm water attached to rocks.

Genus **Chama** Linnaeus

Attached by the left valve, concentric sculpture of irregularly flattened spines and lamellae, foliaceous.

Chama ruderalis Lamarck Figs 43e-g; 72a-d

Thick, orbicular, lamellose, white, length 32, height 36 mm.

On rocks and debris on reefs at depth of 1 to 15 m on medium to high energy coasts westerly from Beachport.

Superfamily LEPTONACEA

Equivalve, thin, mostly more or less covered by mantle, byssiferous, resilium small, cardinal teeth tubercular, laterals elongated and partly atrophied. Three apertures in the mantle- an anterior (buccal), median (pedal), and posterior (anal), but often there are only two openings.

Four families of Leptonacea are represented in southern Australia—Erycinidae, Kelliidae, Leptonidae and Montacutidae. They are mostly minute shells less than 5 mm long requiring microscopic study. The species most likely to be found is *Lasaea australis* Lamarck which commonly lives among the byssal threads of *Xenostrobus pulex*.

Family ERYCINIDAE

Genus **Melliteryx** Iredale

Shell very small with one blunt rounded cardinal tooth in each valve and strong laterals; external surface punctate.

Melliteryx acupunctum (Hedley) Figs. 68w,x

Shell very small, thin, transversely trigonal, external surface punctate in flaring lines, hinge narrow, one cardinal tooth in each valve, blunt, rounded, one anterior and one posterior lateral in each valve. Length 4.5, height 3.5 mm.

Superfamily CYAMIACEA

Equivalve, somewhat thickened, with resilium adjacent to nymph slightly hollowing the hinge plate, lateral teeth distinct. Mantle with two posterior apertures, foot with a byssal gland.

Bivalves of this superfamily are a very small element of the fauna, requiring further microscopic study. The family CYAMIIDAE, which has several recorded species in southern Australia, characteristically inhabits Antarctic and Subantarctic waters.

Superfamily CARDITACEA

Equivalve, trigonal to heart-shaped, trapezoidal or mytiliform, with external radial sculpture and internal radial riblets which crenulate the margin; lunule small, depressed, escutcheon ill-defined; beaks prosogyrate; hinge of the curved lucinoid type, ligament internal or external on a nymph, isomyarian, pallial line entire; pedal scars distinct.

Family CARDITIDAE. Carditas

Small to large, mostly trigonally ovate, strongly radially ribbed, shell margin crenulated; ligament external.

Genus **Cardita** Bruguière

Transversely inequilateral, with the posterior side much longer than the anterior, radial ribs strong, nodulose; hinge with obliquely trigonal divergent cardinals and weak anterior laterals in the LV.

Cardita crassicosta Lamarck Figs 43j,k; Pl.5m,n

Trapezoidal, with about 14 ribs, those on the anterior flank smaller and shorter than the rest, with imbricating scales, interspaces flat, narrower than the ribs. Colour salmon pink, brown between the ribs, interior white. Length 48, height 33 mm.

Lives buried in sand pockets on reefs from 5 to 20 m deep in areas of medium to high energy or high current.

Cardita 'tasmanica T. Woods' is a small species, often mistaken for juveniles of *C. crassicosta*, which lives attached by the byssus under rocks on reefs 1 to 20 m deep in areas of medium to high energy or high current. Its nomenclature should be investigated.

Genus **Venericardia** Lamarck

Oblong ovate or roundly trapezoidal, beaks strongly prosogyrous, with penetrating lunule; hinge with laminar 3a, the cardinals curved, laterals weak or obsolete.

Venericardia quoyi (Deshayes)

Of moderate size, solid, thick, convex, anterior margin rounded, posterior margin truncated, umbo high, incurved, hinge fairly broad with 4b, 2 and AII in the left valve, a weak AI, 3a and a strong triangular 3b in the right valve (Fig. 35); with 22 strong radial ribs surmounted by prominent tubercles. Length 28, height 26 mm.

Superfamily CRASSATELLACEA

Equivalve, trigonal, trapezoidal or rounded, sculpture concentric; lunule and escutcheon distinct; beaks pointed, prosogyrate, hinge lucinoid, ligament external or internal; isomyarian, pallial line entire. Animal with fully open mantle or communication between branchial and pedal openings; gills unequal, mantle edge papillate.

Family CRASSATELLIDAE

Subquadrangular to trigonal, rounded anteriorly, more or less truncated posteriorly, smooth or concentrically ribbed; ligament in pit, commonly obliterating part of tooth 4b, behind pit a narrowly marginal nymphal ridge.

Genus **Eucrassatella** Iredale

Large, thick, heavy, equivalve, ovately subquadrate to subtrigonal, posteriorly produced; sculptured with concentric ribs near the umbo but dying out ventrally; hinge with a large triangular ligament pit and in the left valve 3a, 3b, 5b and LPI fitting into LAII, 2,4b of the right valve.

The genus *Eucrassatella* was revised by Darragh in 1964.

Eucrassatella kingicola (Lamarck) Figs. 44d,e

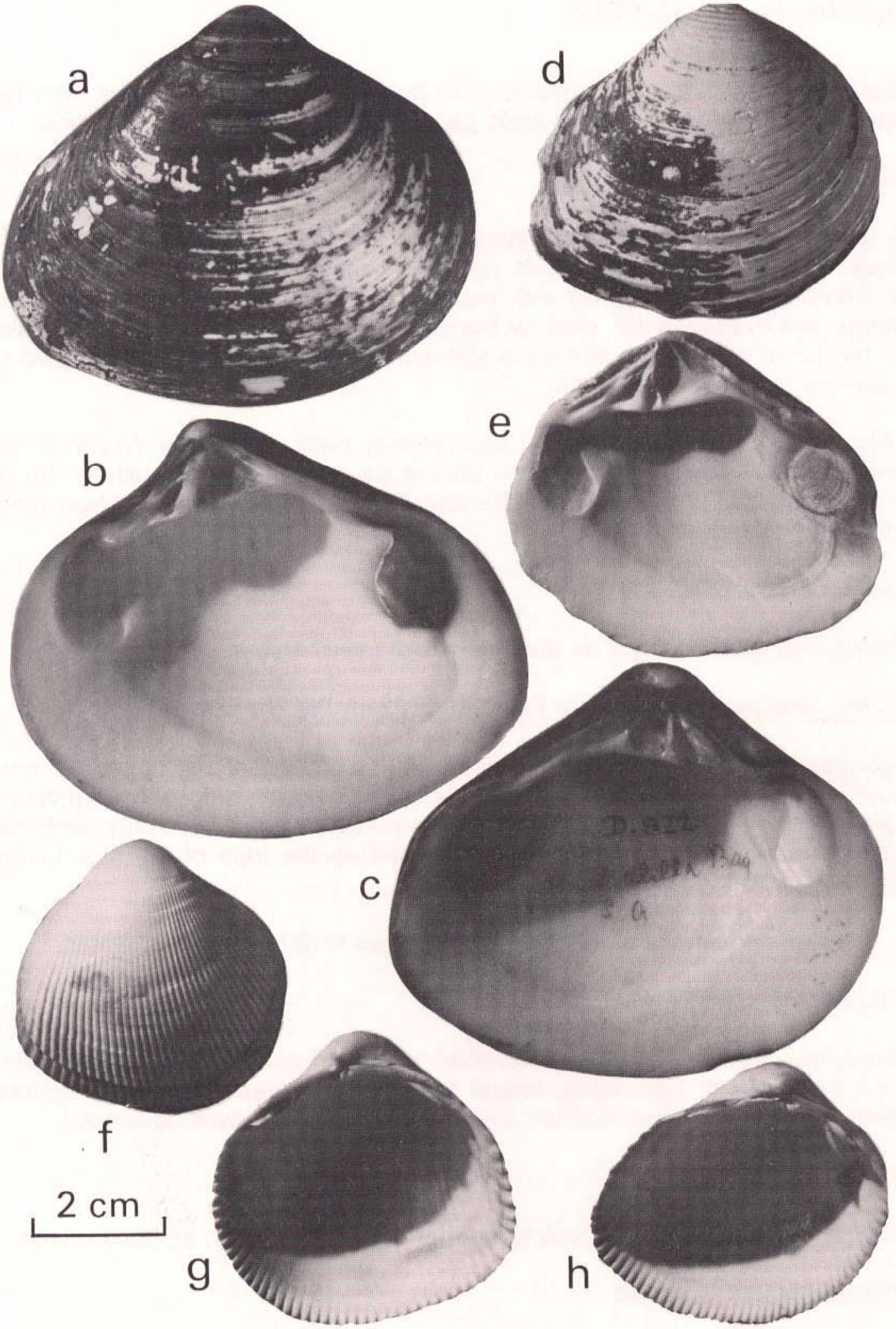
Elongate to ovately wedge-shaped; 10 to 15 concentric ribs within 20 mm of the umbo, rest of the valve smooth. Shell white, umbones rose-coloured, epidermis grey to brown, interior white, purplish near the posterior margin; posterior adductor scar dark brown, radially striate. Length 75, height 64 mm. The species extends into South Australia from Bass Strait.

Eucrassatella donacina (Lamarck) (= *E. verconis* Iredale) Figs 44a-c

Wedge-shaped, smooth or slightly concentrically ribbed, posterior side slightly produced; umbones prominent. Epidermis dark brown to light grey, shell yellow to white, interior white with brown patches on the adductor scars. Length 65, height 52 mm, although specimens reach a length of 117, height 92 mm.

Lives buried in sand often in association with seagrasses *Posidonia and Amphibolis* from 10 to 40 m deep, on medium to high energy coasts and high current areas.

Fig. 44 a,b,c. *Eucrassatella donacina* a. RV exterior, b. LV interior, c. RV interior; d,e. *Eucrassatella kingicola* RV d. exterior, e. interior; f,g,h. *Fulvia tenuicostata* f. LV exterior, g. RV interior, h. LV interior. x 2/3.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Superfamily CARDIACEA

Equivalve, trigonal, trapezoidal or rounded, sculpture radial, hinge with two conical cardinal teeth, lateral teeth distanct, dimyarian, pallial line entire.

Family CARDIIDAE Cockles

Ligament external, short, parivincular, set in a groove; hinge cyclodont with two bifid cardinal teeth in each valve, left valve with one anterior and one posterior lateral, right valve with two anterior and one posterior lateral; foot large, sickle-shaped for shallow burrowing in sand, siphons short, tubular, fused together, without elaborate siphonal retractor muscles, surrounded by sensory papillae or tentacles.

The family in Western Australia has recently been studied by Wilson & Stevenson (1977), whose publication should be consulted for details of *Nemocardium thetidis, Fulvia tenuicostata* and *Acrosterigma cygnorum* which range into South Australia.

Genus **Fulvia** Gray

Fulvia may also be used as a subgenus of *Laevicardium.*

Fulvia tenuicostata (Lamarck) Figs 44f-h; 72e,f; Pls 8b, 9l,m

Sculptured with 46 to 59 fine smooth radial ribs broader and stronger, narrower and strongly crossed on the anterior and posterior slopes by concentric growth lamellae. Colour cream, often with yellow or brownish bands, umbones pink, periostracum brown, raised and frilled on the tops of the ribs. Length 51, height 50 mm.

Lives gregariously in sand and mud from two to 30 m depth of water.

Superfamily MACTRACEA

Equivalve, trigonal, hinge with inverted V-shaped cardinal tooth in left valve, two cardinals in right valve, lateral teeth usually present, internal ligament seated in a socket-like resilifer; dimyarian, pallial sinus well developed.

Family MACTRIDAE

Smooth or concentrically sculptured, periostracum glossy; siphons united.

Genus **Mactra** Linnaeus

Trigonal to oval, lunule and escutcheon delimited and not set off by groove; lateral teeth smooth.

Mactra australis Lamarck Figs 45e,f; 73b,e; Pl.6i-l

Subequilateral, somewhat produced and angulate posteriorly, tending to have two radial umbonal-ventral folds on the slight keel and flat posterior slope, sculptured with fine concentric lirae and growth ridges, with a light brown glossy periostracum, hinge strong with a deep posteriorly inclined triangular ligament pit below the umbo, in the left valve two short anterior cardinals meeting in an inverted V, no posterior cardinal, two posterior and two anterior laterals. Colour bands of cream or grey and violet, interior tinged with violet. Length 37, height 30 mm.

In great numbers on sand patches in the infra-littoral fringe where they are frequently bored by gastropods.

Mactra eximia Reeve Figs 73a,f

A large, inflated, rather thin-shelled *Mactra* living in eastern Australia from southern Queensland to New South Wales. It has been found in South Australia in the Glanville Formation.

Mactra rufescens (Lamarck) Figs 45c,d; Pl.6g,h

A large solid *Mactra* sculptured with concentric striae, the anterior and posterior slopes are well developed and flexuously wrinkled; it is fawn-coloured sometimes with reddish purple rays and often stained with orange red on the slopes.

It lives in sand and mud, with a preference for ocean beaches.

Mactra pura Deshayes (Figs 45a, b; 73c,d) is large, white and solid, tumid, subequilateral, with a light brown silky periostracum.

In sand patches in the infralittoral fringe.

Genus **Spisula** Gray

Shell trigonal to ovate, lunule and escutcheon delimited, ligament and resilium not separated by shelly lamella, pallial sinus oval.

Spisula (Notospisula) trigonella (Lamarck) Figs 45m-o; 74e-h; Pl.11p

Trigonally ovate, the anterior margin rounded, posterior more or less produced and broadly angled; concentrically striate or lirate. Hinge narrow, left valve with two lamellar cardinals joined at a high angle under the umbo in front of the deep triangular resilium which usually cuts through the dorsal margin under the umbo, high lamellar anterior and posterior laterals, each finely ridged on both sides; right valve with two small lamellar cardinals, one flush with the dorsal margin and the other at an angle to it, two anterior and two posterior laterals ridged only on the sides of the pits between them for the reception of the left laterals. Adductor scars oval, pallial sinus narrowly rounded, about as deep as the width of the posterior adductor. Ventral margin weakly crenate. Colour cream or white. Length 24, height 19 mm.

Lives in mud or sandy mud in estuaries or river mouths where it has the habit of dying out and then reappearing in great numbers from south Queensland to the Swan Estuary. It can be confused with *Anapella cycladea* if the details of the hinges are not examined carefully.

Spisula (Diaphoromactra) versicolor (Tate) Figs 45g-i; Pl.11r

This little species can be confused with juveniles of *S. (N.) trigonella.* It has a Spisula-type hinge with faintly striate lateral teeth. Length 12.5, height 9.5 mm.

It lives in great abundance in Lake MacDonnell and also in a marginal lake near Israelite Bay in Western Australia.

Genus **Lutraria** Lamarck

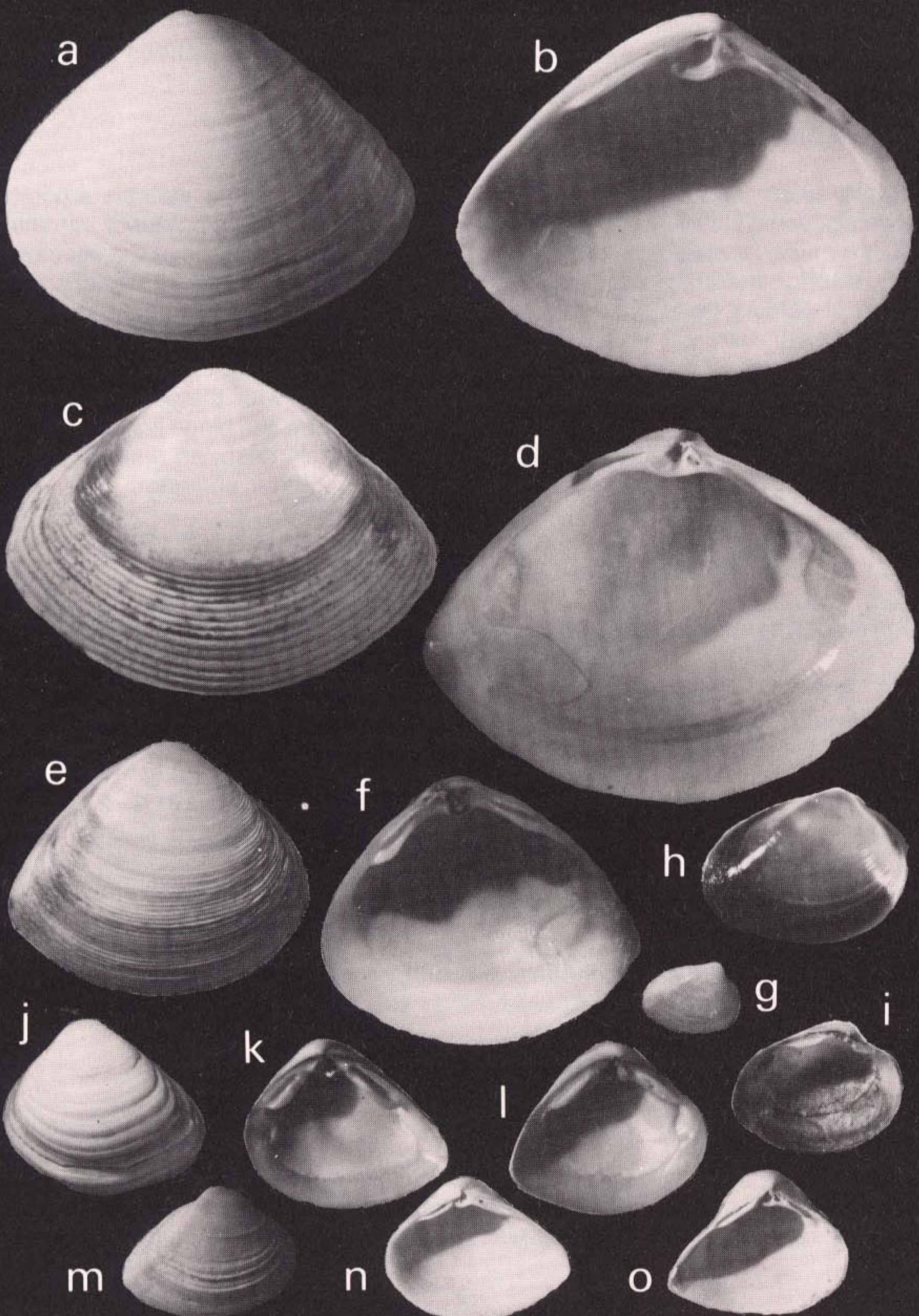
Shell oblong-elliptical, inequilateral, widely gaping, hinge short with a conspicuous broadly triangular projecting chondrophore; left valve with a bifid anterior cardinal and short narrow anterior lateral and longer posterior lateral, right valve with corresponding pits for their reception, two smaller anterior cardinals and weak anterior and posterior laterals; pallial sinus large, siphons not retractile, covered with periostracum.

Lutraria rhynchaena Jonas Figs 46a, b; Pl.11s

Large, solid, rather compressed, widely gaping and broadly rounded posteriorly, narrowly rounded anteriorly, interior nacreous, adductor scars semicircular, pallial sinus large, oval, horizontal; white, covered with brown periostracum. Length 100, height 40 mm.

Lives deeply buried vertically in sand to sandy mud in water from 2 to 20 m deep, the long siphons reaching to the surface of the substrate. The siphons have the appearance of an encrusted solitary ascidian on the substrate surface.

Fig. 45 a,b. *Mactra pura* LV a. exterior, b. interior; c,d *Mactra rufescens* LV c. exterior, d. interior; e,f. *Mactra australis* RV e. exterior, f. interior; g,h,i. *Spisula (Diaphoromactra) versicolor* g. RV exterior x 1, h. RV exterior x 2, i. LV interior x 2; j,k,l. *Anapella cycladea* j. LV exterior, k. RV interior, l. LV interior; m,n,o. *Spisula (Notospisula) trigonella m.* RV exterior, n. RV interior, o. LV interior. x 1 unless otherwise stated.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Family MESODESMATIDAE

Shells wedge-shaped, more or less compressed, solid, siphons retractile, naked, separated or nearly so.

Genus **Amesodesma** Iredale

Shells small, inequilateral, hinge with strong but somewhat variable smooth laterals, usually well developed; LV anterior cardinal 2a high, posterior cardinal 4b triangular, variable, on the lower edge of the hinge plate above the ligament pit, anterior lateral AII variable, long or short, posterior lateral PII variable; RV anterior cardinal 3a high, lamellar, posterior cardinal 3b triangular, high, meeting the anterior cardinal in an inverted V if not cut through by the ligament, anterior lateral AI long or short, posterior lateral PI weak. Ligament internal, triangular, long, narrow, oblique, directed anteriorly with the resilifer deeply excavated into the chondrophore and projecting below the hinge line. Adductor scars pear-shaped, pallial sinus rounded, moderately deep, an anterior pedal retractor scar visible under the hinge above the anterior adductor.

The affinities of the genus *Amesodesma*, which was regarded by Beu (1971) as a subgenus of *Paphies* are being discussed elsewhere.

Amesodesma angusta (Reeve) Figs 46d,e; 58g,h; 74i-k; Pl.9c,d,g,h

Small, smooth, shining, anterior end truncated, ventral margin only slightly convex or nearly straight; foot flat, large, acuminate-cordate, pinkish buff, siphons relatively short. Length 16, height 10 mm.

Lives in sand betwen tides, where, according to Hedley (1917), it quickly reburies itself when it is exposed by the wash of the tide. It is cast up in countless numbers from WA to NSW.

Amesodesma cuneata (Lamarck) Figs. 46f-h; 58i-j; 74l; 80g-l; Pl.9a,b,e,f

Larger than *A. angusta*, variable in shape but generally roundly wedge-shaped with a curved ventral margin, solid; hinge strong; length 27, height 16 mm.

Habitat similar to *A. angusta.*

Genus **Anapella** Dall

Shell robust, thick, ovate-trigonal, equivalve, inequilateral, hinge heavy with one cardinal tooth, more or less bifid, anterior to the deep, long and narrow central resilium, anterior and posterior lateral strong, thick, high. No pallial sinus.

Fig. 46 a,b. *Lutraria rhynchaena* RV a. exterior, b. interior; c. *Solen vaginoides;* d,e. *Amesodesma angusta* d. RV exterior, e. RV interior; f-h. *Amesodesma cuneata* f. LV interior, g. RV, interior, h. RV exterior; i,j. *Sanguinolaria (Psammotellina) biradiata;* x 1.


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Anapella cycladea (Lamarck) Figs 45j-l; 74a-d; Pl.11n,o

Anterior margin rounded, posterior produced and roundly angulate, posterior dorsal area flattened; left valve with a prominent cardinal partly overhanging the resilium and high posterior and anterior laterals, right valve with two rather weak and prong-like diverging cardinals and strong triangular, rough anterior and posterior laterals; adductor scars reniform, pallial sinus very shallow, represented by an angle in the pallial line. Colour dirty white to brown, periostracum brown. Length 25, height 22 mm.

Common in southern Australia in estuaries and tidal inlets such as the Port River and on mud flats in Gulf St Vincent in the midlittoral zone.

The species has been variously described as *A. pinguis, A. tasmanica, A. triquetra*, all of which are synonyms of *cycladea.*

Superfamily SOLENACEA

Valves elongate, cylindrical to flattened, gaping at both ends; hinge weak with one to three small cardinal teeth; pallial sinus short.

Family SOLENIDAE. Razor shells

Beaks terminal, animal with siphons fused, foot modified for rapid digging in sand. Called 'razor shells' because of their resemblance to the old cut-throat razor; it is not to be confused with 'razor fish' or *Pinna*. The shell is adapted for slipping vertically or obliquely through sediment.

Genus **Solen** Linnaeus

Anterior margin truncate, ligament external.

Solen vaginoides Lamarck Figs. 46c; 74m

Shell thin, fragile, umbones close to the anterior end, which is obliquely truncate, posterior end slightly rounded, shell white periostracum brown. Length 84, height 15 mm.

Burrows at a high angle in sheltered bays and estuaries.

Superfamily TELLINACEA

Equivalve, inequilateral, ligament external or in a pit on the hinge plate, two cardinal hinge teeth in each valve, tending to be bifid, lateral teeth well developed; dimyarian, pallial line with distinct sinus. Animal with two separate elongate siphons, not fused.

Family TELLINIDAE. Tellins

More or less elongate, triangularly ovate, compressed, valves somewhat unequal, with a posterior flexure.

Genus **Tellina** Linnaeus

Hinge with two cardinals, at least one of which in each valve is bifid, in the LV the anterior cardinal and in the RV the posterior, and a maximum of two laterals in each valve.

A description of the shell morphology and anatomy of *Tellina* was given by Boss (1966). (Fig. 47).

The subdivision of the genus *Tellina* has proved somewhat unsatisfactory and the tentative classification of the *Treatise on Invertebrate Paleontology* is used here with some reservations pending further critical studies of the family.

Tellina (Eurytellina) albinella Lamarck Figs 48a,b; Pl.6c,d

Shell thin, shining, compressed, inequilateral, with anterior end rounded, posterior end subangular, the dorsal side oblique; sculpture of fine concentric striae and lamellae particularly on the posterior area; pallial sinus large and confluent with the pallial line; ligament posterior, protuberant, on a thickened nymph; lateral teeth of LV poorly developed, right anterior lateral proximal to

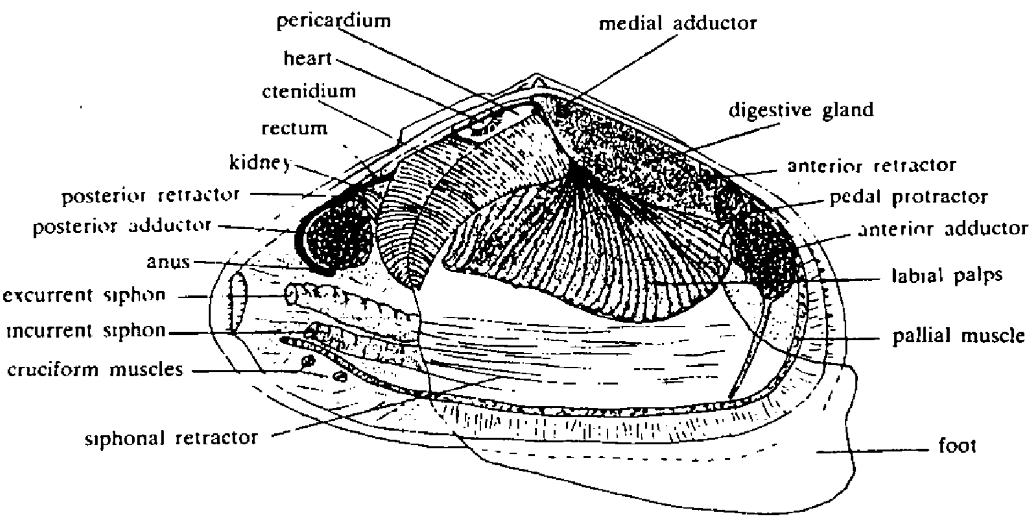


Fig. 47 Anatomy of *Tellina* with RV removed (modified after Boss 1966).

cardinal teeth. Colour mostly pink, orange or white. Length 55, height 32 mm.

Lives in sand just below the surface, particularly near the mouths of rivers.

The genus *Tellinota*, which has been used for *albinella*, is regarded by Boss as synonym of *Eurytellina*.

Tellina (Eurytellina) ensiformis Reeve

Broadly triangularly ovate, posteriorly rostrate, posterior margin straight. Length 25, height 16 mm.

Tellina (Macomona) deltoidalis Lamarck Figs 48c-e; 74n-q; 80m-o; Pl.9i

Solid, triangularly ovate, subequilateral, anterior side rounded, posterior side produced, a thickened flexure over an umbonal dorsal ridge, posterior dorsal margin straight, both valves flexed, sculptured with concentric striae; two cardinal teeth in each valve, posterior lateral weak, at the posterior end of the hinge; pallial sinus very large. Colour creamy white. Length 39, height 28 mm.

Very abundant in mud and muddy sand in the middle to lower littoral zone in estuaries and sheltered bays from southern Qld to the Swan River.

Tellina (Macomona) mariae Tenison Woods Fig. 74r,t

Shell thin, oval, compressed, subequilateral, anterior margin rounded, posterior margin slightly produced and more narrowly rounded; sculpture of fine concentric growth striae. Length 34, height 22 mm.

Tellina (Pseudarcopagia) victoriae Gatliff & Gabriel Figs 48f,g;81a,b

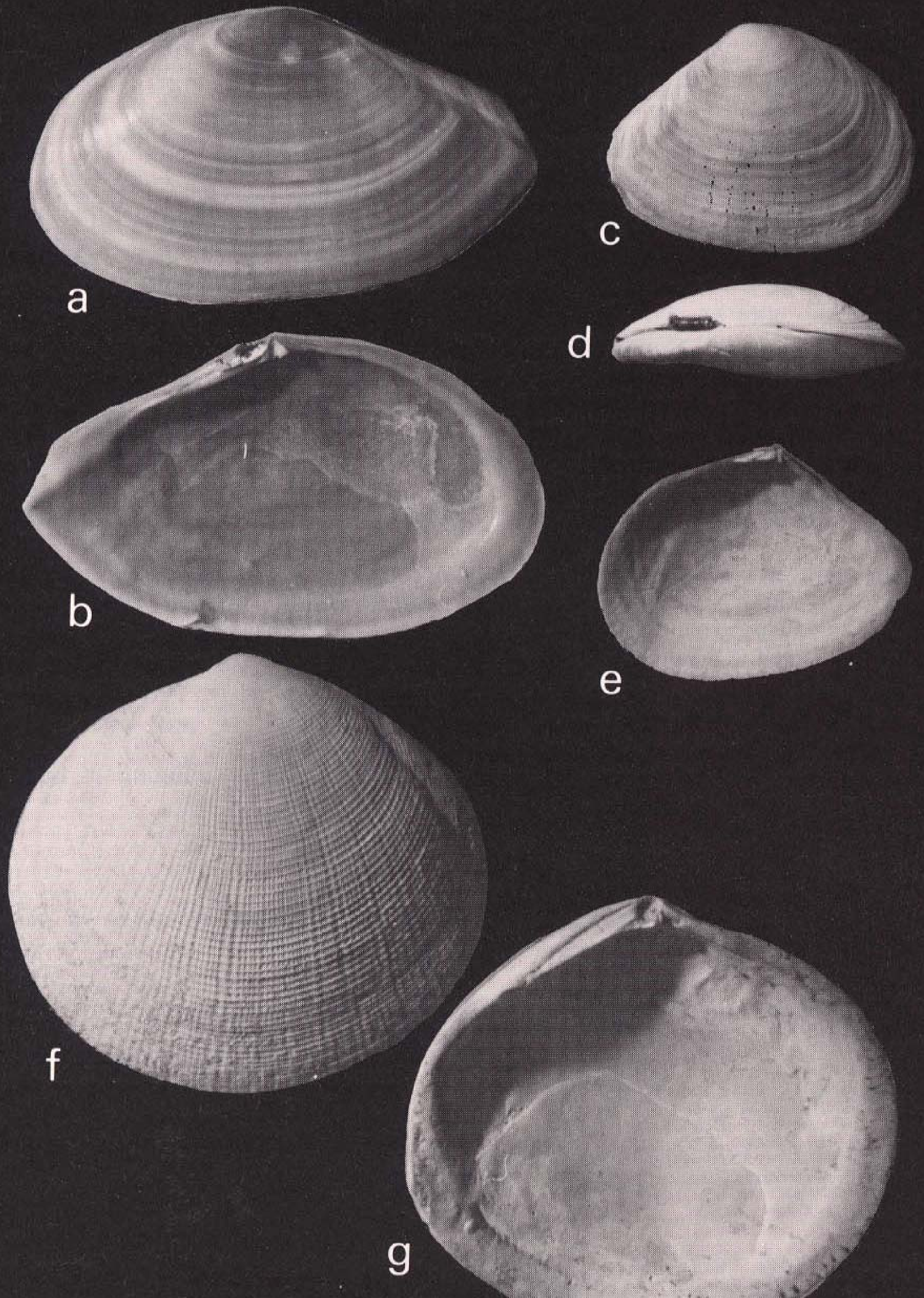
Fairly large, thick, rounded subequivalve, subequilateral, sculptured with fine concentric ridges crossed and cancellated by radiating threads; hinge with two cardinals and an anterior and posterior lateral in each valve. Pallial sinus large, oval. Colour dirty white. Length 56, height 51 mm.

Lives in sand or sandy mud near reefs, 2 to 20m deep, on medium to high energy coasts.

Family DONACIDAE

Shell trigonal, solid, inequilateral, opisthogyrate, hinge with two cardinals and well-developed laterals, pallial sinus normally present.

Fig. 48 a,b. *Tellina (Eurytellina) albinella* LV a. exterior, b. interior; c,d,e. *Tellina (Macomona) deltoidalis* c. RV exterior, d. both valves, dorsal view, e. RV interior; f,g. *Tellina (Pseudarcopagia) victoriae* LV f. exterior, g. interior. x 1.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Genus **Donax** Linnaeus

Radial sculpture usually present.

Donax (Plebidonax) deltoides Lamarck. Pipi, Goolwa cockle Figs 49a,b

Wedge-shaped, fairly large, flat, with a slight carina from the umbo to the posterior-ventral margin; very finely sculptured with microscopic radial striae, which are stronger on the posterior part of the shell, and concentric growth ridges; hinge with a prominent bifid cardinal in the RV, two diverging cardinals in the LV, anterior laterals obsolete, posterior distantly separated; adductor scars pear-shaped, pallial sinus extending about half way across the interior. Colour white tinged with lavender or rose, interior blue. Length 51, height 34 mm.

Abundant below the surface on sandy beaches.

Donax (Deltachion) electilis (Iredale) Figs 49c,d

Shell equivalve, nearly equilateral, truncated and keeled posteriorly, very finely radially striated, more strongly towards the posterior. Ligament short, high, tough. Inner ventral margin minutely crenulated. Posterior area with concentric growth striae as well as radial striae. Fairly large for the genus, pinkish white with a green or brown epidermis. Interior purple either all over or at the posterior and anterior ends. Length 41, height 28 mm.

Originally described from a juvenile from Gulf St Vincent. Found at Long Beach, Younghusband Peninsula.

Family PSAMMOBIIDAE

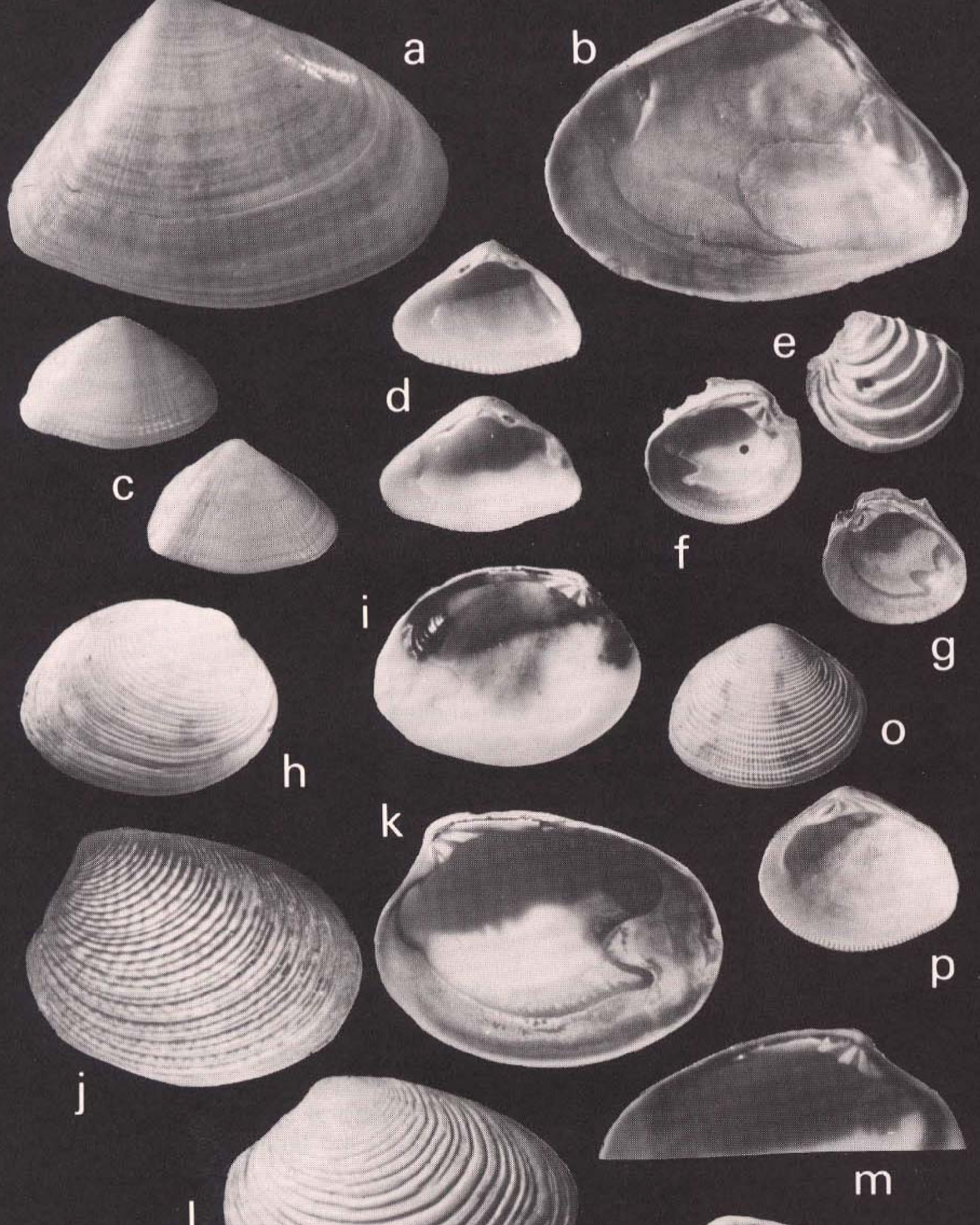
Inequilateral, usually gaping especially posteriorly, hinge with one or two cardinals, laterals weak or absent, ligament on nymph.

The southern Australian fauna includes several species of *Gari*, which are not particularly common; they live in sand in the sublittoral zone.

Genus **Gari** Schumacher

Elongate-ovate to quadrate, anterior margin rounded, posterior truncated and angulate, one pedal muscle scar in front of the cardinal teeth.

Fig. 49 a,b. *Donax (Plebidonax) deltoides* RV a. exterior, b. interior; c,d. *Donax (Deltachion) electilis* RV c. exterior, d. interior; e,f,g. *Placamen flindersi* e. LV exterior, f. LV interior, g. RV interior; h,i. *Katelysia peronii* h. RV exterior, i. LV interior; j,k. *Katelysia scalarina* j. LV exterior, k. RV interior; l,m,n. *Katelysia rhytiphora* l. LV exterior, m. LV hinge, n. RV hinge; o,p. *Tawera lagopus* RV o. exterior, p. interior. x 1.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One species, presently identified as *Gari alba* (Lamarck) is abundant in coarse sand in areas of high current, such as the shifting sand bars of offshore reefs and islands, in shallow water.

Genus **Sanguinolaria** Lamarck

Smooth or nearly so, inequilateral, ovate, pallial sinus large.

Sanguinolaria (Psammotellina) biradiata (Wood) Figs 46i,j; 75g,h; 80p,q. Pl.7m,n

Shell of moderate size, thin, fragile, covered with a deciduous horny periostracum, gaping at both ends which are rounded, the posterior more sharply than the anterior. Umbones sharp, continuous, ligament fairly long, on nymphs which are strong and high, hinge narrow, left valve with two short cardinals, the anterior slightly bifid, the posterior high, right valve with two divergent cardinals, laterals absent; anterior adductor scar long, posterior adductor scar rounded with a slight mid ridge; pallial sinus large. Length 46, height 27 mm. Cream or flesh-coloured, stained with purple and with two posterior rays.

Common in sand and mud, in sheltered bays and estuaries, in the intertidal zone to 3 m depth.

Sanguinolaria (Psammotellina) donacioides Reeve Figs. 75i-k

Roundly oblong, of moderate size thin-shelled, almost equilateral, gaping at both ends, anterior and posterior margins rounded. Colour purple with a strong periostracum. Length 40, height 20 m.

Lives in sheltered bays and tidal inlets such as the Port River.

Family SEMELIDAE

Shell subovate, well sculptured, with a posterior flexure, ligament both external and internal, ligament pit sunken or in a small chondrophore, hinge with two cardinal teeth and usually with laterals; pallial sinus large, rounded. The family is not well represented in southern Australia, most being small shells found in sand at low tide level or dredged in the sublittoral zone. They have been recorded as belonging to the genus Semele, but the family needs revising in South Australia.

Genus **Semele** Schumacher

Medium to large shells, inequilateral, longer anteriorly than posteriorly, resilium in ovoid depression of the hinge plate, cardinal teeth subequal, laterals stronger in RV than in LV, pallial sinus oblique.

Semele monilis Tate

Oblong-ovate, thin, flattish, the right valve slightly flatter than the left, both sides more or less rounded, the posterior more so than the anterior; umbones acute; sculptured with rounded concentric lirae about equal to the inter-spaces and thick radial threads separated by flat furrows passing across and minutely crenulated at the intersections with the lirae; colour whitish to pale yellow with scattered rosy blotches. Length 27, height 23 mm.

Found cast up on the beach or dredged in the sublittoral zone in Gulf St Vincent or from Backstairs Passage to southwestern Australia. It has not yet been found alive.

Genus **Abra** Lamarck (ex Leach)

Abra (Syndosmya) exigua A. Adams Fig. 68y,z

Shell rather small, subovate, broadly rounded anteriorly, posterior short, subangulate with a strong flexure; sculpture of fine concentric lirae; hinge (RV) strong, 3a small, 3b bifid, AI and PI lamellar and raised distally; resilium internal, small, oblique, pallial sinus large and rectangular extending two-thirds over the length of the shell and partly confluent with the pallial line. Length 16, height 15 mm.

Superfamily VENERACEA

Equivalve, ovate, sculpture predominantly concentric; beaks anterior, prosogyrate; ligament external, opisthodetic; three cardinal hinge teeth in each valve; pallial sinus usually present.

Family VENERIDAE

Lunule and escutcheon usually well developed; lateral teeth weak or absent, pallial sinus variable in size and shape. The family is divided into a number of subfamilies, but the division is pragmatic.

Subfamily CIRCINAE

Genus **Circe** Schumacher

Equivalve, subequilateral, umbones terminal, low, lunule and escutcheon narrow, ligament deeply sunken, sculpture of concentric threads and ribs with bifurcating radial ribs on some parts of the shell.

Circe weedingi Cotton Figs 50a,b; 76a,b; Pl.8d,e

Roundly trigonal, compressed, sculpture with concentric ribs and nodulose bifurcating ribs which are confined to both the anterior and posterior areas in the juvenile part of the shell but only the posterior area in the adult. Periostracum thin, light brown. Hinge wide, with three smooth or slightly grooved cardinals and a strong, short anterior lateral in the left valve, two in the right; ligament deeply sunken, encroaching on the cardinal teeth; adductor scars long, concentrically striate, pallial sinus slight, ventral margin smooth. Colour cream or buff to grey, interior white. Length 52, height 52 mm.

This large flat venerid apears to be confined to Gulf St Vincent and Spencer Gulf where it is common, buried at an angle in fine sand to silt in good current flow areas from 10 to 30 m depth.

Subfamily SUNETTINAE

Genus **Sunetta** Link

Smooth, concentrically ribbed; ligament in a deeply excavated escutcheon, hinge with short posterior cardinals; pallial sinus fairly large, rounded, inner ventral margin crenulate.

Sunemeroe Iredale is a synonym,.

Sunetta aliciae Adams & Angas Figs 50c,d; Pl.7i,l

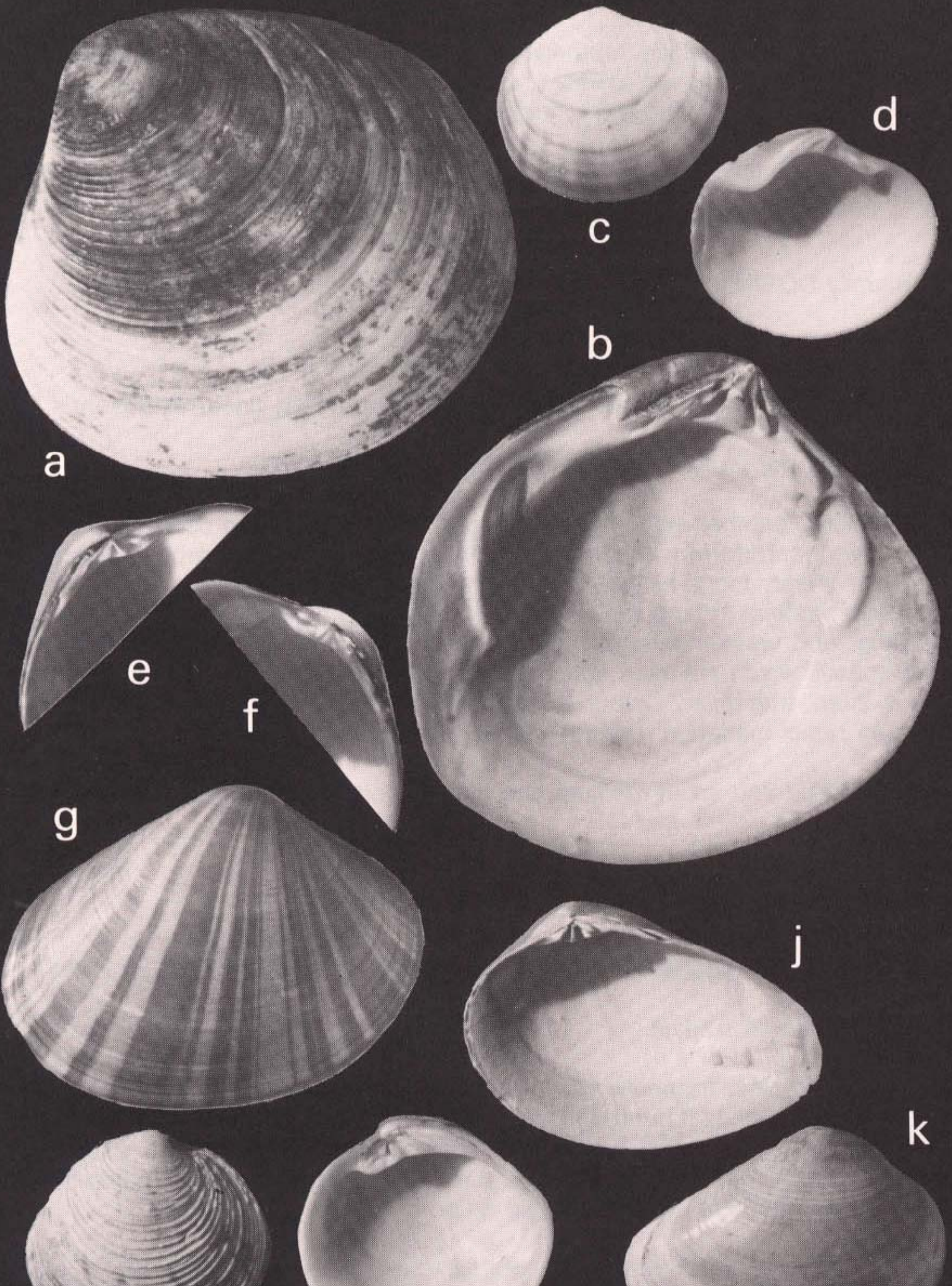
Shell thick, solid, suboval, subequilateral, posterior margin rounded, anterior margin narrowly rounded, ventral margin well rounded, finely crenulate within, hinge wide and thick with a very large deep escutcheon; short high posterior cardinal and narrow small anterior cardinal, a thick short anterior lateral in the LV. Colour whitish with waving lines and rays of rose or rosy purple. Length 29, height 25 mm.

Subfamily PITARINAE

Genus **Notocallista** Iredale

Inequilateral, cardinal teeth tending not to radiate, narrow almost parallel in the RV, anterior laterals well developed; glossy, sculptured with concentric grooves and ridges; pallial sinus wide, horizontal, pointed.

Fig. 50 a,b. *Circe weedingi* LV a. exterior, b. interior; c,d. *Sunetta aliciae* LV c. exterior, d. interior; e,f,g. *Notocallista kingi* e. LV, f. RV hinge, g. RV exterior; h,i. *Dosinia (Kereia) victoriae* RV h. exterior, i. interior; j,k. *Eumarcia fumigata* RV j. interior, k. exterior x. 1.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Notocallista kingi (Gray) Figs 50e-g

Triangularly ovate, solid, somewhat compressed, concentrically irregularly striated, lunule long, well defined; colour cream or pinkish, irregularly rayed with reddish-brown; length 53, height 42 mm.

Lives in clean sand in areas of high current flow from 10 to 40 m deep, often with *Tawera* sp.

Subfamily DOSINIINAE

Genus **Dosinia** Scopoli

Orbicular, with a well defined lunule, escutcheon nearly linear or absent.

Dosinia (Kereia) victoriae Gatliff & Gabriel Figs 50h,i; Pl.8c

Inequilateral, anterior side shorter than posterior, umbones prosogyrate, lunule impressed, cordiform with lamellae radiating from beneath the beak, ligament sunken, linear, long; hinge broad, with three cardinals in the RV, a short anterior cardinal, triangular median and longer, higher, grooved posterior cardinal and weaker laterals; sculpture of thin lamellae, narrower than the interspaces which are microscopically concentrically and radially striate; pallial sinus deep, triangular. Colour cream, with four equally spaced brown arrow-shaped radial markings. Length 29, height 27 mm.

Lives in sand and silt in medium energy and good current areas from 5 to 20 m deep.

Subfamily TAPETINAE

The subfamily Tapetinae was revised by Fischer-Piette and Métivier (1971).

Genus **Eumarcia** Iredale

Of moderate size, trigonally oval, inequilateral with anterior margin rounded, posterior produced, inflated, smooth; lunule large but not impressed, ligament long, on nymph; posterior adductor scar roundly quadrate and extending under the posterior end of the hinge, anterior adductor scar oval, pallial sinus fairly large, quadrate, ventral margin smooth.

Eumarcia fumigata (Sowerby) Figs 50j,k;81c,d

A moderate sized shell, smooth but for microscopic concentric striae and growth folds, inflated, umbo at about the anterior one-third, anterior margin gently rounded, posterior margin sharply rounded; LV with three cardinals the posterior rather long and narrow, the median and anterior grooved, RV with a bifid posterior cardinal, narrow bifid median cardinal and strong oblique anterior cardinal. Colour variable—cream, light fawn or light brown with indistinct light brown rays particularly in young specimens. Length 43, height 30 mm.

Lives in sand and mud in estuaries or tidal inlets; cast up in considerable numbers after storms.

Genus **Katelysia** Romer. 'Cockles'

Shell suboval, solid, compressed, inequilateral, concentrically ribbed, umbones prosogyrate,three radiating cardinals in each valve, pallial sinus conspicuous, short. Three species of *Katelysia* are amongst the most common molluscs of the sandy beach. They are very similar to one another and may be separated by the following key:

1. Shell obliquely oval, posterior dorsal margin straight, surface sculptured with slightly recurved concentric lamellae . . . . *K. scalarina*

2. Shell oval, posterior dorsal margin gently rounded, surface sculptured with concentric irregular bifurcating ridges crossed by fine radial striae . . . . *K. rhytiphora*

3. Shell roundly oval, rather inflated, posterior dorsal margin gently rounded, surface sculptured with flat concentric ribs separated by linear interspaces . . . . *K. peronii*

Katelysia scalarina (Lamarck) Figs 49j,k; 75d-f; Pl.7f

Shell obliquely oval, equivalve, inequilateral, umbones small, prosogyrate, at the anterior one-fourth, posterior dorsal margin straight or slightly curved. Surface sculptured with slightly recurved concentric lamellae about equal to the interspaces. Hinge of moderate width with three straight divergent cardinals, the posterior the longest and the anterior the shortest; ligament long and narrow, lunule long and of moderate width, only slightly depressed; adductors scars oval, concentrically microscopically striate; there is a conspicuous pedal retractor scar under the hinge above the anterior adductor. Colour variable, cream variously mottled with zigzag lines and dots of purple; interior white, purple outside the pallial line. Lenth 39, height 32 mm.

Common on sandy shores in the lower littoral zone.

Katelysia rhytiphora (Figs 49 l-n; 75b,c; Pl.7d,e) is found in a similar habitat, while *K. peronii* (Figs 49h,i; 81e-h Pl.11k) prefers sandy mud in the midlittoral zone of estuaries.

Genus **Venerupis** Lamarck

Oblong-ovate to ovate-elliptical, relatively thin, sculptured with irregular radial and concentric riblets; posterior dorsal margin nearly straight, posterior margin oblique, anterior rounded; members of the genus have a nestling habit and are frequently distorted as a result of growing in crevices. Hinge with three short cardinal teeth in each valve, adductor scars roundly oval, pallial sinus deep, roundly triangular or rounded.

Three species in southern Australia belong to *Venerupis*, most of the others which have previously been placed in Venerupis should be placed in the genus *Irus*. Most of them are not greatly distorted.

Venerupis galactites (Lamarck) Figs 51e,f; 76c-f; Pl. 7j,k

Moderately large, sculptured with fine radial threads crossed by frequent concentric growth lines or low lamellae. Colour white, hence the name 'milk stone'. Length 39, height 25 mm.

Lives in gravelly sand to mud in the littoral zone to 15 m depth.

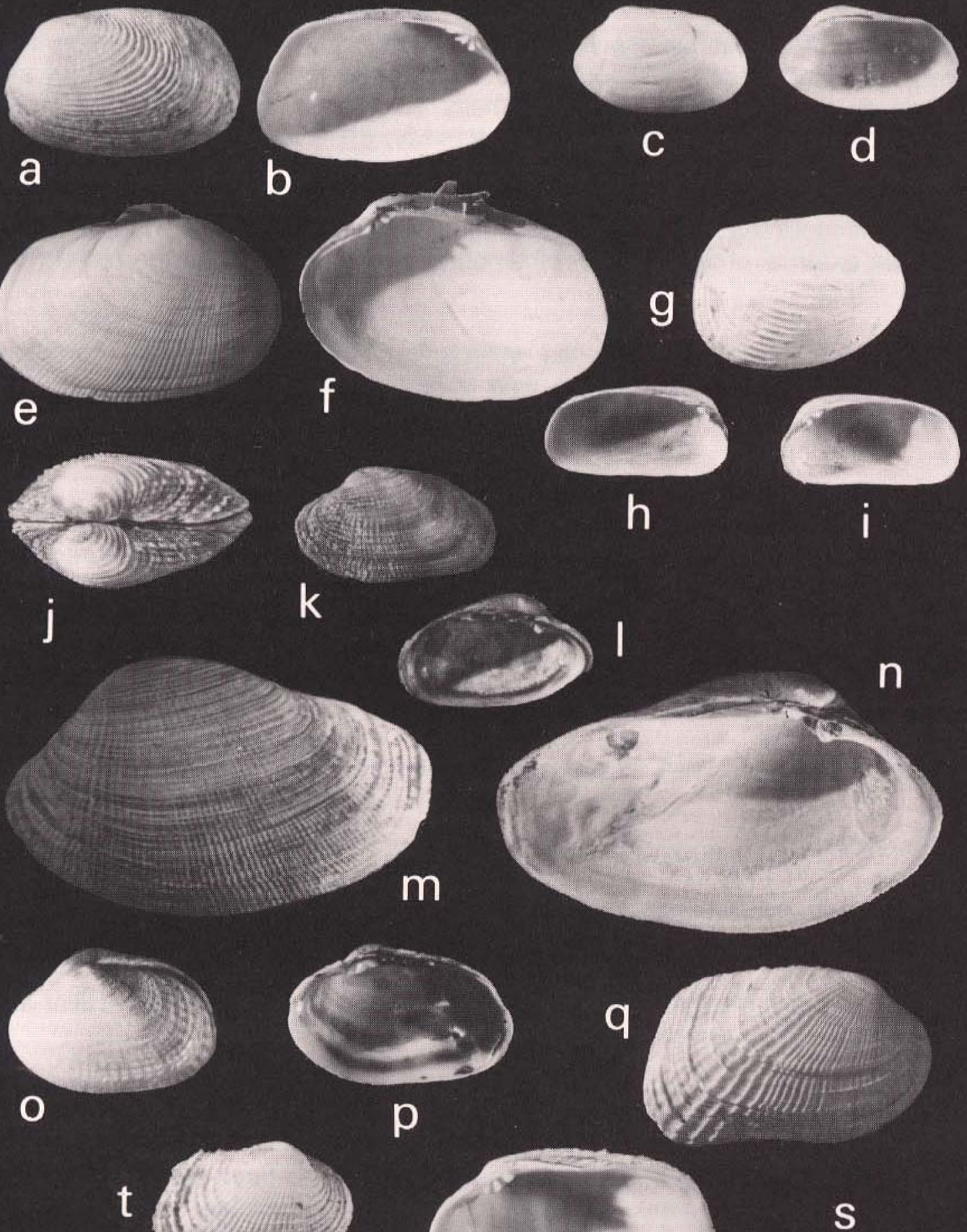
Venerupis anomala (Lamarck) Figs 51a-d

More usually known as *Venerupis fabagella*, shown by French workers to be a synonym of *V. anomala.* The small form (Figs 51c,d) is shaped like a small bean, hence its popular name 'Little Bean'. It is sculptured with fine regular concentric threads which are surmounted by microscopic radial striae. The sculpture is discrepant on the posterior area where there are coarser threads with two or three fine threads between them; the coarse threads may be high and lamellose and extend over the rest of the shell. Colour white, with zigzag markings. Length 20, height 12 mm.

Found in S.A. in gravelly sand or mud in crevices in sheltered waters such as the Port River, Holdfast Bay and Aldinga Bay, and at other localities in southern Australia and New Zealand.

Venerupis iridescens Tate (Figs 51g-i) is similar to *V. anomala* but more coarsely and consistently sculptured all over with concentric lamellose threads with four fine threads in the interspaces. Although the interior is glossy, it is not iridescent. Length 28, height 17 mm.

Fig. 51 a-d. *Venerupis anomala* LV a. exterior, b. interior; c,d. small variety c. LV exterior, d. RV interior; e,f. *Venerupis galactites* RV e. exterior, f. interior; g,h,i. *Venerupis iridescens* g. RV exterior, h. LV interior, i. RV interior; j,k,l. *Irus crebrelamellatus* j. both valves, k. LV exterior, l. LV interior; m,n. *Irus crenatus* LV m. exterior, n. interior; o,p. *Irus cumingi* o. both valves, p. RV interior; q,r,s. *Irus distans* RV q,s, exterior, r. interior; t,u,v. *Irus (Notopaphia) griseus* t. RV exterior, u. LV interior, v. RV interior. x 1.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Genus **Irus** Oken

Members of this genus are readily separated from *Venerupis*, in which they were formerly placed. Although distorted through the nestling habit, they are more or less subquadrate, solid shells sculptured with raised concentric lamellae intersected by radial ribs or threads; there is a very slight tendency for part of the marginal lamellae to overlap the other valve in some adults, but this seems to be distortion resulting from the restricted habitat. Conspicuous and distinguishing features are the deep angular pallial sinus (Figs 51n,p,r) and an external chalky layer sometimes evident only between the radial ribs. (Figs 51j,o).

The nomenclature of the species seems to have been completely confused in the past, but French workers with access to types collected on the early French voyages have made considerable revision.

Irus crebrelamellatus (Tate) Figs 51j,k,l

Elongate-elliptical, with the umbones at the anterior one-third; sculptured with concentric lamellae which anteriorly are scalloped and broken by fine radial lirae, radials weakening posteriorly and the lamellae become broader and frilled, umbonal area with both fine radials and concentric lamellae. Colour grey, adductor scars and pallial line purplish brown, pallial sinus triangular. Length 24, height 14 mm.

Described as burrowing in stiff clay, Patawalonga River, Glenelg.

Irus crenatus (Lamarck) Figs 51m,n; Pl.111,m

The largest species, sculptured with fine concentric lamellose threads crossed and cancellated by fine radial threads. Length 47, height 29 mm.

Lives in mud in mangrove swamps and tidal inlets such as the Port River and Christmas Cove, Kangaroo I.

Irus cumingii (Deshayes) Figs 51o,p

This species is very common in Encounter Bay. It has been placed by authors in *Claudiconcha*, a genus or subgenus of the Petricolidae, because of the tendency for the RV to overlap the LV. In some adult distorted shells the ventral margin of the RV tends to embrace that of the LV but usually the shells are equivalve. The shape varies from suboval to elongate-quadrate, sculpture of numerous erect lamellae crossed and scalloped by chalky radial ridges. Shell dirty grey, umbo stained purple, interior more or less purple-brown, particularly at the posterior end; pallial sinus narrow, long, angulate. Length 29, height 19 mm.

Irus distans (Lamarck) Figs 51q-s

This is the shell previously misidentified by most authors as *Venerupis exotica.*

The shell is relatively large, oval-rhomboidal, sculptured with radial ribs crossed by from four to six distant concentric lamellae, more elevated in the posterior part, between which there are numerous fine concentric lirae. Three small hinge teeth, two of them bifid, in each valve. Colour pinkish-cream, fresh specimens have reddish radial lines on the posterior area. Length 39, height 21 mm.

The species was first collected by the French at the Islands of St Peter and St Francis in the west of South Australia. It appears to be common on Yorke Peninsula.

Irus (Notopaphia) griseus (Lamarck) Figs 51t-v

The subgenus *Notopaphia* is conspicuous by its crenulated inner ventral margin, the pallial sinus is shorter but angular, the hinge teeth are well defined; very little distorted, sculpture of well separated erect lamellae becoming frilled posteriorly, crossed by strong radials. Colour cream, interior more or less stained with purple, particularly at the posterior. Length 21, height 14 mm.

The species is known chiefly from Tasmania as *Venerupis tasmaniensis*, which is a synonym. Tate recorded it from Port Elliot as *Venerupis mitis.*

Subfamily CHIONINAE

Genus **Bassina** Jukes-Browne

Trigonally suboval, lunule well defined, striate, bordered by a groove,without escutcheon but with a weak corselet, sculpture concentric, frilled in some forms, cardinal teeth strong, 3a and 1 close together, 3b and 2b grooved; adductor scars pyriform, pallial sinus linguiform.

Bassina pachyphylla (Jonas) Figs 52a,b; Pl.6e,f

Thick, solid, convex, umbones prosogyrate, anterior margin rounded, posterior margin roundly angulate, ventral margin well rounded and finely crenulate within; sculpture of fine concentric growth striae and a few distant, low lamellae near the anterior margin. Colour fawn or light brown with three broad radiating darker bands, interior white. Length 50, height 45 mm.

NSW, Tas. to SA, littoral on beaches such as Middleton, Goolwa, Port Fairy.

Genus **Circomphalus** Morch

Trigonal, compressed, cordate, lunule impressed, escutcheon and corselet well defined, larger in LV; sculpture of raised lamellae.

When one includes in *Callanaitis* the compressed and distinctive frilled cockles such as the Australian *Callanaitis disjecta* and the Japanese *Callanaitis hiraseana*, it becomes difficult to accept that the New Zealand *Callanaitis* (type species *Venus yatei* Gray) is correctly classified as a subgenus of *Bassina. C. disjecta* has many features in common with the type species of *Circomphalus, C. foliaceolamellosa* (Dillwyn) (= *Venus plicata* Gmelin) (see figure Cox, 1969, p. N40), which seems to have been overlooked. Attention is therefore drawn to the similarities by transferring *disjecta* to *Circomphalus.*

Circomphalus disjecta (Perry). Frilled cockle Figs 52e,f; 75a; Pl.8g

Somewhat quadrately ovate, with an umbonal-posterior ridge, compressed, with from seven to ten conspicuous high, thin lamellae which are curved on most of the shell but produced and frilled on the umbonal-posterior ventral ridge bordering the posterior area (corselet); interspaces wide and with fine concentric growth lines; hinge well developed but rather narrow, three cardinal teeth in each valve, the anterior and posterior in the left valve narrow, the median triangular and bifid; in the right valve the anterior narrow, the median and posterior cardinals bifid and well separated by a pit for the reception of the median cardinal of the left valve; adductor scars oval, pallial sinus moderately long, subtriangular; inner ventral margin weakly crenulate or without crenulations. Colour cream, tinged with pink. Length 63, height 50 mm.

The frilled cockle is one of the region's most attractive shells, living offshore in the sublittoral zone, as, for example, at 30 m off Outer Harbor in Gulf St Vincent, in sand usually associated with the seagrass *Posidonia.*

Genus **Placamen** Iredale

Ovate-trigonal, lunule short, heart-shaped, escutcheon long, bevelled, ligament fairly long; surface sculptured with high recurved concentric lamellae; hinge oblique, short, wide, with two strong curved cardinals and a weaker narrow posterior cardinal, adductor scars oval, pallial sinus short, inner ventral margin crenulate.

Placamen flindersi Cotton & Godfrey Figs 49e-g; Pl.8h,i

Surface sculptured with from ten to twelve high recurved lamellae, sharply frilled and ending abruptly posteriorly at the escutcheon; median and anterior

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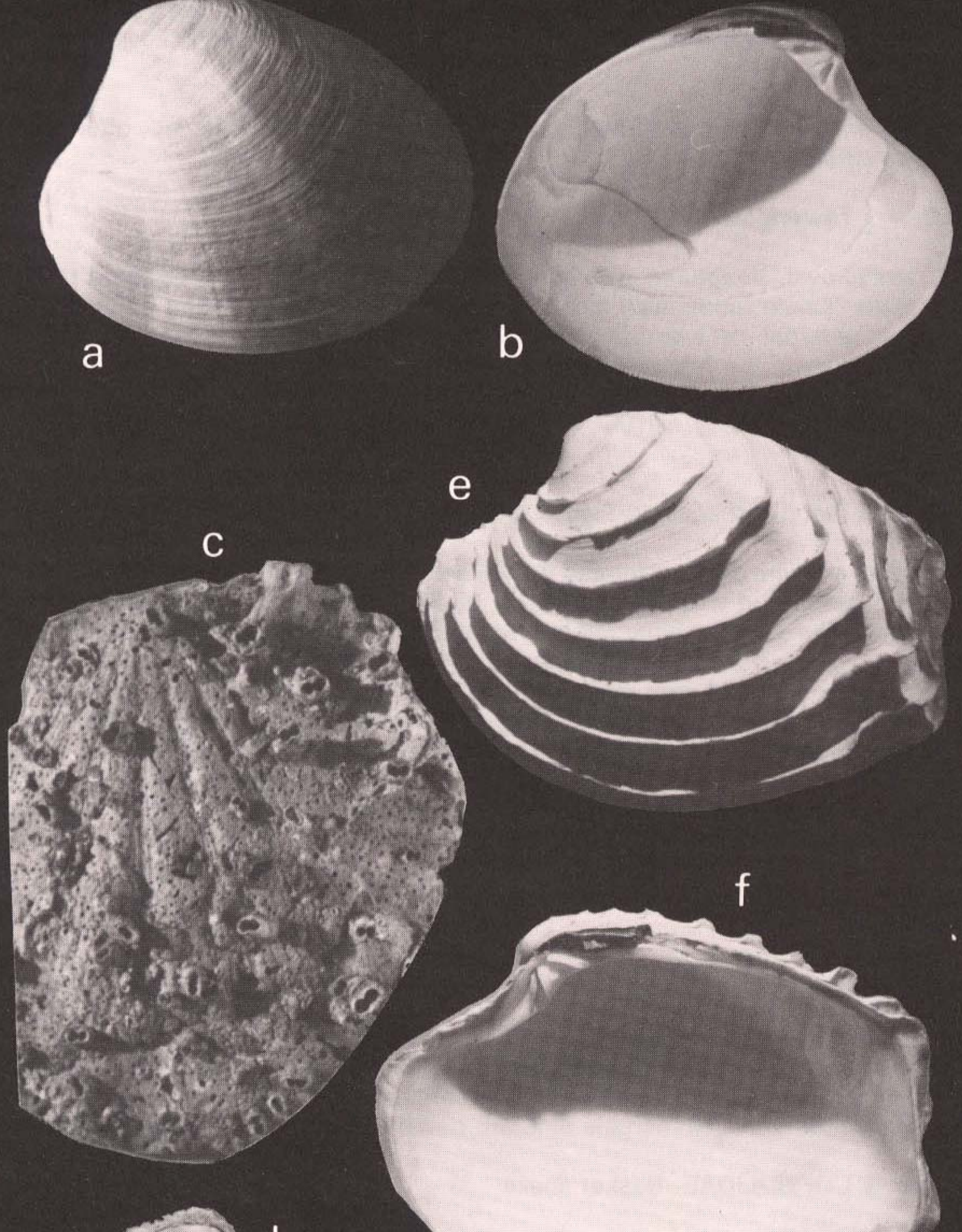
Fig. 52 a,b. *Bassina pachyphylla* LV a. exterior, b. interior; c,d. *Gastrochaeana tasmanica* c. flasks on dead *Chlamys* shell, d. two valves in protective flask; e,f. *Circomphalus disjecta* e. LV exterior, f. RV interior, x 1.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cardinals strong and tending to be bifid, posterior cardinal narrow, weaker; adductor scars well impressed, pallial sinus triangular, short, nearly horizontal. Colour cream with pink rays, interior pink and cream. Length 20 m, height 18 mm.

Lives in sand, in areas of high current flow from 10 to 40 m deep, often with *Circe weedingi.*

Genus **Tawera** Marwick

Trigonal-oval, sculptured with concentric riblets crossed by interrupted radial threads; lunule moderately elongate-cordate, escutcheon poorly defined, ligament external, on a nymph; hinge fairly wide with three divergent cardinals, the median in the left valve bifid, the anterior narrow, the posterior narrow and separated from the ligament nymph by a slight groove; in the right valve the anterior cardinal narrow, the median and posterior cardinals larger and bifid.

Tawera lagopus (Lamarck) Figs 49o,p

Shell of medium size, sculptured with raised slightly dorsally directed concentric ribs crossed and weakly gemmulated by fine radial threads corresponding to denticulations on the inner ventral margin; inner margin denticulate all around except for the posterior-dorsal margin, the denticulations finer on the anterior-dorsal margin; adductor scars oval, the anterior oval-pyriform, pallial sinus oval, moderately large, slightly oblique. Colour cream or white, with three widely separated rays of brown blotches. Length 29, height 27 mm.

Often numerous in clean sand in areas of good water movement on medium to high energy coast from 5 to 30 m deep.

Order MYOIDA

Superfamily MYACEA

Subequivalve, elongate or ovate, porcelaneous to chalky, with a thin periostracum, hinge edentulous or with one cardinal tooth in each valve; ligament mainly internal; valve margins smooth, pallial sinus poorly or well developed.

Family CORBULIDAE. Basket shells

Mostly small subtrigonal shells, inequivalve, inequilateral, left valve tending to be smaller and fitting snugly into the right valve; a resilifer usually in one valve. The family is represented in southern Australia by species of *Corbula* which have a distinctive hinge with a large conical anterior cardinal tooth which fits into a corresponding socket in the left.

They live in the sublittoral zone on muddy, silty or sandy bottoms in places such as Port Albert in Victoria or Yankalilla Bay in South Australia, but are infrequently collected. (Figs 55a,b).

Corbula (Notocorbula) flindersi Cotton Fig. 76h-j

Elongately subtrigonal-ovate, slightly inequivalve, rounded anteriorly, produced posteriorly and with a posterior umbonal-ventral carination; RV embracing the LV, both valves sculptured with fine imbricating threads. Length 18, height 12 mm.

Superfamily GASTROCHAENACEA

This is a small but widely distributed group of boring or burrowing bivalves which frequently build a flask-shaped tube in which the shell and animal are enclosed; shell gaping. porcelaneous, hinge without teeth. One family GASTROCHAENIDAE.

Genus **Gastrochaena** Spengler

Shell small, long, narrow, smooth, contained within a short tube closed at the inflated lower end and built up of successive increments of shell and other debris.

Gastrochaena tasmanica Tenison Woods Figs 52c,d

Elongated, thin, fragile, gaping the whole length of the ventral margin, posterior margin rounded, anterior margin short, concentrically sculptured with rugose striae, valves with an oblique ridge in the middle. Colour white. Length 12, height 4.5 mm.

The animal attaches itself to dead bivalves, sponges, coral and the like, and builds the protective flask. It burrows in limestone in the Port River.

Superfamily HIATELLACEA

Nestling or burrowing shells, quadrate to trapezoidal, valves gaping; hinge with one or two weak teeth, ligament on nymph; pallial sinus well developed.

Family HIATELLIDAE. Rock borers

Genus **Hiatella** Bosc

Small, irregularly elongate, trapezoidal, with a thin periostracum; hinge in juveniles with one or two weak cardinal teeth, in adults without teeth. Nestling in holes or crevices, taking hold of the end of the burrow with the foot or byssus.

Hiatella australis (Lamarck) Figs 53c,d

Shape irregular, taking on the form of the crevice where it lives; periostracum light brown, anterior side shorter, more or less truncated, sculpture of irregular concentric raised growth ridges; hinge in the juvenile with a single cardinal tooth and corresponding socket in each valve. Colour white or cream. Dimensions variable, usually about length 32, height 21 mm.

Found all along the coast nestling in rock crevices, on other shells, at the bases of ascidians and seaweeds and particularly in free-standing sponges in 5 to 20 m deep good water movement.

Genus **Panopea** Menard

Shell large and thick, ends gaping, elongate-subquadrate, posteriorly truncated; ligament nymph large, high; hinge with a single cardinal tooth in each valve; pallial sinus wide. Siphons long in a common leathery sheath. Only a single species *Panopea australis* Sowerby (Figs 53a,b) lives now in southern Australia. It burrows deeply in sand in the sublittoral zone, but is not common.

Superfamily PHOLADACEA

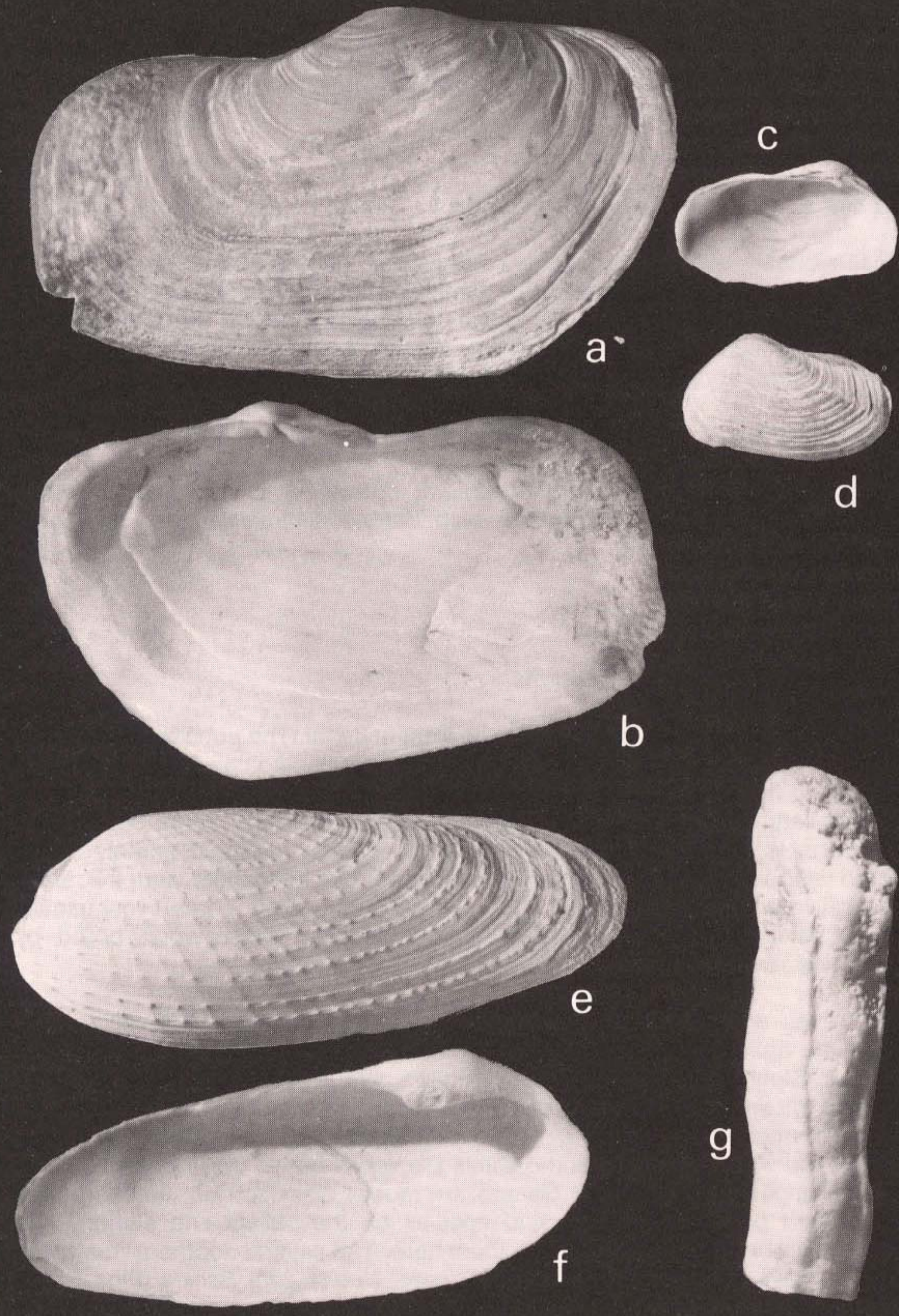
Highly specialised shells adapted for boring. Inequilateral, dorsal margin reflected anterior to beak for attachment of anterior adductor muscle; hinge without teeth but with a small chondrophore and internal ligament; ventral adductor muscle at union of anterior slope and disc; accessory plates or pallets. Mantle closed, foot truncate,more or less circular, and developed as a suction disc. The Pholadacea are a highly specialised group of borers including the pholads and the shipworms which cause great damage. Special morphological terms are used for the families, details of which and the differences between the pholads and the teredinids are given by Tebble (1966) and by Turner (1969). Figs 54 summarises these differences, with acknowledgement to those authors.

Family PHOLADIDAE. Piddocks, Angel wings

The pholads are borers boring into soft rock such as shales, friable sandstone, low grade cement, wood, peat. Fossil borings are sometimes exposed on weathered surfaces of sedimentary rocks.

Shells elongate-ovate to globular, usually with imbricate or denticulate concentric ridges and radial ribs anteriorly; accessory plates present; pallial sinus deep; siphons usually united, commonly enclosed in periostracal sheath.

Fig. 53 a,b. *Panopea australis* RV a. exterior, b. interior; c,d. *Hiatella australis* LV c. interior, d. exterior; e,f. *Barnea australasiae* LV, e. exterior, f. interior; g. *Humphreyia strangei*. x 1.


a
b
c
d
e
f
g

Genus **Barnea** Leach in Risso

Accessory plate a simple calcareous protoplax; umbonal reflection simple, pedal gape from narrow to broadly oval, sculpture of concentric ridges and radial ribs.

Barnea australasiae (Sowerby) Figs 53e,f

Shell elongate-ovate, thin, fragile, inequilateral, gaping at both ends, anterior side rounded, posterior produced, sculptured with concentric striae and growth folds crossed by narrow radial riblets forming prickles at the intersections; umbonal reflection high, a tooth-like apophysis under the hinge in each valve. Colour white. Length 70, height 28 mm.

Widely distributed in Australia burrowing in the sublittoral zone.

A smaller species, *Pholas obturamentum*, burrowing in mud and soft rock, belongs to the genus **Pholas** in which *Barnea australasiae* has also been placed by some authors.

Family TEREDINIDAE. Shipworms

The Teredinidae bore only into wood or plant material. The principal differences between them and the Pholadidae are that the Pholadidae have accessory plates and the intestine traverses the heart (Figs 54a,b), while the Teredinidae have pallets and the intestine does not traverse the heart (Figs 54c,d). The shipworm is a long, limp, wormlike bivalve consisting almost entirely of the joined siphons the tip of which is protected by the pallets and the small visceral mass at the anterior end is covered by the shell. The burrow usually has a calcareous lining secreted by the siphons. Fossil wood bored by teredinids is not uncommon.

The valves are divided into three parts; condyles on which the valves rock when the animal is burrowing, an umbonal-ventral ridge and apophyses are present. Siphons may be separate or united, with a pair of pallets at the base to close the end of the burrow when the siphons are withdrawn. The shipworms are very destructive molluscs which do considerable damage by boring in pilings and wooden ships. As the shells are very variable they have little value in classification of teredinids. Genera are mostly classified on the characters of the soft parts and pallets, and species on the pallets and siphons. No attempt will be made to distinguish them here. The several southern Australian species have been described under *Teredo, Nototeredo, Bankia* (Figs 54c,d) and *Nausitoria*. An illustrated catalogue of the Teredinidae was published by Turner (1966).

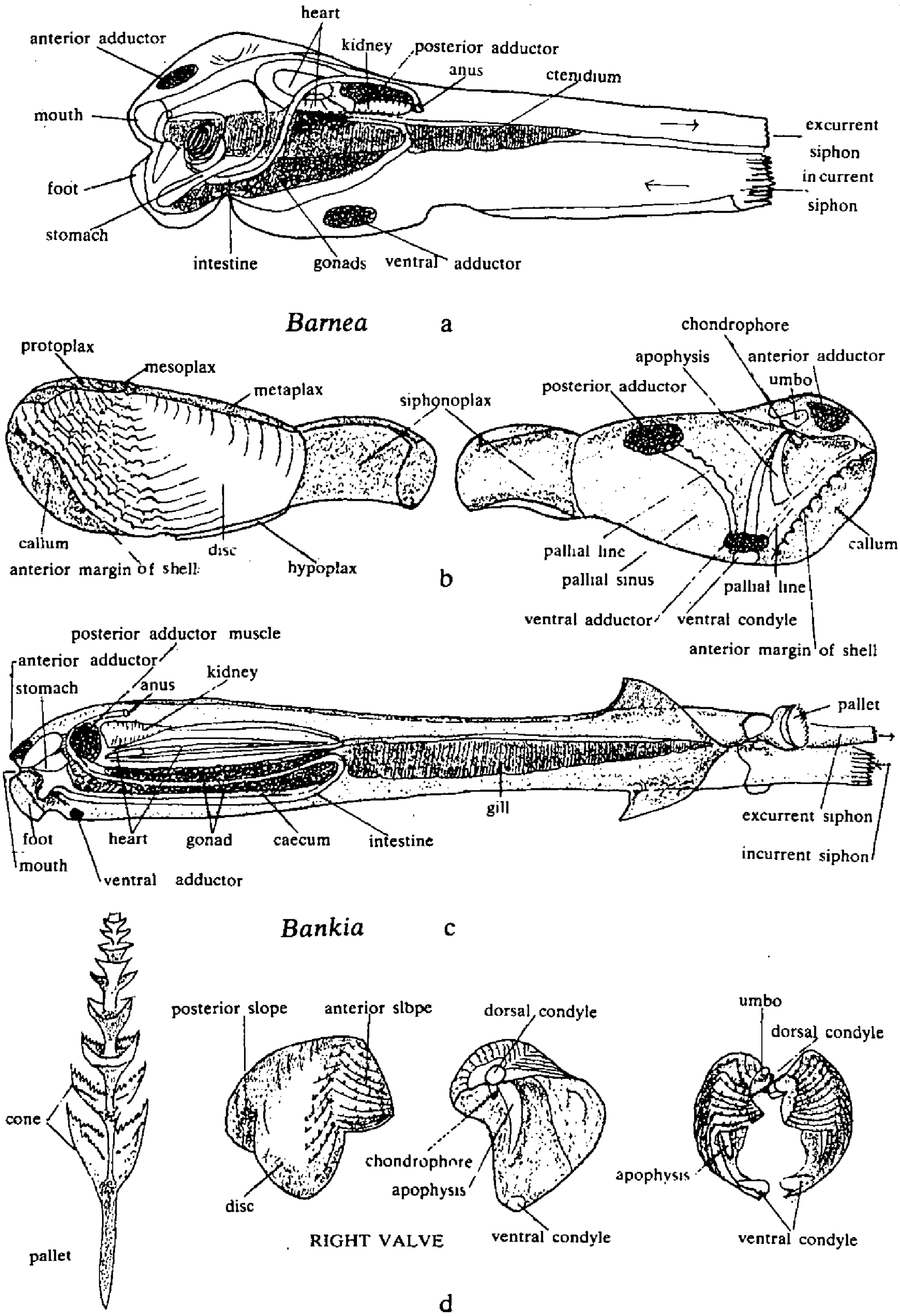


Fig. 54 Difference between anatomy and shell structure of pholads *(Barnea)* and teredinids *(Bankia)* a,b. *Barnea a.* soft parts, with mantle folded back, b. shell exterior and interior; c,d. *Bankia,* c. with mantle folded back to show soft parts, d. parts of shell and pallet.

Subclass ANOMALODESMATA

This is a very ancient and diverse group which has living representatives. The evolution of the group has recently been reviewed by Morton (1981). The Anomalodesmata include nestling or burrowing forms with ventrally fused mantle lobes; they are generally isomyarian, the hinge margin thickened or enrolled, edentulous or with one tooth and corresponding socket; living forms eulamellibranchiate.

Order PHOLADOMYOIDA

Superfamily PHOLADOMYACEA

Nestling shells, equivalve, ovoid to elongate,ligament simple, external, opisthodetic.

Family PHOLADOMYIDAE

The family is represented only by a rather small rare shell, *Pholadomya tasmanica,* dredged below 100 m, for which the preoccupied generic name **Notomya** was introduced. *Pholadomya tasmanica* is regarded as belonging to the genus **Panacca** Dall, which has eight species known only from deep water.

Superfamily PANDORACEA

Sedentary or burrowing shells, inequivalve, elongate or gaping, inner layer nacreous, hinge margin reinforced by buttresses or denticles; ligament and resilium sheathed with a calcareous layer.

Family PANDORIDAE

Compressed, inequivalve, with the dorsal border of one valve overlapping the other, ligament wanting, resilium internal, in some species reinforced by elongate lithodesma, dorsal margin edentulous, with laminar buttresses beside the resilium.

Genus **Pandora** Bruguière

Flat, thin, RV flatter than LV, anterior end rounded, posterior rostrate.

Pandora (Frenamya) patula Tate

This rare small species is the only representative of the family in southern Australia. The LV has the laminae united by a transverse plate; lithodesma absent; sculpture of concentric wrinkles.

It lies horizontally just below the surface of the substrate of fine sand or silt in areas of high current from 5 to 15 m deep.

Family CLEIDOTHAERIDAE

Shell solid, inequivalve, attached by the right valve, ligament wanting but with a submerged resilium with lithodesma; left valve with one cardinal tooth.

Genus **Cleidothaerus** Stutchbury

Fixed on anterior slope of shell; left valve with a single tooth, right valve with large pit for its reception; lithodesma long, curved.

Cleidothaerus albidus (Lamarck) Figs 55c-e ;76k

Large, solid, trigonal, globose, inequilateral, inequivalve, right valve convex except for the anterior slope which is irregularly wrinkled and folded as the surface of attachment; left valve flat; sculpture of irregularly concentric growth threads and striae; hinge with one conical cardinal tooth in the LV and a corresponding pit in the RV. Interior nacreous. Colour white, cream or brown. Length 42, height 52 mm.

Adhering to stones in the sublittoral zone, dredged from 1 to 7 m or cast up on beach.

Family LATERNULIDAE Lantern shells

Shell thin, subequivalve, elongate, gaping posteriorly, internally subnacreous, umbones low, with an external crack, hinge edentulous, ligament on a prominent spoon-shaped chondrophore in each valve, each supported by a thin buttress or clavicle; pallial sinus broad.

Genus **Laternula** Röding

Subcylindrical, roundly gaping posteriorly.

Laternula creccina (Reeve) Figs 55h-j; Pl.11q

Shell large, thin and fragile, elongate-oblong, inequilateral, the posterior side smaller than the anterior, surface sculptured with concentric growth folds and irregular striae, interior pearly; colour white. Length 35, height 18 mm.

Lives buried in mud or sand in shallow water to 10 m in good current.

Laternula recta (Reeve) is a more rectangular, equilateral species which is very common buried in mud on tidal flats.

Family MYOCHAMIDAE

Free or sessile shells, inequivalve, interior subnacreous, dorsal margins overlapping, hinge edentulous, ligament external or absent, resilium internal.

Genus **Myochama** Stutchbury

Sessile, attached by the flat right valve and modified by the form of the surface to which it is attached; resilium between two tooth-like projections on each valve. Bivalves of this genus attach themselves to other bivalves and to *Haliotis;* they are restricted to Australasia.

Myochama anomioides Stutchbury

Shell solid, roundly triangular; upper or left valve free, convex and sculptured with strong radial ribs, crossed by irregular concentric striae; adductor scars well excavated, pallial sinus small, broad; colour fawn, cream inside. Length 22, height 18 mm.

Genus **Myadora** Gray

Free, trigonal, anterior margin rounded, posterior margin truncated, RV convex, overlapping the LV; a flattened cardinal area on either side of the beaks; hinge with a triangular resilifer, pallial sinus shallow.

Myadora complexa Iredale Figs 55f,g

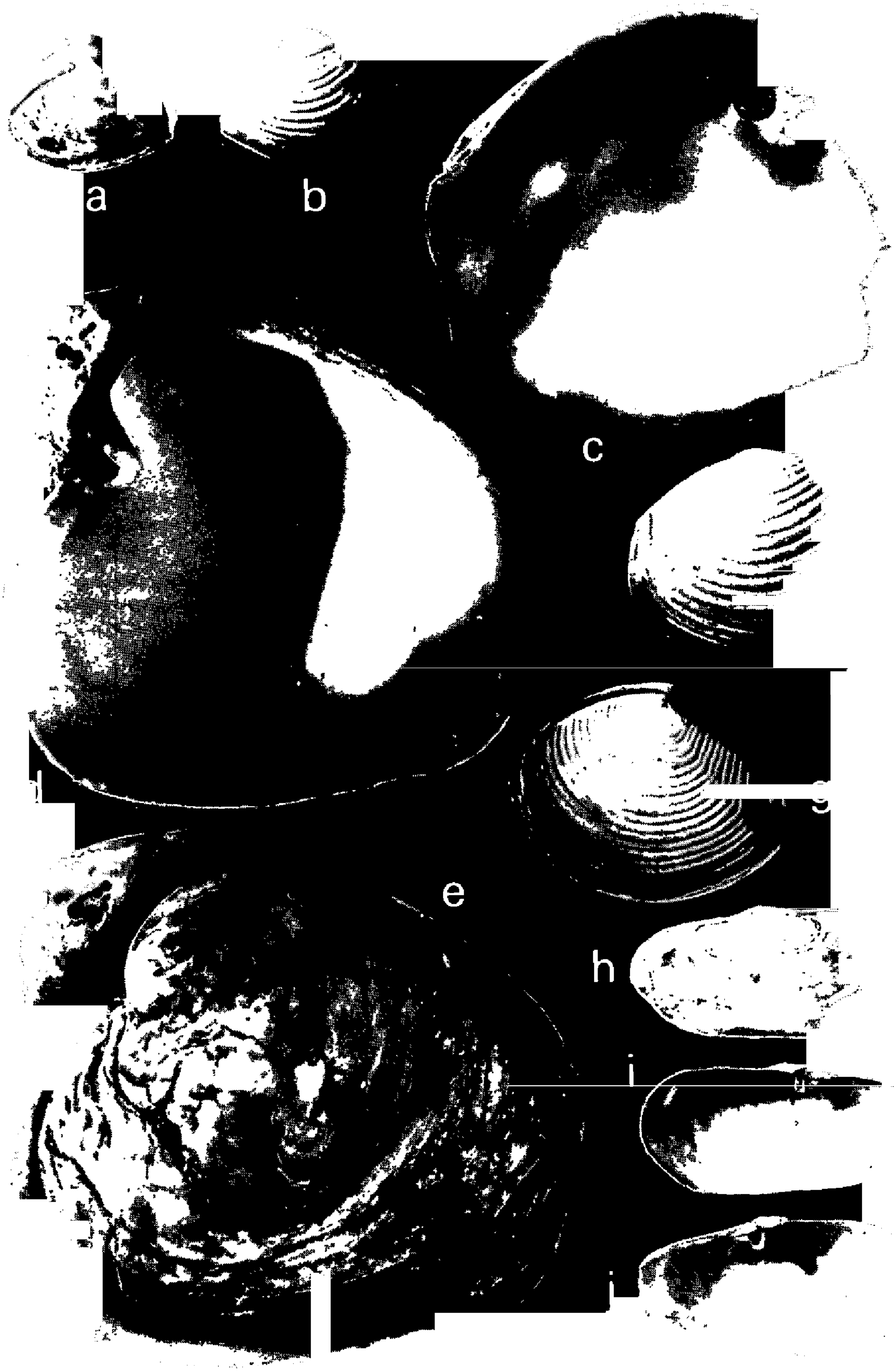
Inequilateral, oblong-ovate, umbones acute, adjacent, that of the right valve overriding the left valve; sculptured with about 24 strong concentric ridges crossed by fine radial striae which in the South Australian specimens are visible only on worn specimens particularly on the flat valve; colour white or cream, interior white. Length 32, height 25 mm obtained by dredging in sandy mud in the sublittoral zone from NSW to south western WA.

Lives in sand to sandy mud from 5 to 30 m depth in areas of good current.

Family PERIPLOMATIDAE

Shell strongly inequivalve, subnacreous, beaks with a slit, hinge edentulous, resilium in two spoon-shaped chondrophores directed anteriorly or downward; pallial sinus mostly wide and shallow.

Fig. 55 a,b. *Corbula iredalei* both valves a. LV on top, b. RV; c,d,e. *Cleidothaerus albidus* c. LV interior, d. RV interior, e. both valves exterior; f,g. *Myadora complexa* f. RV exterior, g. both valves with LV on top; h,i,j. *Laternula creccina* h. RV exterior, i. RV interior, j. LV interior. x 1.


a
b
c
d
e
g
h
i

Genus **Periploma** Schumacher

Shell thin, RV more convex than LV and overlapping it, beaks opisthogyrate, chondrophores usually supported by a clavicle.

Periploma (Offadesma) angasi Crosse & Fischer

Large, very thin and fragile, obliquely ovate, translucent, anterior side longer, rounded, posterior side rostrate, truncated, chondrophores directed downward, pallial sinus deep, narrow. Colour white. Length 73, height 48 mm. Burrows deeply in muddy sand in sheltered bays.

Family THRACIIDAE

Shell smooth, thin, non-nacreous, inequivalve with the RV larger than the LV, surface often granular, hinge edentulous, chondrophore directed obliquely to the posterior, pallial sinus well developed.

The thraciids constitute a family of mostly small, fragile, rather insignificant shells mostly obtained by dredging in the sublittoral zone.

Superfamily POROMYACEA

Equivalve, rounded to elongate, hinge with cardinal and lateral teeth, resilium reinforced by lithodesma; pallial sinus small. Gills septibranch or absent, i.e. they are virtually lamellibranchs without gills, and with greatly reduced labial palps and style sac. They are highly specialised bivalves which might be placed in a separate order SEPTIBRANCHIA. The gills are replaced by a perforated muscular septum used for pumping water through the pallial cavity. They are peculiar bivalves which have developed into scavengers or carnivores, burrowing slowly through mud and ooze in very deep water and drawing on food, mainly dead crustaceans, by a pumping and sucking action of the muscular septum.

Family POROMYIDAE

Roundly qudarate, shell surface granulate, often in radial rows. Ligament external, hinge with cardinal tooth in one valve.

The two genera, **Ectorisma** Tate and **Questimya** Iredale, recorded in southern Australia are both considered to be synonyms of *Poromya* Forbes, 1844.

Poromya granulata (Tate) and Poromya granifera (Cotton) are very small, rare, dredged in deep water.

Family CUSPIDARIIDAE

Shell small to medium, thin, ovate, mostly drawn into a spout posteriorly; ligament external and/or internal, resilium on small resilifer, hinge teeth present or absent; muscular septa across the mantle cavity. Carnivorous.

Genus **Cuspidaria** Nardo

Inequivalve, LV more convex than RV, posterior end strongly rostrate, hinge with posterior lateral tooth in RV, chondrophore inclined, attached by posterior edge. Siphons encased in shells by fusion of the outer lobe of the mantle; glandular patches near the genital opening that can act as sperm receptacles.

Eleven species of *Cuspidaria* have been described locally. They are nearly all very small thin shells obtained by dredging to 600 m.

Family VERTICORDIIDAE

Small cordate shells, with strong radial ribs, nacreous within. Hinge weak, with one or two low teeth.

Genus **Verticordia** Sowerby

Small to minute shells, with raised well developed ribs, ligament external, lunule deep in LV, shallower in RV; RV with one cardinal tooth, LV with a lateral behind the beak. *Verticordia* has normal but very muscular gills. In the subgenus *Spinosipella* Iredale, the ribs are prickly and the lunule wanting. Three species of *Verticordia* have been dredged off southern Australia to a depth of 600 m.

Superfamily CLAVAGELLACEA

Burrowing shells, nacreous, free when young, with one or both valves embedded in an elongate calcareous tube; no hinge plate, ligament external.

Family CLAVAGELLIDAE. Watering pot shells

Tube anteriorly rounded or discoid, fringed with simple or branching tubules, or partially closed by a calcareous disc having several pedal foramina. Recent revisions of the family have been made by Smith (1971, 1976, 1978).

This curious group of rare bivalves has one or both of the valves fused into a shelly tube closed at the anterior end, perforated by small tubular holes like the rose of a watering pot; it is open at the posterior end to give the siphons access to the exterior. The animals bore or burrow into rock, coral or mud and live attached to hard substrates or buried in sand. Their anatomy is inadequately known as they have been described mainly from dead shells cast upon on beaches.

Genus **Clavagella** Lamarck

One valve fused with the tube,the other remaining free inside the anterior cavity; both adductors present in adult. *Clavagella* can reach as much as one metre in length with a tube 50 mm in diameter.

Clavagella (Clavagella) multangularis (Tate)

Tube small, less than 30 mm long, with six or more longitudinal ridges, slightly constricted at the junction with the anterior end; hinge forming apex of anterior end; tubules mainly from anterior end. The species was described from Holdfast Bay and has been recorded from localities along the southern coast. Nothing is known of its anatomy, behaviour, or habitat.

Genus **Humphreyia** Gray

Tube twisted and round to angular, square in section, siphonal end simple or with plaited ruffles; valves large, united into a single plate forming most of the anterior baglike cavity; anterior end with short tubules.

Humphreyia strangei (A. Adams) Fig. 53g

The species can be recognised from the angular tube almost square in section and the two large valves making up one side of the anterior chamber. The tube can be as long as 123 mm. usually found attached to hard surfaces such as rocks or large dead shells, the anterior tubules often appear as root-like structures. The species is known only from southern and southeastern Australia.

Genus **Brechites** Guettard

Both valves fused with the tube, valves small, tube circular.

Brechites (Foegia) veitchi Smith

In the subgenus *Foegia* the siphonal end is simple, the disc often indistinct, without fringe, umbones usually almost covered with swollen prominences. *B. (F.) veitchi* is large, anterior end greatly swollen; tubules covering bulbous portion except around valves which are small and tending to become covered by swollen prominences, small anterior slit, tube wide. Length as much as 226 mm, anterior end diameters 47 and 50 mm. Animal with a thick muscular body wall, anterior part a bag-shaped structure which fills the swollen anterior part of the shell. Long tubular contractile portion posterior to this ends in short fused siphons. Dredged 10-13 m off Cape Donnington near Port Lincoln.

GLOSSARY

Abapical: away from the apex along the axis
Abaxial: outward away from the axis
Aboral: away from, or on the opposite side of, the body to the mouth
Acrembolic proboscis: a proboscis of which the entire length is invaginable—contrast pleurembolic
Acuminate: tapering to a point
Adapical: towards the apex along the axis
Adaxial: inward, towards the axis
Adductor muscle(s): muscles in bivalves which draw the valves together
Adoral: on the same body surface as the mouth
Albumen gland: the gland which produces the fluid surrounding the eggs
Alivincular: type of ligament in bivalves between cardinal areas of each valve, with lamellar layer anterior and posterior to fibrous layer
Amphidetic: bivalve ligament extending on both anterior and posterior side of beaks
Anisomyarian: having the anterior adductor muscle reduced or absent
Aperture: opening of gastropod or cephalopod shell through which head-foot can emerge
Apex: initial end of shell of gastropods; central point of posterior edge of intermediate valve of chitons
Apophysis: a narrow finger-like projection on the inside of some myoidan bivalves to which the foot muscles are attached; another name for sutural lamina of chitons
Articulamentum: shell layer in chitons between tegmentum and hypostracum
Auricle: ear-like extension of dorsal region of bivalve
Auriform: ear-shaped
Axial: parallel to the axis
Axis: imaginary line through the apex about which shells are coiled

Base: the part of the last whorl on the abapical side of the periphery
Beak: point above the hinge of bivalves where growth of shell began; in chitons the projection of the apex of an intermediate valve
Benthonic: (also *Benthic*): bottom-dwelling, living in the benthos
Biconical: having the shape of two cones, joined at their bases
Bifid: divided into two parts by a cleft
Bipectinate: ctenidia having two rows of leaflets with a median axis
Buccal: of or relating to the mouth
Buccal cavity: the pharynx or cavity into which the mouth opens and into which the buccal and salivary glands discharge
Buccal ganglia: the nerve centres of the mouth
Buccal mass: a complex muscular tongue-like apparatus or odontophore which supports and manipulates the radula in the buccal cavity
Byssiferous: having a byssus
Byssus: bundle of hair-like strands by which bivalves can attach themselves to objects

Caecum: apical end of siphuncle or cavity associated with digestive system in *Nautilus*
Calloused: thickened by callus
Callum: apparatus for closing pedal gape in some Pholadacea
Callus: thickened shelly layer (inductura)
Canaliculate: channelled
Cancellate: having sculpture or ornament produced by spiral and axial (or radial and concentric) cords or threads intersecting more or less at right angles (contrast with decussate)
Capsule gland: the gland which produces either the jelly in which egg masses are deposited or the material of the egg capsules
Cardinal area: flattish, commonly triangular, ligamental area between beak and hinge margin of bivalves
Cardinal tooth: hinge tooth close to the beak
Carina: keel-like ridge
Carinated: having a sharp ridge or keel
Carnivorous: flesh-eating
Cerebral ganglia: the nerve centres receiving nerves from the eyes, tentacles and hearing organs
Cerebro-pleural ganglia: the nerve centres serving the labial palps, anterior adductor and the anterior part of the mantle
Chitinous: horny
Chomata: collective term for small tubercles or ridges in one valve and pits for their reception in the other, usually near the hinge
Chondrophore: the process with pit for attachment of internal ligament
Chromatophore: a pigment cell in the body wall
Cicatrix: scar
Cilia: hair-like projections
Ciliated: having cilia
Cingula: (pl. *Cingulae*): spiral cord(s) (from Latin *cingula*, girdle)
Clathrate: with sculpture of spiral and transverse threads or cords intersecting to form a lattice
Clavicle: shelly buttress supporting chondrophore
Collabral: conforming to the shape of the outer lip, shown in growth lines
Columella: pillar surrounding the axis, formed by adaxial walls of whorls
Columellar fold: spiral ridge on columella
Concentric: corresponding in direction to former shell margin or growth lines
Condyle: part of valve on which teredinids rock during boring process
Conical, Conispiral: with spire of shell coiled in the shape of a cone
Connecting rings: in *Nautilus* tubular membrane connecting septal neck with septum behind it
Cordate, Cordiform: heart-shaped
Corselet: differentiated posterior area in some venerids
Costa: (pl. *Costae*): rib
Costella(e): small rib
Crenate, Crenulate: notched along the edge

Crura, Cardinal crura: narrow lamelliform teeth close to the dorsal margin of each auricle in the Pectinidae
Crystalline style: a flexible, glass-like rod in the style sac which stirs up the stomach contents in the digestive process
Ctenidium (Gill): organ of respiration in aquatic animals
Ctenolium: comb-like row of small teeth on lower side of byssal notch in some Pectinacea
Cuneiform: wedge-shaped

Decussate: sculpture produced, particularly in the Turridae, by two sets of oblique lirae or threads which cross to form a rhombic pattern (contrast with cancellate)
Dentate: toothed
Denticle: small rounded tooth-like protuberance
Denticulate: having denticles
Dextral: having genitalia on right side of the head-foot; in dextral or right-handed shells with the apex directed upwards, the aperture is on the right hand side
Dimorphism: having two distinct forms
Dioecious: with male and female reproductive organs in separate individuals
Dimyarian: having two adductor muscles
Divaricating: ornament or sculpture of divergent or zigzag threads or ribs
Diverticula: tubules in the digestive gland
Docoglossate: having a radula with a small number of claw-like teeth
Dorsal: region of bivalve shell where the valves are connected
Dorsum: in nautiloids, side of animal or conch opposite the venter
Duplivincular: ligament formed of alternate bands of hard and soft tissue
Dysodont: with small weak teeth close to the beaks

Eaves: in chitons, parts of the tegmentum over the line from under which the insertion plates and sutural laminae project
Edentulous: without teeth
Entire: gastropod aperture having margin uninterrupted by canal
Epidermis: (also *Periostracum):* coat of horny material covering shell
Epifaunal: living on the substrate
Equilateral: with anterior and posterior parts of shell equal
Equivalve: with two valves of equal shape and size
Escutcheon: dorsal lozenge-shaped area posterior to the beaks
Eulamellibranchiate: gill of advanced bivalves, with adjacent filiments united by cross connections
Excurrent, Exhalant: used of siphons forming passage for current of water expelled from mantle cavity

Filibranchiate: having each gill forming a W in section
Foot: muscular structure extending from body and used for locomotion
Foramen (pl. *Foramina):* hole

Fossula: in Cypraeidae, a shallow depression of the inner lip
Funicle: in Naticidae a narrow spiral ridge extending from the inner lip into the umbilicus

Ganglion (pl. *Ganglia*): a nerve nucleus or bundle of nerve cells in the nervous system
Genital: applied to the organs of reproduction
Gill (*Ctenidium*): organ of respiration in aquatic animals
Girdle: muscular integument of chitons in which valves are imbedded and held in place
Gladius: the cuttlebone or pen of squids and cuttlefish
Globose: rounded like a globe or sphere
Gonad: a sex gland
Gradate: having a spire rising in steps
Granules: small tubercles
Granulose: covered with small tubercles

Head valve: anterior valve of chiton
Helicone: the coiled tube forming the gastropod shell
Herbivorous: plant-eating
Hermaphrodite: with characteristics of both sexes
Heterodont: having differentiated cardinal and lateral teeth
Heteromyarian: having one (anterior) adductor muscle reduced
Hinge: dorsal structure of bivalves on which valves open and close
Hinge plate: dorsal internal platform of bivalves bearing hinge teeth
Homomyarian: with two equal or nearly equal adductor muscles
Hypobranchial: (or *Mucous*) *gland:* the gland on the roof of the mantle cavity in many prosobranchs which secretes an adhesive mucus
Hypoplax: long ventral plate covering space between valves in Pholadacea
Hypostracum:
(1) inner layer of shell secreted by the mantle
(2) shell wall secreted at attachments of adductor muscles
(3) in chitons, lowest ventral calcareous layer of valve

Imbricating: overlapping like roof tiles
Incurrent siphon: siphon through which water current is drawn into the mantle cavity
Inequilateral: shell with anterior and posterior parts unequal
Inequivalve: having one valve larger than the other
Infaunal: living in the substrate
Inhalant siphon: same as incurrent siphon
Ink-sac: a glandular diverticulum of the rectum in most cephalopods which releases a black pigment
Insertion plates: marginal extension of articulamentum layer in valves of chitons which projects into the girdle

Intestine: lower part of the alimentary canal
Iridescent: having a show of rainbow colours
Isodont: hinge with a few symmetrically arranged teeth
Isomyarian: having two adductor muscles equal or nearly equal

Jugal angle: in chitons, angle formed by two halves of an intermediate valve
Jugal area: in chitons, upper surface of a valve adjacent to the jugum
Jugal sinus: sinus or depression between the sutural laminae in chitons, also called the sutural sinus
Jugum: in chitons, longitudinal ridge of an intermediate valve

Labial palps: large pallial organs on either side of the mouth of bivalves, consisting of two pairs of leaf-like ciliated lamellae which sort out particles of food and pass them on to the mouth
Lamella: thin plate
Lamellar: in thin plates
Lamina: thin plate
Last whorl: last complete volution in gastropods
Lateral area: the area on the side and to the posterior of an intermediate valve of chitons, usually separated from the rest of the valve by a diagonal ridge; often different in sculpture from the rest of the valve
Lateral tooth: hinge tooth situated some distance from the beaks
Lateropleural areas: in chitons, upper part of the side slopes of an intermediate valve in some species where the lateral area is not clearly differentiated from the pleural area.
Ligament: elastic dorsal structure joining two valves
Linguiform: tongue-shaped
Lira: fine thread
Lirate: having fine threads
Lithodesma: small calcareous plate reinforcing internal ligament
Lunule: depressed area anterior to beaks, commonly cordate

Maculated: irregularly spotted
Mantle: integument that encloses vital organs and secretes the shell
Mantle cavity: the large cavity surrounded by the mantle forming a respiratory chamber and an enclosure in the digestive process
Mesoplax: plate over the umbones in Pholadacea to protect the anterior adductor muscle
Metaplax: long dorsal plate covering the space between valves in Pholadacea
Monopectinate: ctenidium with leaflets arranged on one side only of an axis
Mucro: in chitons, point or projection on the tail valve
Mucronate: coming to a sharp point

Nacreous: iridescent, pearly
Neck: distal part of gastropod shell where the siphonal canal contracts

Nodose: with knot-like protuberances
Nymph: narrow platform extending posteriorly from the beak along the dorsal margin for attachment of ligament

Obconical: conical, but with cone inverted
Obsolete: used in the sense of being poorly developed
Oesophagus: the tubular food passage from the mouth to the stomach
Operculum: structure borne by foot for closing the aperture
Opisthodetic: (of ligament) located posterior to beaks
Opisthogyrate: (of beaks) pointing in posterior direction
Ornament: pattern on shell
Orthocline: at right angles to growth direction of helicone
Orthogyrate: (of beaks) pointing directly towards the other valve
Osphradium: sense organ located near the gill; may be simple knob-like prominence or a leaf-like structure
Otocysts: hollow oval bodies in the foot of many bivalves thought to be organs of orientation
Outer lip: abaxial margin of aperture extending from suture to base of columella
Ovary: female reproductive organ
Ovate: shaped like longitudinal section of an egg
Oviduct: the duct carrying the ova from the ovary

Palatal: belonging to the outer lip
Pallet(s): calcareous structures in Teredinidae closing the end of the boring when siphons are retracted
Pallial: pertaining to the mantle
Pallial line: line on interior of valve near the margin marking the line of attachment of pallial muscles to the shell
Pallial sinus: embayment in pallial line forming line of attachment of siphonal retractor muscles
Pallium: mantle
Parietal callus: callus on parietal lip
Parietal lip: part of inner lip on basal surface of the shell
Parivincular: of elongated ligament posterior to beaks like a cylinder split on one side
Paucispiral: having few whorls
Pectinate: like a comb
Pedal elevator muscle: muscle attached to shell and used for raising the foot
Pedal ganglia: the nerve centres in the foot
Pelagic: pertaining to or living in the ocean or open sea
Periostracum: coat of horny material covering the shell; in chitons the very thin layer of organic material on top of the tegmentum
Periphery: part of shell or whorl furthest from axis
Planktonic: drifting; used of the plankton, or microscopic plants and animals which drift with the oceanic or other waters which they inhabit
Peristome: margin of aperture
Pharynx: cavity behind the mouth

Phragmocone: chambered portion of conch of cephalopods
Pleural area: in chitons, side slopes of the upper part of a valve excluding the jugal and lateral areas where the lateral area is clearly differentiated by a ridge or distinctive sculpture
Pleural ganglia: the nerve centres serving the walls of the body cavity, siphon etc.
Pleurembolic proboscis: one in which retractor muscles are inserted in the sides mainly towards the base and on their retraction only this part is invaginated to form the proboscis sac
Plica: fold or rib involving the entire thickness of the shell
Porcelaneous: translucent, porcelain-like
Proboscis: a long retractable extension from the head of some gastropods with the mouth at the end
Prodissoconch: shell secreted by larva or embryo
Prosocline: leaning forward with respect to growth direction of helicone
Prosogyrate: curved so that beaks point to the anterior
Prostate gland: a gland in the male reproductive system receiving spermatozoa from the male gonad and passing them through a duct to the penis
Protandrous: a brief period of male sexuality in hermaphrodite molluscs
Protobranchiate: bivalves with small, primitive gills
Protoconch: early apical whorls of shell
Protoplax: accessory plate at anterior end of dorsal margin in some Pholadidae
Ptenoglossate: of radula with long, hooked teeth
Punctate: pitted
Pustules: small pimple-like elvations on the surface
Pustulose: pimply
Pyriform: pear-shaped

Quincuncial arrangement: arrangement in diagonal cross lines by joining central and four corner points of a square
Quincunx: the central and four corner points of a square

Rachiglossate: of radula with tooth formula 1:1:1 or 1:1:0; median tooth with 1 to 14 cusps
Radula: chitinous ribbon bearing transverse rows of teeth, located on the floor of the buccal cavity in most molluscs
Rays: used of colour pattern of radial colour markings
Resilifer: structure in the hinge for attachment of the internal ligament
Resilium: internal ligament of bivalves
Reticulate: having a network of obliquely intersecting ridges
Retractile: capable of being drawn back
Rhipidoglossate: of radula with tooth formula ∞:ca5:1:ca5:∞; very numerous marginals, long, narrow, hooked, arranged like a fan
Rostrate: beak-like
Rugose: wrinkled

Salivary ducts: ducts carrying saliva from the salivary glands into the pharynx
Salivary glands: glands producing saliva
Schizodont: with one hinge tooth broad and bifid
Sculpture: relief pattern on shell surface
Septibranchiate: bivalves having gills transformed into a muscular septum dividing the mantle cavity into two chambers, one ventral and one dorsal
Sessile: attached, permanently in one place
Shagreened: like shark skin
Shoulder: angulation of whorl forming abaxial edge of shelf or sutural ramp
Sinistral: with genitalia on left side of head-foot mass; sinistral shells with apex upwards have aperture on left hand side
Sinus: embayment or indentation
Siphon: tube-like extension of mantle for passage of inhalant or exhalant current
Siphonal canal: extension of abapical part of apertural margin to accommodate inhalant siphon
Siphonal fasciole: band of abruptly curved growth lines near base of columella marking successive positions of siphonal notch
Siphonal notch: notch in apertural margin near base of columella for protrusion of inhalant siphon
Siphonoplax: accessory structure at posterior end of adult valves in Pholadacea
Siphuncle: long tube extending through all the camerae to the apex of some cephalopods
Spatula: spoon-shaped area on the interior of a limpet shell surrounded by muscle scar
Spermatozoa: male reproductive cells
Spicule(s): small sharp pointed or spiky body
Spiculose: ornamented with spicules
Spire: adapical part of shell except the last whorl
Stria(ae): narrow incised groove or furrow
Style: see crystalline style
Style sac: a sac in the intestine where the stomach contents are stirred up by the crystalline style
Subintestinal ganglion: nerve centre on the right of the animal supplying the pallial nerves
Sulcus: radial depression of the surface of shell
Supraintestinal ganglia: nerve centre on the left side of the animal supplying the pallial nerves
Sutural laminae: in chitons, plate-like anterior projections of the articulamentum extending from either side of an intermediate or tail valve
Sutural sinus: see Jugal sinus
Suture: line on surface of gastropod shell where one whorl joins another.

Taenioglossate: of radula with a formula of 2:1:1:1:2, the median tooth having a number of cusps, admedians broad, marginals hook-like
Taxodont: with numerous short hinge teeth mostly transverse to hinge margin

Tegmentum: in chitons, the outer somewhat porous calcareous layer of a valve, between the periostracum and the articulamentum
Teleoconch: entire shell excluding the protoconch
Tentacles(s): flexible appendage or outgrowth used as organ of attachment or touch
Torsion: the process during larval development during which the mantle cavity is twisted to the front of the body
Toxoglossate: of radula consisting only of long teeth
Trema (pl. *Tremata):* orifice in the wall of some shells for excretion
Trochiform: flat-sided conical
Trochophore: ciliated larval form, bilaterally symmetrical, which swims by means of equatorial cilia
Tubercle(s): small rounded elevation on shell surface
Tuberculate: bearing tubercles
Turbinate, Turbiniform: with broadly conical spire and convex base, like *Turbo*
Turriculate: with acutely conical spire composed of numerous flat whorls

Umbilicus: depression formed around shell axis where walls of shell whorls do not join to form a solid columella
Umbo(nes): region surrounding beak or extending to it

Valve: one of the two calcareous structures forming the shell of bivalves; one of the discrete shells or plates of a chiton
*Varix (*pl. *Varices):* prominent transverse elevation marking a growth halt during which a thickened outer lip developed
Veliger: larval form, modified from trochophore by appearance of adult organs and a ciliated lobe, the velum
Ventral: area of shell opposite hinge where valves open most widely
Ventricle: one of the two pumping chambers of the heart
Ventricose strongly inflated
Vermiform: worm-like
Visceral ganglion: nerve centre between the mantle cavity and the visceral mass
Visceral mass or *hump:* in coiled gastropods the soft parts remaining permanently within the shell
Volution: a complete coil of the shell or conch

Whorl: a complete coil of the shell or the exposed surface of any complete coil
Wing: triangular, more or less elongate, terminal part of dorsal region in some bivalves such as the Pectinacea

3. PLEISTOCENE EPOCH

The Pleistocene Epoch is popularly known as The Ice Age because during part of this time the Northern Hemisphere was subjected to extensive glaciation. However, the description does not apply to the whole of the Epoch and the earlier concept that the beginning of the Pleistocene is marked by the onset of glaciation is now considered incorrect. The climate alternated between times of glacial intensity and warmer interglacial periods when the ice melted and sea levels rose. Apart from the Kosciusko region of southeastern Australia and high areas of Tasmania, most of Australia did not experience glaciation at this time, although South Australia was affected by rises in sea level during interglacial periods.

This is demonstrated in a great system of more-or-less parallel sand ridges in the Lower South-East of the State which formed as beach dunes during Pleistocene high sea level stands. The ridges become progressively younger from Naracoorte westward. The Naracoorte Range (or Dune) is believed to be of Early Pleistocene age, confirmed by the presence of *Hartungia dennanti chavani* (p. 232) permitting correlation with the Point Ellen Formation and Roe Calcarenite. Nearer the coast, the Woakwine Range (or Dune) has abundant *Anadara trapezia* (p. 144) and is thought to have formed during the Late Pleistocene when the Glanville Formation was laid down. Between these two are a further 14 to 18 dune ridges, and all are thought to have formed during successive high sea level stands.

There is a considerable literature on the succession of dunes, and a general study of the molluscan faunas was made by Crocker & Cotton (1946). However, the molluscs need to be recollected and studied in greater detail. They are mainly accessible in artificial drains which cut through the dune ridges.

At the time of writing the base of the Pleistocene in Australia is accepted as equivalent to the base of the Calabrian stage in Italy, which was designated by the 19th International Geological Congress in 1952 as the oldest stage of the marine Pleistocene. It acts as a point of reference with which strata with similar faunas can be correlated. As a result, strata in Australia and elsewhere which had been previously regarded as Late or latest Pliocene were placed at the base of the Pleistocene. In Victoria and South Australia the stage name Werrikooian has been used for them from their outcrops in western Victoria. The Roe Calcarenite in Western Australia and the Point Ellen Formation and the Burnham Limestone in South Australia, from the information presently available, are considered to be of Early Pleistocene age.

In the last twenty years a new method of correlating rocks younger than 3.5 Ma (including the Quaternary) has been developed, following the discovery that at certain times the earth's magnetic field has been reversed. Rocks that are normally and those that are reversely magnetised can be correlated all over the world. The age at which these geomagnetic reversals have taken place can be established by potassium-argon (K-Ar) dating of volcanic rocks whose position in the stratigraphic column is known. If volcanic rocks occur within sediments containing fossils it is possible to obtain not only a correlation from the fossil content but also a K-Ar date to relate it to the geomagnetic time scale. Larger polarity intervals (Chrons) such as Bruhnes (normal), Matuyama (reversed) and Gauss (normal) are named after their discoverers while smaller intervals (Subchrons) such as Jaramillo (normal), Gilsá (normal) and Olduvai (normal), all within the Matuyama, are named after the sites from which they were measured.

The amount of data on K-Ar ages and the magnetic polarities of volcanic rocks spanning the last four million years is quite formidable, and as data accumulate and new palaeontological evidence is produced, the position of the boundary between the Pleistocene and the Pliocene tends to be modified by specialists. This is not unusual at stratigraphic boundaries and can be quite confusing to the non-specialist.

Dating is also possible by oxygen isotope analyses of marine fossils and by amino-acid racemization measurements in fossil molluscs. Amino acids, which are bonded in the protein of organisms during life, are released after death and racemization (or interconversion) of isonomers 'L' and 'D' takes place. However, obtaining an age from isonomer ratios requires, amongst other things, a precise knowledge of the temperature history of the fossil. As this is usually only poorly known, the age obtained may be very imprecise.

As can be seen from the above, the problem of whether or not strata at present considered to be Early Pleistocene should, as they were seventy years ago, be assigned to the Late Pliocene is not straightforward. Until a greater variety of data are obtained from the limited outcrop remnants found in southern Australia, the main bases for identifying their age rest with their rather poorly preserved faunas.

The relative position of the strata above limestones and calcareous sandstones of the Hallett Cove Sandstone and Dry Creek Sands which are regarded as of Late Pliocene age may provide supplementary evidence.

The specialist or student seeking further information on dating the Quaternary will find extensive references to the literature in Berggren & Van Couvering (1974) and Bowen (1981).

Early Pleistocene: Point Ellen Formation and Burnham Limestone.

Faunas regarded as of Early Pleistocene age can be found in the Point Ellen Formation and the Burnham Limestone. Although the outcrop at Point Ellen on Kangaroo Island has been known since 1914, and a limited molluscan fauna identified, the fauna has only recently been more thoroughly collected and described (Milnes *et al.* 1983; Ludbrook 1983). Their equivalent in Western Australia is the very richly fossiliferous Roe Calcarenite at the western end of the Eucla Basin, the molluscs of which were described by Ludbrook (1978).

The Point Ellen Formation is of very limited extent, known only from thin outcrops on the south coast of Kangaroo Island at Point Ellen, Point Reynolds and Cape Willoughby and at Cape Jervis on Fleurieu Peninsula (Fig. 56). It overlies limestones which are equivalent to the Hallett Cove Sandstone. The Burnham Limestone is a thin remnant overlying the Hallett Cove Sandstone principally at Port Willunga and Maslin Bay.

The molluscs in the Point Ellen Formation are more closely related to those of the Late Pliocene formations than to those of the Late Pleistocene deposits, and the formation may prove to be of Late (or latest) Pliocene age.

The Burnham Limestone is poorly fossiliferous and contains only nine species, but can be correlated with the Point Ellen Formation.

The small outcrop in the cliff section at Point Ellen (Pls 12,13) is the only locality from which a good fauna has been collected. As most of the specimens are held tightly in a calcareous matrix they are on the whole only moderately well preserved, as will be seen from the figures; shells are usually broken or coated with calcium carbonate from the overlying calcrete. There are 51 species of molluscs, listed below, the most diagnostic of which are *Nerita milnesi* Ludbrook and *Hartungia dennanti chavani* Ludbrook. Some 19 species have been collected from chalky Point Ellen Formation at Cape Jervis. Description of the fauna is contained in Ludbrook (1983) which may be consulted for details not included here.

The fauna is that of a rocky coast with sandy bays. It contains rock-dwelling living species which are not found in the Late Pleistocene Glanville Formation nor in the Holocene St Kilda Formation which were deposited in a different environment.

GASTROPODA

HALIOTIDAE

Haliotis (Exohaliotis) cyclobates Peron & Lesueur
p. 42 Figs 12a,b; 57c

A living species known from fragments from Point Ellen.

FISSURELLIDAE

Clypidina (Montfortula) rugosa (Quoy & Gaimard)
p. 44 Figs 13i-k; 57b

A living species found at Point Ellen and Cape Jervis.

ACMAEIDAE

Patelloida nigrosulcata (Reeve) p. 48 Figs 15d,e

Has a continuous record from the Early Pleistocene to the present day.

PATELLIDAE

Patella (Scutellastra) peronii Blainville p. 52 Figs 14e;57a

TROCHIDAE

Cantharidus (Phasianotrochus) apicinus (Menke)
p. 54 Fig. 78h

A living species rare in the Burnham Limestone.

Cantharidus (Phasianotrochus) eximius (Perry) p. 56 Figs 16n, 57g

A living species found at Point Ellen.

Diloma (Fractarmilla) concamerata (Wood)

p. 56 Figs 16e,f; 57d,e; 63m-n, Pl. 1h

Has a continous record from the Early Pleistocene to the present day.

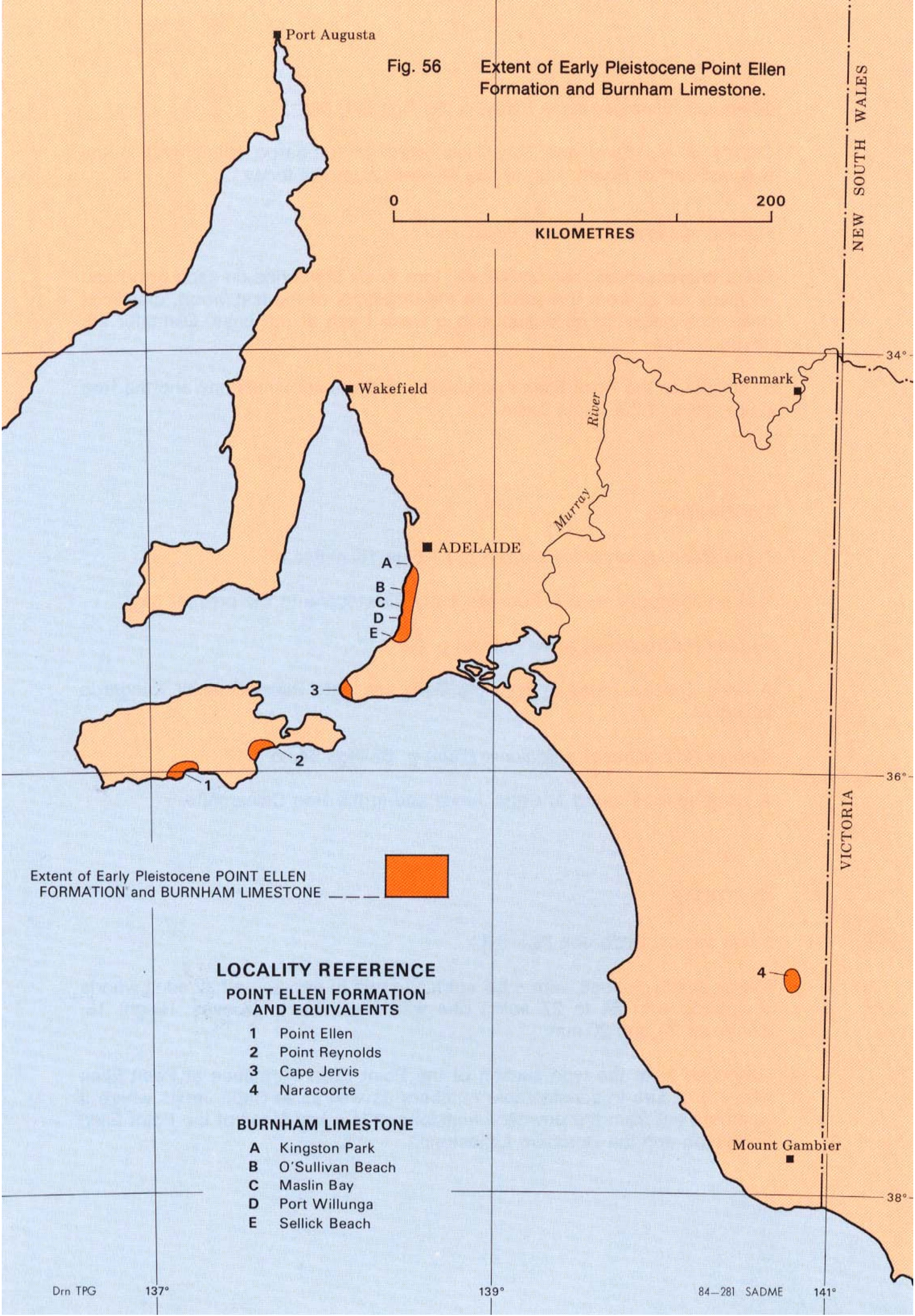


Fig. 56 Extent of Early Pleistocene Point Ellen Formation and Burnham Limestone.
0
200
KILOMETRES
Port Augusta
Wakefield
ADELAIDE
Renmark
Murray River
Mount Gambier
NEW SOUTH WALES
VICTORIA
34°
36°
38°
137°
139°
141°
A
B
C
D
E
1
2
3
4
Extent of Early Pleistocene POINT ELLEN FORMATION and BURNHAM LIMESTONE
LOCALITY REFERENCE
POINT ELLEN FORMATION AND EQUIVALENTS
1 Point Ellen
2 Point Reynolds
3 Cape Jervis
4 Naracoorte
BURNHAM LIMESTONE
A Kingston Park
B O'Sullivan Beach
C Maslin Bay
D Port Willunga
E Sellick Beach
Drn TPG
84—281 SADME

Diloma (Fractarmilla) rudis (Gray) p. 56 Figs 57f, 68c

Occurs in the Early and Late Pleistocene of Kangaroo Island and in the western part of South Australia to Western Australia today.

Monilea euclensis Ludbrook Figs 57h,i

Solid, depressed conical, umbilicate; four to six spiral ribs on each whorl and as many as 22 from the suture to the umbilicus of the last whorl, umbilicus deep, columellar lip calloused with a weak tooth at the base. Diameter 23, height 16 mm.

Restricted to the Point Ellen Formation and Burnham Limestone and the Roe Calcarenite of the Eucla Basin.

TURBINIDAE

Turbo (Ninella) torquatus Gmelin p. 61 Figs 16l,m;64a,b

Has a continuous record from the Early Pleistocene to the present day.

Astraea (Micrastraea) aurea (Jonas) p. 62

A living species found in both the Early and Late Pleistocene of Kangaroo Island.

Astraea (Micrastraea) rutidoloma (Tate) p. 62 Figs 64c,d

A living species found at Cape Jervis and in the Roe Calcarenite.

NERITIDAE

Nerita milnesi Ludbrook Figs 57j,k

Rather small, globose, with a flat spire and one to one-and-a-half adult whorls sculptured with 24 to 27 spiral ribs with linear black grooves. Height 16, diameters 24 and 20 mm.

Described from the type section of the Point Ellen Formation at Point Ellen where it occurs in considerable numbers as well as at Cape Jervis where it weathers out from the powdery limestone. It is a key fossil of the Point Ellen Formation and the Burnham Limestone.

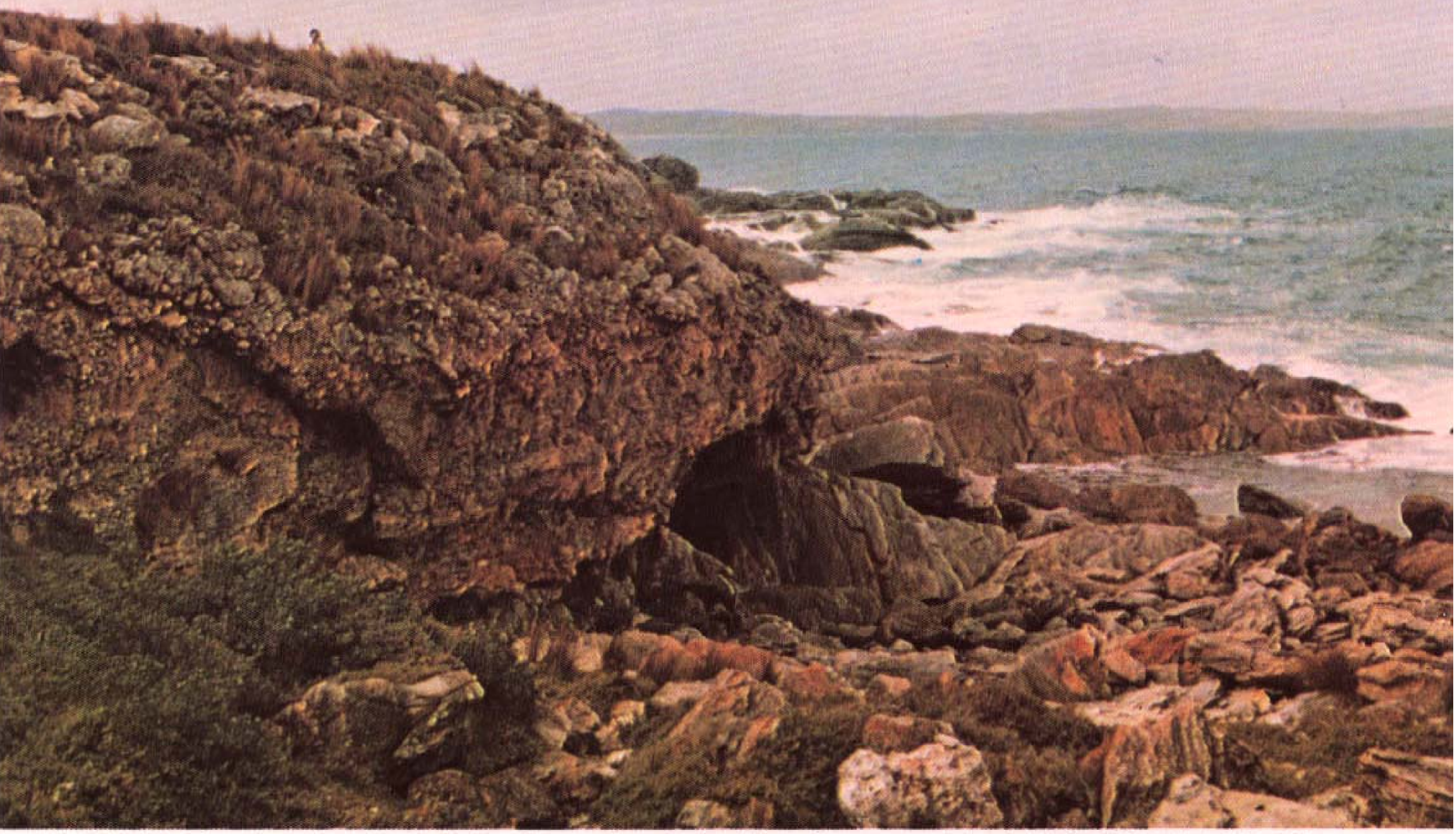


PLATE 12 Type locality of Point Ellen Formation, Point Ellen, Kangaroo Island. KINGSCOTE 1:250 000 sheet. (Trans. 24545)

PLATE 13 Detail of Point Ellen Formation, crowded with *Nerita milnesi* and *Hartungia dennanti chavani.* (Trans. 24546)

PHASIANELLIDAE

Phasianella angasi Crosse.

More material is required to confirm its record at Point Ellen.

Phasianella australis (Gmelin) p. 64 Figs 20a, 57l; 64k; Pl.10p;

Known from the Late Pliocene to the present.

LITTORINIDAE

Bembicium melanostoma (Gmelin) p. 70 Figs 20f-h; 57m,n; Pl.10j

Has a continuous record from the Early Pleistocene to the present.

Bembicium nanum Lamarck p. 70 Fig. 20i; Pl.1l

Has an irregular record in the Quaternary.

POTAMIDIDAE

Batillaria (Batillariella) estuarina (Tate)

p. 78 Figs 21h,i; 64e; Pl.11c

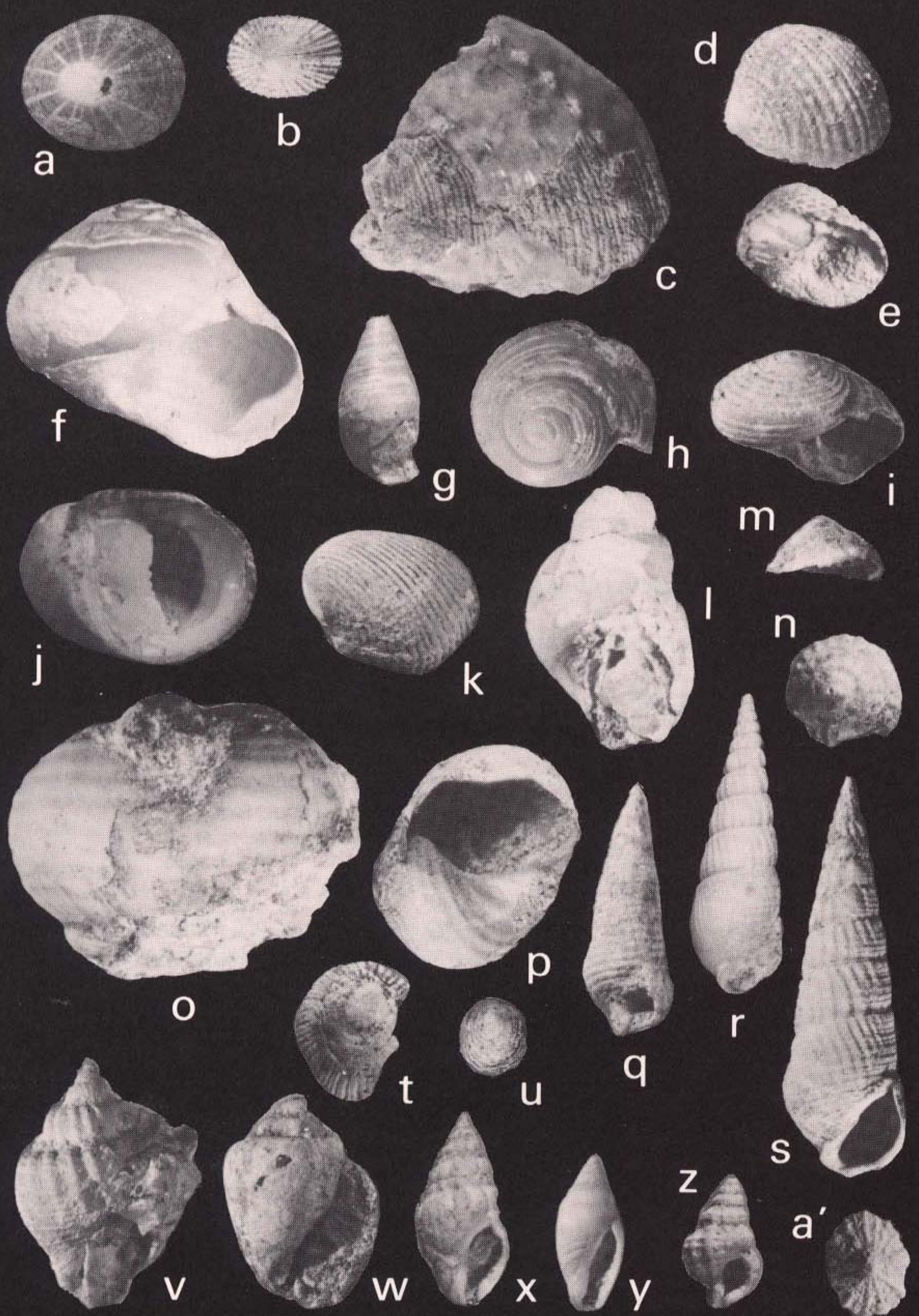
Has a continuous record from Early Pleistocene to the present where it is an inhabitant of estuaries and tidal inlets. It is abundant in the Burnham Limestone at Maslin Bay.

Batillaria (*Zeacumantus*) *diemenensis* (Quoy & Gaimard)

p. 77 Figs 21f,g; 57q; 64g; 78p; Pl. 11b

Occurs more or less abundantly from the Late Pliocene to the present.

Fig. 57 Point Ellen Formation—Early Pleistocene. All x1 a. *Patella (Scutellastra) peronii;* b. *Clypidina (Montfortula) rugosa;* c. *Haliotis (Exohaliotis) cyclobates;* d,e. *Diloma (Fractarmilla) concamerata;* f. *Diloma (Fractarmilla) rudis;* g. *Cantharidus (Phasianotrochus) eximius;* h,i. *Monilea euclensis;* j,k. *Nerita milnesi;* l. *Phasianella australis;* m,n. *Bembicium melanostoma;* o,p. *Hartungia dennanti chavani;* q. *Batillaria (Zeacumantus) diemenensis;* r. *Diastoma melanioides;* s. *Diastoma adelaidense;* t. *Hipponix (Sabia) conicus;* u. *Hipponix (Antisabia) erma* v. *Sydaphera undulata;* w. *Austroharpa kendricki;* x. *Cominella eburnea;* y. *Amalda (Gracilispira) monilifera;* z. *Cymatiella verrucosa;* a'. *Siphonaria (Hubendickula) baconi.*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DIASTOMATIDAE

Diastoma adelaidense Ludbrook Fig. 57s

Elongate, turreted, with 14 adult whorls all more or less variced often with three varices per whorl, 15 to 20 oblique axial plicae per whorl surmounted by fine spiral lirae. Height 48, diameter 14 mm.

Has a range of Miocene to Early Pleistocene.

Diastoma melanioides (Reeve) p. 76 Fig. 57r

A living species found in the Point Ellen Formation and the Roe Calcarenite of the Eucla Basin.

CERITHIIDAE

Diala lauta A. Adams p. 78 Figs 21k,l; 68j;78k; Pl.11e

A ubiquitous small species found throughout the Quaternary.

Campanile symbolicum Iredale p. 79 Fig. 58a

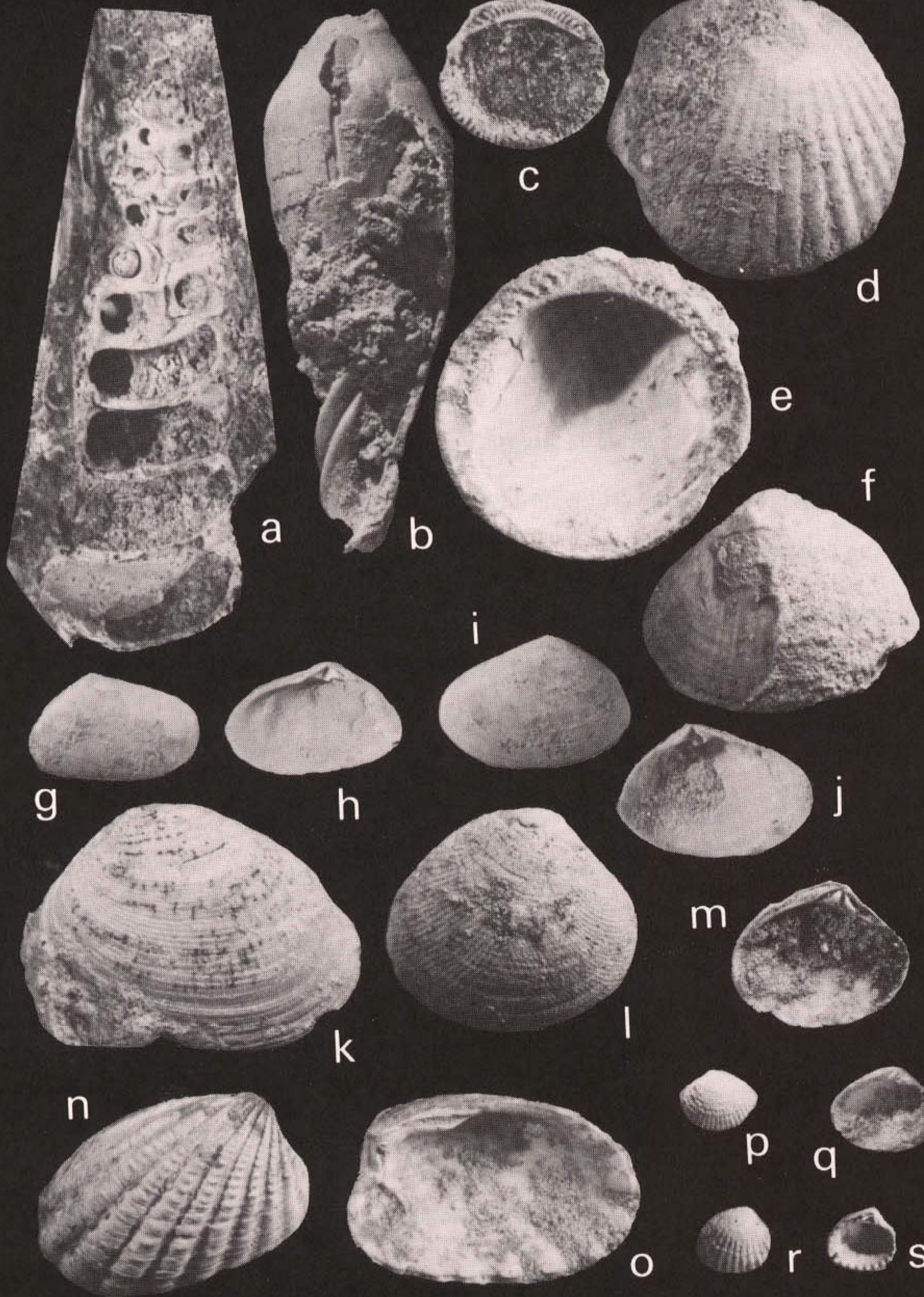
A living species common in the Roe Calcarenite and rare in the Point Ellen Formation.

JANTHINIDAE

Hartungia dennanti chavani Ludbrook Figs 57o,p

Large, thin, turbinate-ovate, nonumbilicate, adult whorls 2¾ inflated, with from 10 to 12 flattish rounded ribs on the last whorl, aperture nearly vertical, basal lip with a conspicuous sinus near the junction with the outer lip. Height 44, diameter 38 mm. A full description and commentary on this important pelagic species is contained in Ludbrook (1978). Its pelagic habit makes it potentially very valuable for purposes of stratigraphic correlation. It is common in the Roe Calcarenite and in the Point Ellen Formation at Point Ellen and less common at Cape Jervis.

Fig. 58 *Point Ellen Formation—Early Pleistocene. All x1 a. Campanile symbolicum;* b. *Amoria grayi;* c. *Glycymeris (Veletuceta) pseudaustralis;* d,e. *Glycymeris (Tucetona) convexa;* f. *Glycymeris (Tucetilla) radians;* g,h. *Amesodesma angusta;* LV i,j. *Amesodesma cuneata* LV; k. *Katelysia scalarina;* l,m. *Gafrarium perornatum;* n,o. *Cardita subdeceptiva;* p,q. *Timoclea (Veremolpa) kendricki;* r,s. *Pleuromeris subpecten.*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HIPPONICIDAE

Hipponix (Sabia) conicus (Schumacher)

p. 82 Figs 20o,p; 57t; 64l; Pl. 5h

This species has a range from the Late Pliocene to the present but is rare in the Point Ellen Formation.

Hipponix (Antisabia) erma (Cotton) Fig. 57u

This is a living species which needs more material for further study as it may be synonymous with *H. (A.) foliaceus*. It is poorly represented in the Pleistocene.

NATICIDAE

Polinices (Conuber) conicus (Lamarck) p. 88 Figs 24a, 64n; Pls, 8j, 10c

The species is common from the Late Pliocene to the present.

CYMATIIDAE

Cymatiella verrucosa (Reeve) p. 93 Figs 24h,l; 57z

Known from a single specimen from Point Ellen, then found from the Late Pleistocene to the present.

BUCCINIDAE

Cominella eburnea (Reeve) p. 104 Figs 20x,y 57x

Occurs throughout the Quaternary to the present day.

NASSARIIDAE

Niotha pyrrhus Menke p. 106 Figs 27l,m; 65f,g; Pl.11h

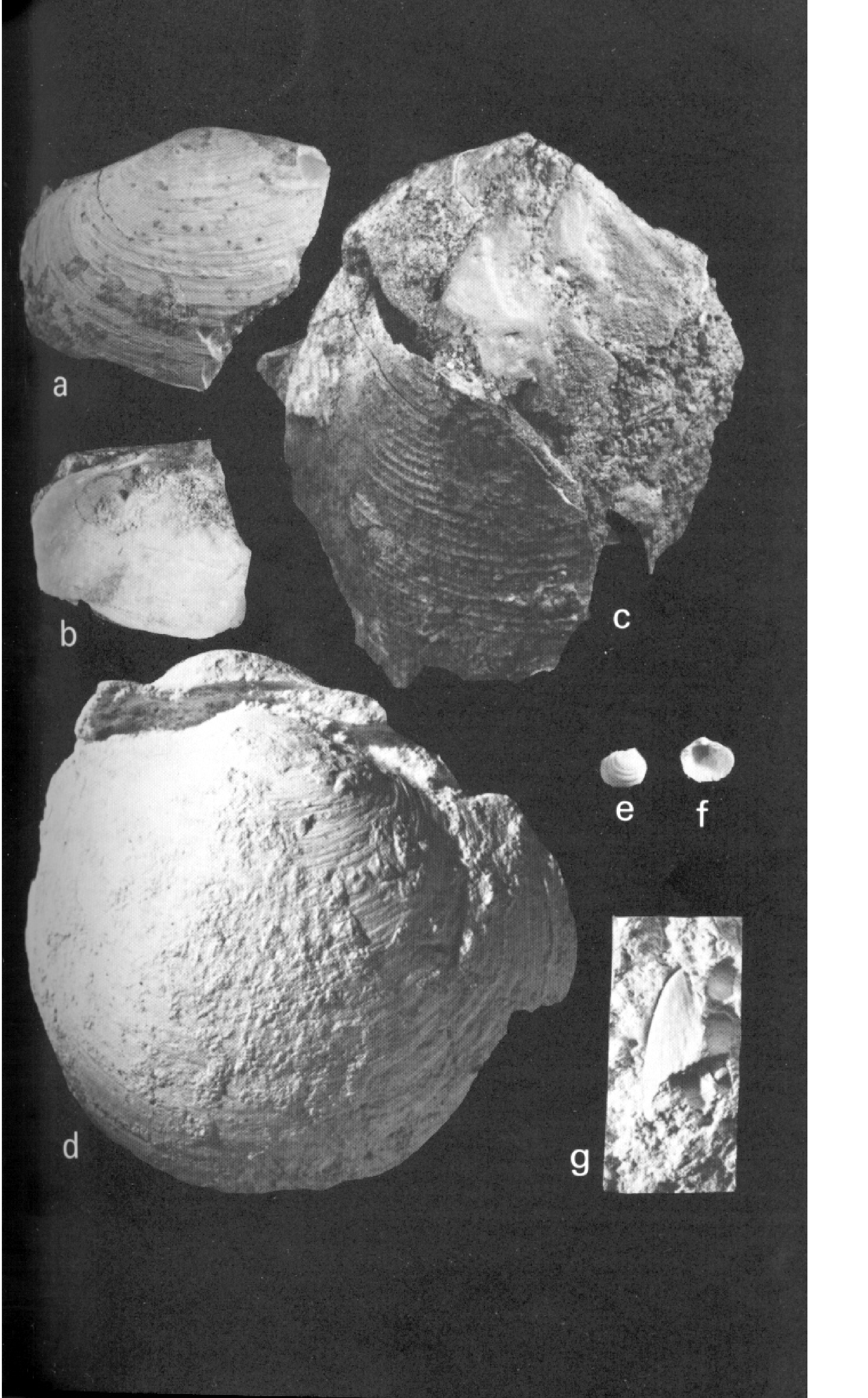
This living species also occurs throughout the Quaternary.

FASCIOLARIIDAE

Microcolus dunkeri (Jonas) p. 110 Figs 66f,g

Has a continuous record from Early Pleistocene to the present; rare in the Burnham Limestone.

Fig. 59 *Point Ellen Formation—Early Pleistocene All x1. a,b. Tellina* sp.; c. *Miltha hamptonensis;* d. *Anodontia sphericula;* e,f. *Linga (Bellucina) praetermissa;* g. *Brachidontes suberosus.*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c
d
e
f
g

OLIVIDAE

Amalda (Gracilispira) monilifera (Reeve) Fig. 57y

A living species common in the Roe Calcarenite and Point Ellen Formation.

HARPIDAE

Austroharpa kendricki Ludbrook Fig. 57w

Unequally biconical with a gradate spire less than one-third total height of shell; sculpture of low spiral sulci, 12 on the last whorl, overriding 20 high axial lamellae per whorl, aperture elongate, fairly narrow. Height 42, diameter 27 mm.

A cast from the Burnham Limestone may belong to this species.

VOLUTIDAE

Amoria (Amoria) grayi Ludbrook p. 114 Fig. 58b

This is a species living in Western Australia from Geographe Bay to Cambridge Gulf. Its occurrence in the Late Pliocene Dry Creek Sands and the Roe Calcarenite and Point Ellen Formation needs to be confirmed from additional better preserved material as the fossils may not be identical with the living species. This is, however, variable in shape.

CANCELLARIIDAE

Sydaphera undulata (Sowerby) p. 115 Figs 28f, 57v

A living species rare in the Point Ellen Formation and the Roe Calcarenite.

SIPHONARIIDAE

Siphonaria (Hubendickula) baconi Reeve p. 126 Figs 30j,k;57á;67k,l

SCAPHOPODA

DENTALIIDA

Dentalium latesculcatum Tate

Large, thick and solid with seven to 16 strong primary ribs equal to the interspaces in which secondary ribs are often developed by intercalation.

More material is needed to confirm the presence of this Pliocene species in the Point Ellen Formation. A fragment was found at Cape Jervis.

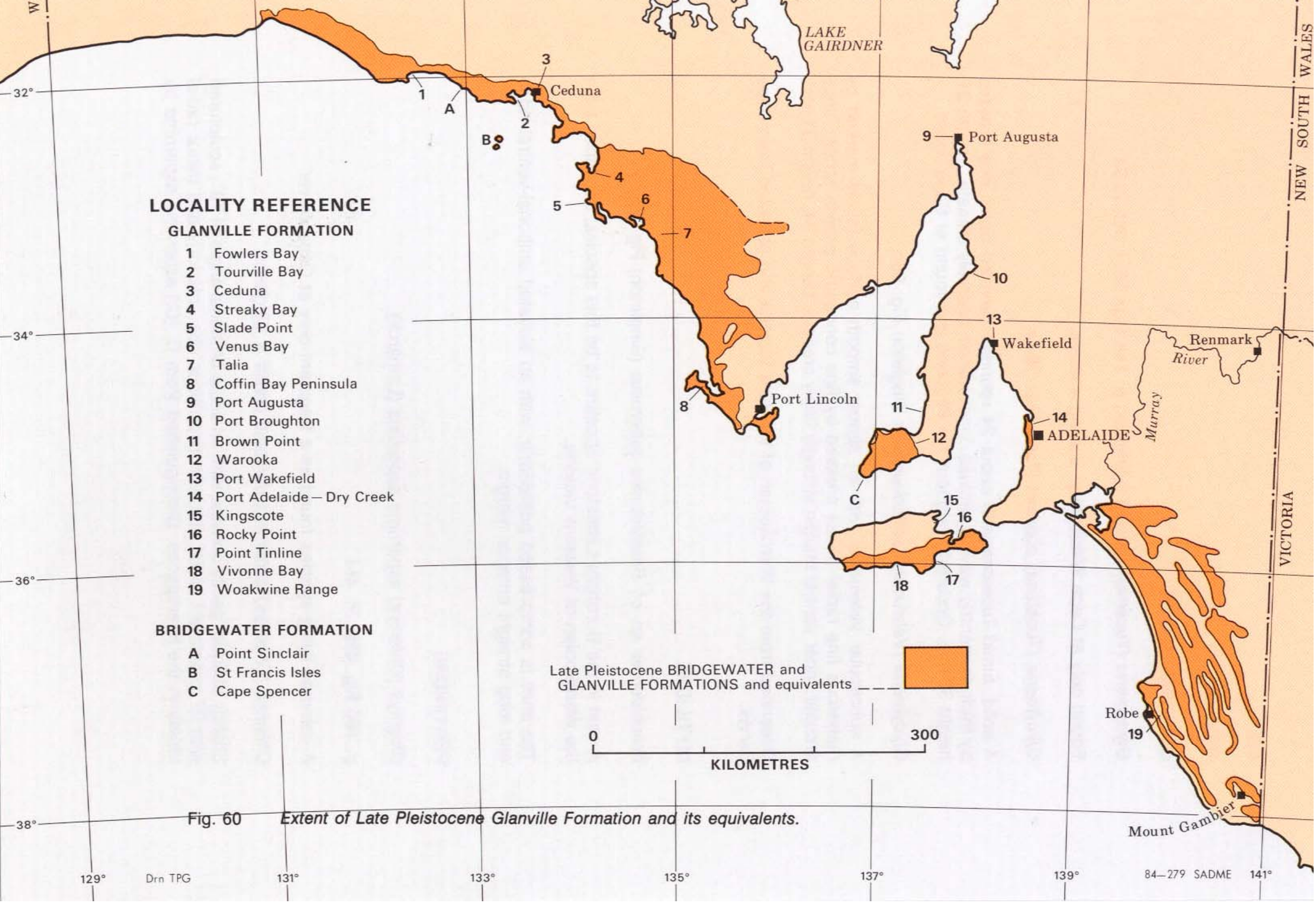


Fig. 60 *Extent of Late Pleistocene Glanville Formation and its equivalents.*

BIVALVIA

GLYCYMERIDIDAE

Glycymeris (Tucetilla) radians (Lamarck) p. 146 Figs 35i,j; 58f; Pl.8a

Found only at Cape Willoughby; a living species.

Glycymeris (Tucetona) convexa (Tate) Figs 58d,e

A solid, tumid *Tucetona* with about 24 rounded elevated radial ribs crossed by thick concentric waving laminae, inner margin coarsely crenate. Length 31, height 33 mm. Occurs throughout the Pliocene and found at Cape Jervis.

Glycymeris (Veletuceta) pseudaustralis Singleton Fig. 58c

A subcircular *Veletuceta* with an almost smooth surface faintly marked by numerous fine radial riblets crossed by fine concentric growth striae; hinge arcuate, inner ventral margin strongly finely crenate. Length 34, height 31 mm.

Described from the Werrikooian of Western Victoria and collected from Cape Jervis.

MYTILIDAE

Brachidontes sp. cf. Brachidontes suberosus (Singleton) Fig. 59g

A cast in the Burnham Limestone appears to be this species, described from the Werrikooian of Western Victoria.

The shell is compressed posteriorly, with an elevated umbonal-ventral ridge and long straight anterior margin.

PECTINIDAE

Chlamys (Chlamys) asperrima asperrima (Lamarck)

p. 160 Fig. 41a; Pl. 4f-i

A common living species found as a fragment only at Cape Jervis.

Chlamys (Chlamys) asperrima dennanti Gatliff & Singleton

Slightly oblique, gently convex, with an acute umbonal angle of 79°, sculptured with 27 prominent radial ribs with two minor ribs anteriorly and minor radial riblets in the interspaces. Distinguished from C. (*C.*) *asperrima asperrima* by

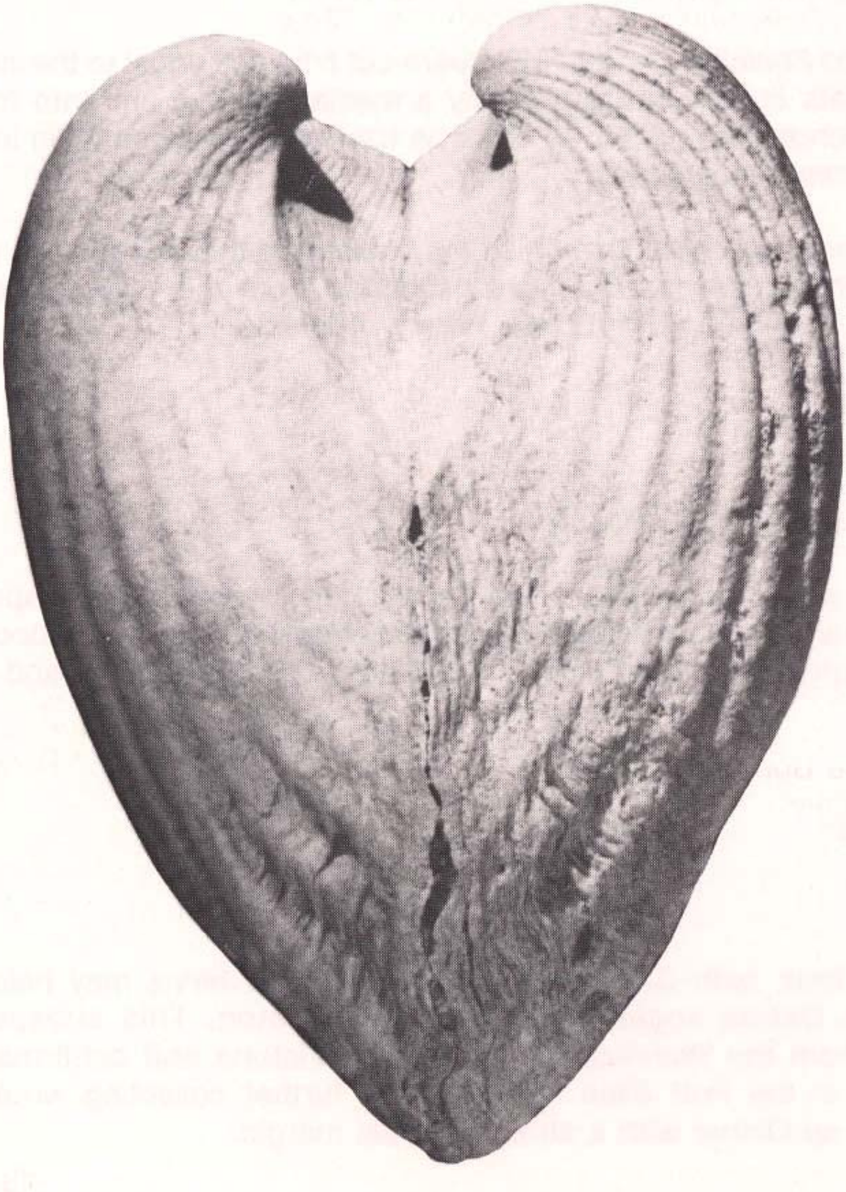


Fig. 61 *Anadara trapezia*—both valves

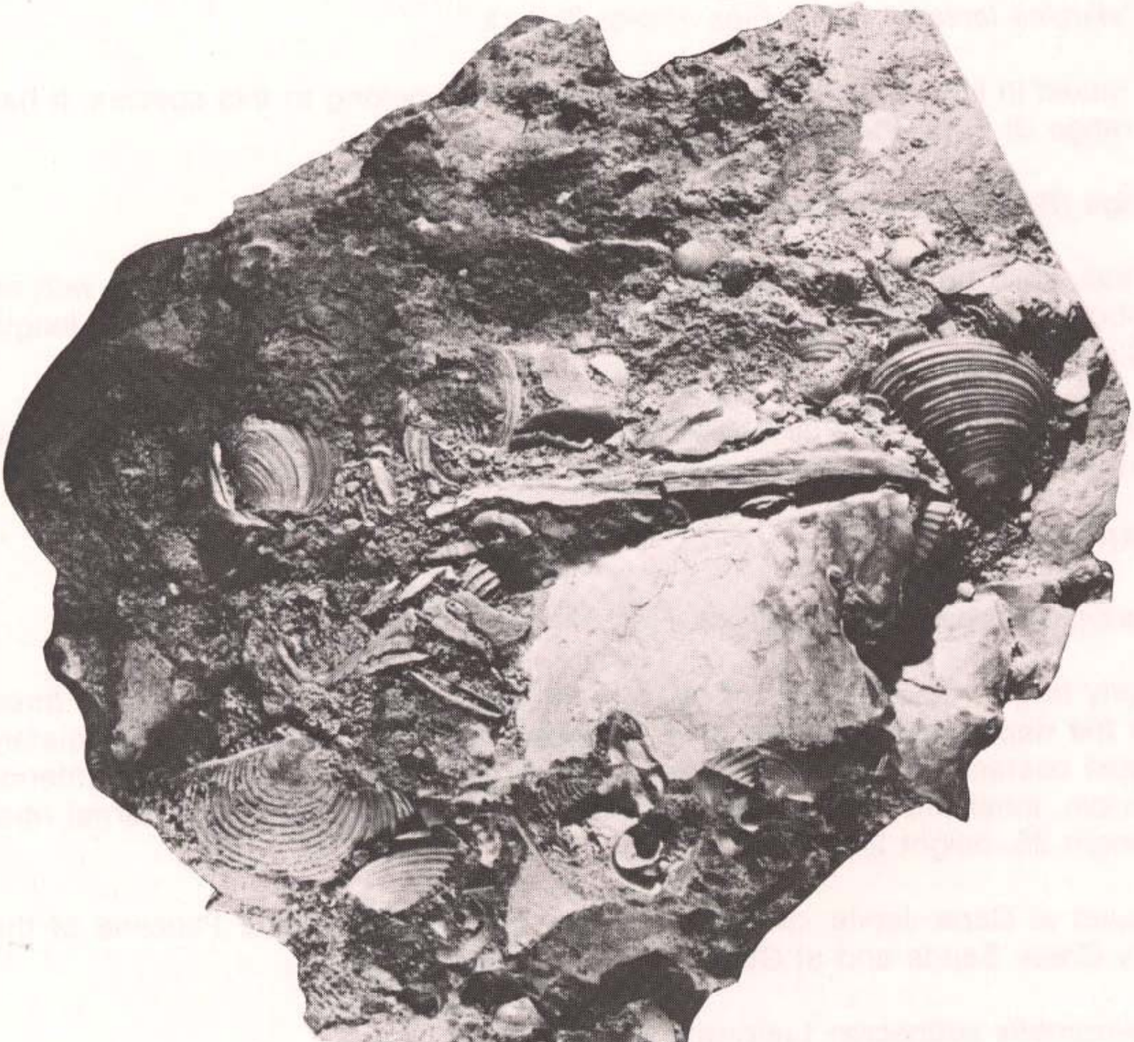


Fig. 62 *Pinctada carchariarum* in matrix from Ceduna, 'subfossil, Murat Bay' of Verco, 1910.

the relative narrowness of the shell and narrower and relatively more prominent radial ribs. Length 53, height 58 mm.

The subspecies is doubtfully identified from fragments. It was described from the Werrikooian of Western Victoria and further collecting would help to confirm its identity in the Point Ellen Formation.

Chlamys (Equichlamys) bifrons subbifrons (Tate)

A rather small *Equichlamys* with 12 square-cut bifid ribs equal to the interspaces, cut into riblets in the early stages by a median groove and into four or five riblets by dichotomous grooves towards the ventral margin; main interspaces and rib grooves shagreened.

A poorly preserved specimen which may belong to this subspecies was found in the Burnham Limestone. It was described from the Late Pliocene of the former quarry behind Government House, Adelaide.

LIMIDAE

Limatula ludbrookae Buonaiuto

An internal mould in the Burnham Limestone is probably this species. It is elongate-oval, inflated, narrow, with two subequal auricles and about 29 radial costae. Its previous record is from the Hallett Cove Sandstone and Dry Creek Sands.

OSTREIDAE

Ostrea sp.

Fragments from both Cape Willoughby and Cape Jervis may belong to the subspecies *Ostrea angasi glenelgensis* Singleton. This subspecies was described from the Werrikooian of Western Victoria and confirmation of its occurrence in the Port Ellen Formation by further collecting would be very useful. It is an *Ostrea* with a straight dorsal margin.

LUCINIDAE

Anodontia sphericula Basedow Fig. 59d

A large, globose, thin-shelled *Anodontia* sculptured with irregular growth lines about 1 mm apart, hinge edentulous, anterior adductor well within the pallial line, rectangular, posterior adductor subtriangular.

Miltha hamptonensis Ludbrook Fig. 59c

A large thick *Miltha* with a slightly convex left valve and nearly flat right valve; surface sculptured with prominent concentric lamellae about 2 mm apart. Length 91, height 55 mm.

One of the large bivalves near the base of the formation at Point Ellen and found also at Cape Jervis. It was described from the Roe Calcarenite of the Eucla Basin.

?*Callucina lacteola* (Tate) Figs 71b-e; Pl 9 j,k

A mould in limestone from Point Reynolds may belong to this species. It has a range of Early Pleistocene to Holocene.

Linga (Bellucina) praetermissa Ludbrook Figs 59e,f

Small, solid but only moderately thick, globose, truncated posteriorly with an unbonal-ventral flexure, sculptured with fine concentric lirae. Height 10, length 10 mm.

Described from the Point Ellen Formation and known also from the living fauna where it has been confused with *Linga (Bellucina) crassilirata* (Tate).

CARDITIDAE

Cardita subdeceptiva Ludbrook Figs 58n,o

Fairly large, rectangularly ovate, with 14 flatly nodulose radial costae, three on the depressed posterior area, followed by four larger and approximately equal costae, then seven costae gradually descending towards the anterior margin, inner margin coarsely crenulate in conformity with the external ribs. Length 35, height 24 mm.

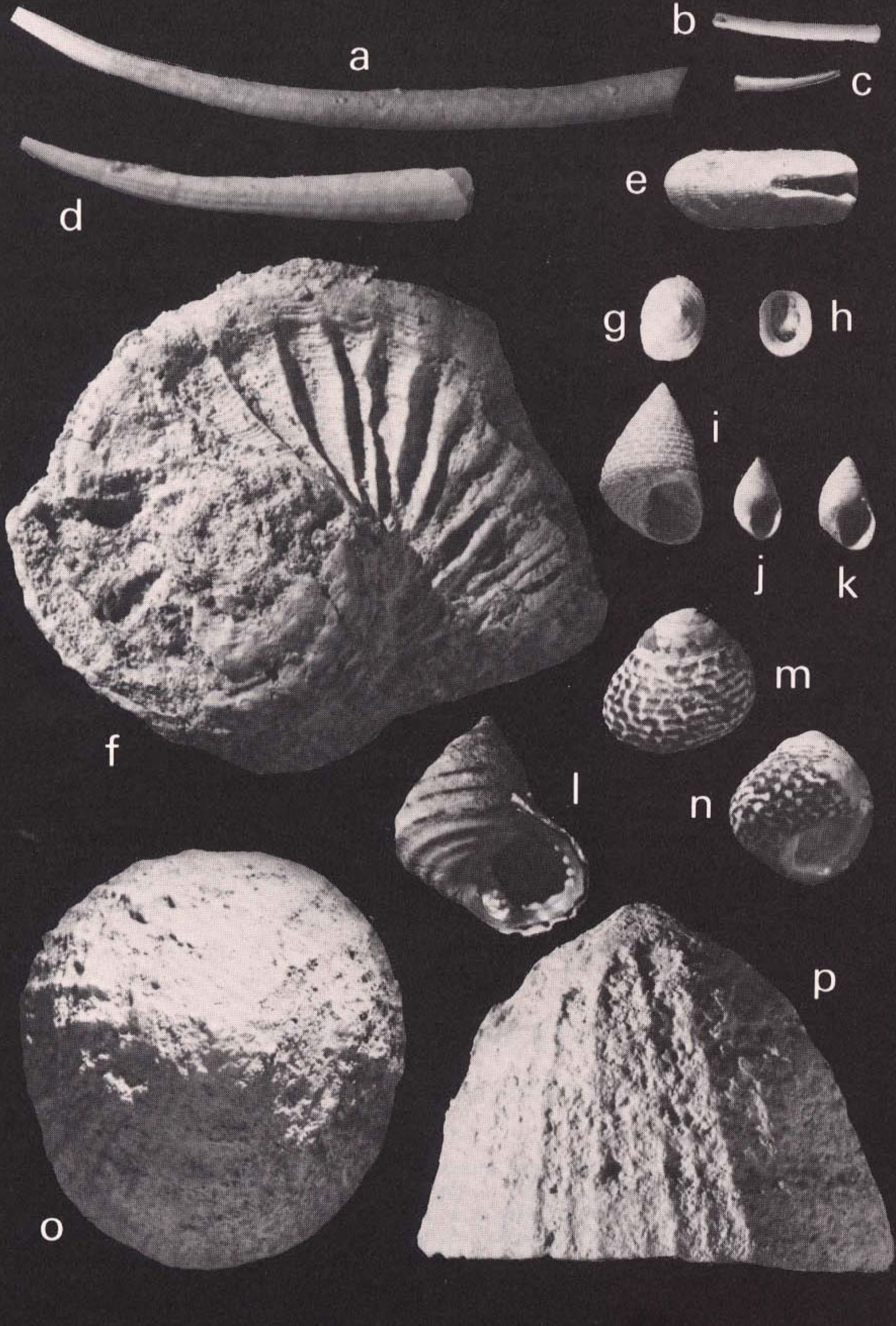
Found at Cape Jervis, otherwise known only from the Late Pliocene of the Dry Creek Sands and at Gum Creek on Kangaroo Island.

Pleuromeris subpecten Ludbrook Fig. 58r,s

Small, triangularly ovate, somewhat depressed, with 17 radial costae equal to the interspaces, bearing numerous elongated oval granules. Length 5.3, height 4.8 mm.

Described from the Dry Creek Sands, otherwise known from two specimens weathered out at Cape Jervis.

Fig. 63 Glanville Formation—Late Pleistocene. All x1 unless otherwise stated. a. *Antalis hyperhemileuron* (Verco); b,c. *Antalis hemileuron* x.2.3; d. *Dentalium (Paradentalium) flindersi* x4.5; e. *Macroschisma (Dolichoshisma) producta;* f. *Haliotis (Padollus) scalaris;* g,h. *Patelloida nigrosculcata;* i. *Thalotia conica;* j,k. *Cantharidus (Phasianotrochus) irisodontes;* l. *Monodonta (Austrocochlea) constricta;* m,n. *Diloma (Fractarmilla) concamerata;* o,p. *Patella (Scutellastra) laticostata.*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MACTRIDAE

Mactra sp. cf *Mactra pura* Deshayes p. 177 Figs 45a,b; 73c,d

An internal cast of a *Mactra* similar in shape to this species was collected at Cape Willoughby. Confirmation of its occurrence would be useful.

MESODESMATIDAE

Amesodesma angusta (Reeve)

p. 180 Figs 46d,e; 58g,h; 74i,k; Pl.9c,d;g,h

Common living on Kangaroo Island where it has a continuous record from Early Pleistocene to the present.

Amesodesma cuneata (Lamarck) p. 180 Figs 46f-h; 58i-j; 74l; 80g,i,; Pl. 9a,b,e,f

Has a similar record to that of the previous species.

Anapella variabilis (Tate)

A rather small inflated subtrigonal *Anapella* with a narrow hinge. It was described from the Hallett Cove Sandstone of Blanche Point, Aldinga Bay, but is quite common in the Burnham Limestone and could, in fact, have come from the formation.

TELLINIDAE

Tellina sp Fig. 59a,b

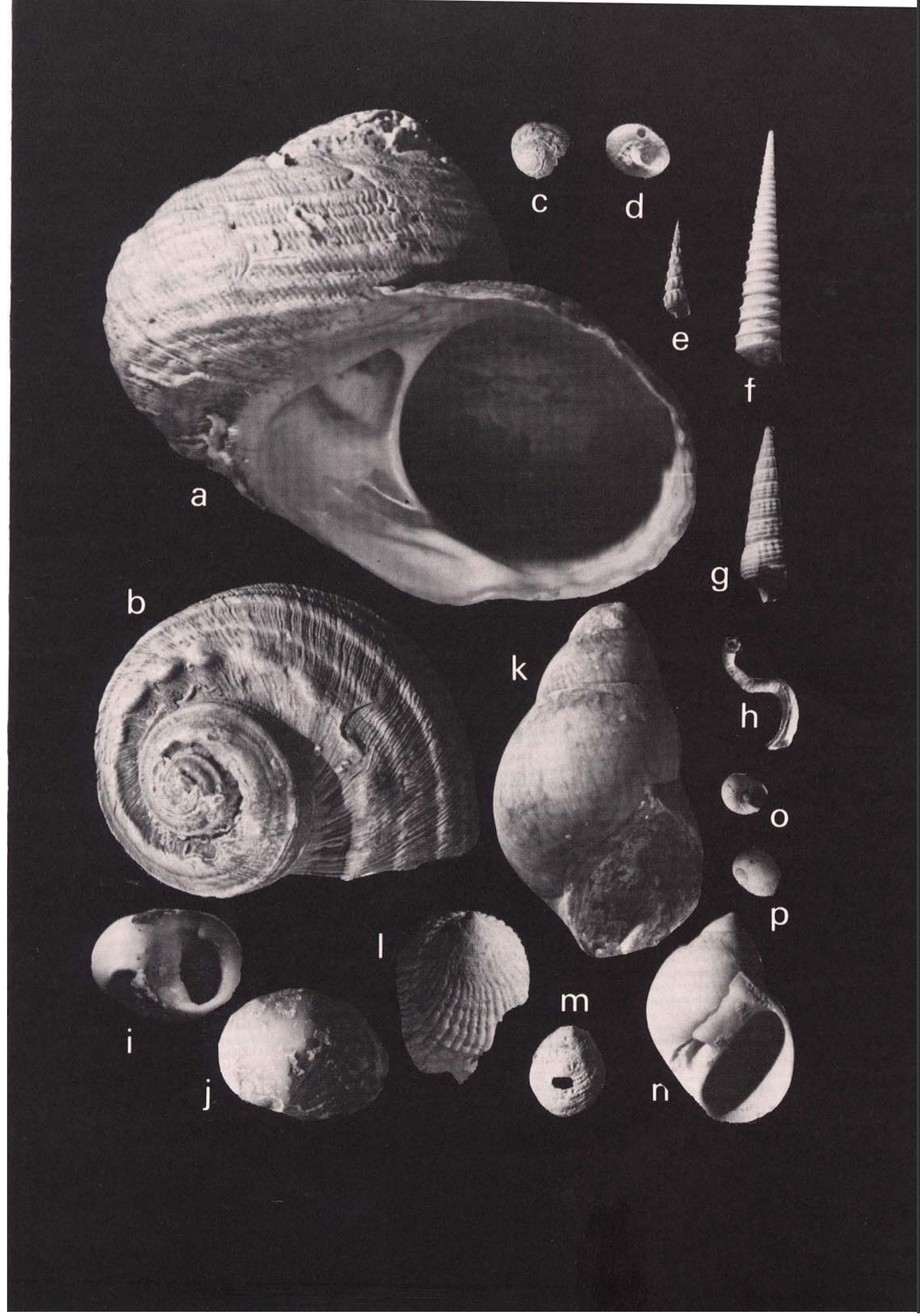
This is one of the original species collected at Point Ellen in 1914. Its identity is not yet established and further material is sought.

VENERIDAE

Katelysia scalarina (Lamarck) p. 193 Figs 49j,k;58k;75d-f

A living species occurring throughout the Pleistocene.

Fig. 64 Glanville Formation—Late Pleistocene. All x1 a,b. *Turbo (Ninella) torquatus;* c,d. *Astraea (Micrastraea) rutidoloma;* e. *Batillaria (Batillariella) estuarina;* f. *Gazameda iredalei;* g. *Batillaria (Zeacumantus) diemenensis;* h. *Tenagodus weldii;* i,j. *Nerita (Melanerita) atramentosa;* k. *Phasianella australis;* l. *Hipponix (Sabia) conicus;* m. *Hipponix (Sabia) erma;* n. *Polinices (Conuber) conicus;* o,p. *Notocochlis gualteriana.*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Timoclea (Veremolpa) kendricki Ludbrook Figs. 58p,q

Solid, thick, ovately triangular, inequilateral with posterior side produced, hinge short and broad with three divergent cardinals in each valve, surface sculptured with about nine fine concentric riblets on the umbo and 20 ribs on the main body of the shell crossed and gemmulated by about 28 radial ribs with equal interspaces. Length 18, height 15 mm.

Described from the Roe Calcarenite and found at Point Ellen and Cape Willoughby.

Gafrarium perornatum Woods Figs. 581,m

Of medium size, subovate, sculptured with fine curving divaricate lirae. Length 30,height 16 mm.

Described from the Dry Creek Sands.

Middle Pleistocene

No marine molluscs of Middle Pleistocene age are known. The environment was terrestrial and there was mild tectonic warping leading to the elevation and erosion of Pliocene and Early Pleistocene strata.

Late Pleistocene: Glanville Formation

The historical record of the Glanville Formation

For over one hundred years shelly beds containing abundant molluscs have been described by a succession of authors. The beds contain *Anadara trapezia*, the Sydney blood cockle, *Pinctada carchariarum* the Shark Bay pearl oyster, as well as a foraminifer *Marginopora vertebralis*. These are inhabitants of warmer seas and are not now living in South Australia. Because it was realised that most of the species were to be found in the present fauna, the beds have been referred to by conchologists as 'Recent raised beaches', 'Sub-Recent', 'Mid-Recent' or 'Subfossil', although Tate as early as 1879 correctly interpreted them as of Pleistocene age.

As an aid to interpreting past literature on the Anadara-bearing beds and the nomenclature used for the molluscs regarded as significant, the following historical record is included. It is intended for use by the student or specialist and not necessarily for the general reader:

1879. As evidence of uplift of the land, Tate referred to raised beaches of Pleistocene age along the South Australian coast including the Lower South-East, Port Adelaide, Port Wakefield and Fowlers Bay.

PLATE 14 Glanville Formation in bulldozer scrape with abundant *Katelysia scalarina,* 9 km E of Point Sinclair. NUYTS 1:250 000 sheet Photo R.B. Flint 015-057. (Trans. 24547)

PLATE 15 Glanville Formation, capped by calcrete, 3 km N of Point Sinclair. NUYTS 1:250 000 sheet. Photo R.B. Flint 015-025. (Trans. 24548)

1882. Tate briefly described the salient features of the geology of Port Wakefield and its environs and its relationship to a borehole sequence described by Rutt in the same year. Tate made the first reference to the 'old beach, excavated for ballast, highly charged with *Anadara trapezia*', which he compared with 'Recent raised beaches' he had described in 1879. The conglomerate used for ballast consists largely of pebbles and cobbles of calcrete with large shells of *Anadara* which have apparently been derived from the original deposit.

1888. Howchin described a section excavated at Glanville for a new graving dock in which an older sea bed with *Anadara trapezia ('Arca trapezia')* and *Marginopora vertebralis ('Orbitolites complanata')* and a younger sea bed were exposed.

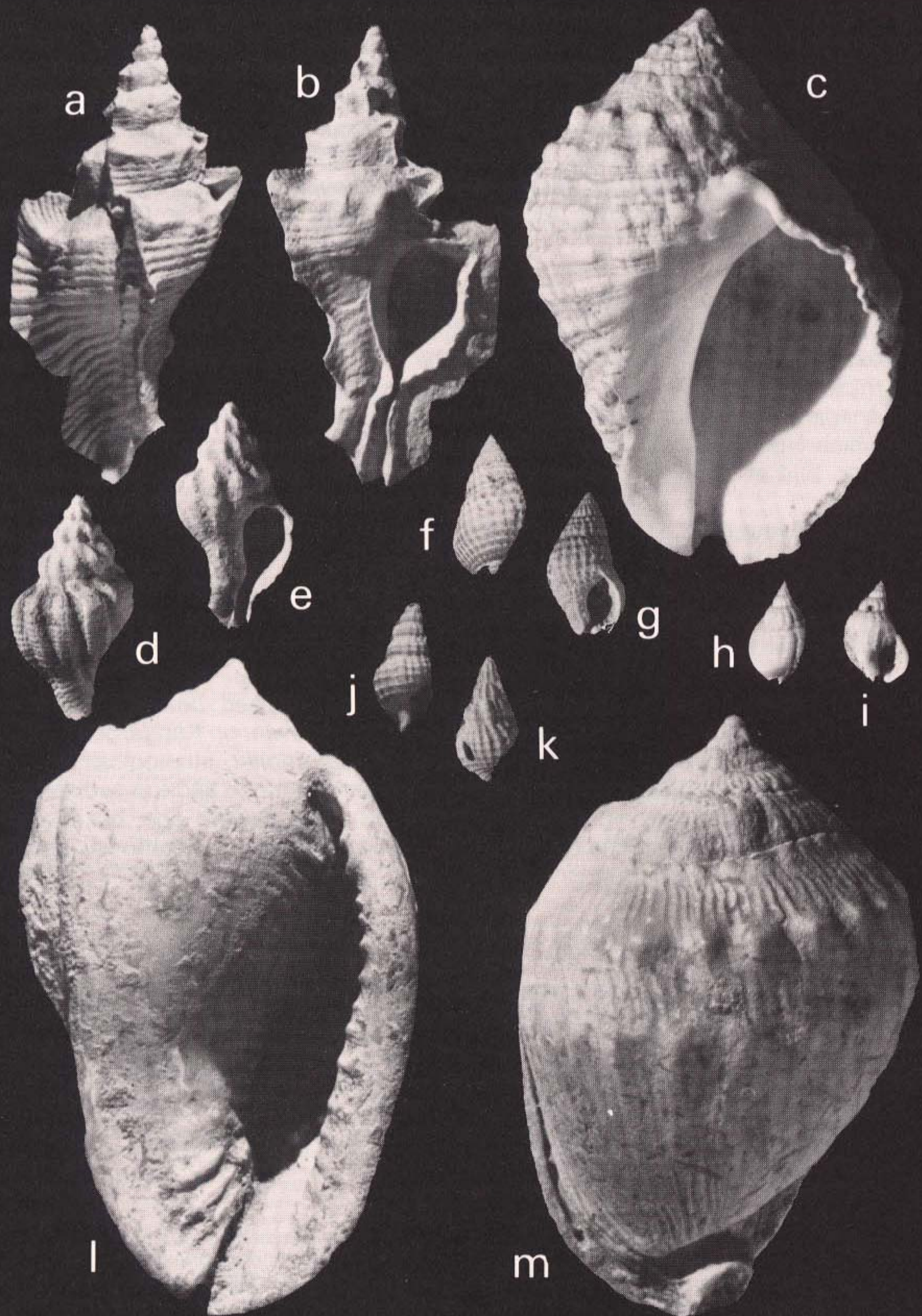
1890. Tate briefly described Pleistocene deposits of southern Yorke Peninsula with fossils belonging to existing species. Without mentioning any specific localities, he remarked that 'the whole of southern Yorke Peninsula is constituted of these Pleistocene deposits, except such limited areas as are occupied by Eocene limestones and Archaean rocks'.

1898. Tate described the section through Tintinara and Port Pirie Bores. Under 7 m of surface calcrete Tintinara Bore passed through 67 m of 'Newer Pleistocene' marine sediments with abundant shells between 8 and 46 m below the surface. He listed 30 species of molluscs from these sediments. Port Pirie Bore passed through 110 m of Newer Pleistocene. No list of the marine shells encountered at 41 m was given.

1902. Greenway and Phillips recorded raised beaches east of Warooka containing abundant *Marginopora vertebralis ('Orbitolites complanata')* with *Anadara trapezia ('Arca trapezia')* and *Pinctada carchariarum ('Meleogrina margaretina'* (Figs 70g-i) which evidently belonged to an older series than the raised beaches along the coast from Point Turton around to Sturt Bay. They drew the conclusion that the raised beaches belong to two geological horizons similar to those described by Howchin from Port Adelaide. The specimen figured (Figs 70g,i) was originally collected by Greenway and Phillips.

1909. Howchin noted that the raised sea beaches of southern Yorke Peninsula and other places contain many forms which are now extinct in our local waters, such as *Anadara trapezia ('Barbatia (Arca) trapezia'), Pinctada carchariarum ('Meleagrina margaritifera')* and immense numbers of the large foraminifer *Marginopora vertebralis ('Orbitolites complanata')*. He considered that in Pleistocene times the entrances to the Gulfs were more restricted, acting as a bar to cold currents and causing the mean temperature of the water in the Gulfs to rise.

Fig. 65 Glanville Formation—Late Pleistocene. All x1 a,b. *Pterynotus triformis;* c. *Thais orbita;* d,e. *Bedeva paivae;* f,g. *Niotha pyrrhus;* h,i. *Niotha pauperata;* j,k. *Cymatiella gaimardi;* l,m. *Cassis (Hypocassis) fimbriata.*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1910. Verco, under *Pyrene versicolor* which was included in the synonymy of *Euplica bidentata ('Columbella bidentata')* made the statement that 'At Murat Bay in a subfossil form in a kind of conglomerate on the beach, they are found in great numbers with *Pinctada carchariarum ('Meleagrina fimbriata')* and *Anadara trapezia ('Barbatia trapezia')* neither of which is found in our waters alive, and in the same condition they occur along the South Australian coastline to the east. Verco was thus responsible for introducing the term 'subfossil' for Pleistocene molluscs of the Glanville Formation. The deposit to which he was referring at Murat Bay is that exposed at Ceduna and illustrated in Fig. 62.

1912. Howchin compared a section exposed in the sinking of a drainage tank at the Metropolitan Abattoirs with that at Glanville and noted the marked difference in faunal composition of the two shell beds, the older 0.60 m thick at a depth of 5.33 m from the surface, containing *Ostrea angasi* and *Anadara ('Arca') trapezia* but no *Marginopora vertebralis* the absence of which Howchin attributed to the shallower water and muddier environment than that at Glanville.

1918. Without citing any age, Howchin stated that a raised beach can be recognised at intervals along the southern coasts of Australia from Western Australia to Victoria and Tasmania. He cited a number of outcrops, most of which are of Late Pleistocene age, but some, such as Cape Jervis, are Early Pleistocene.

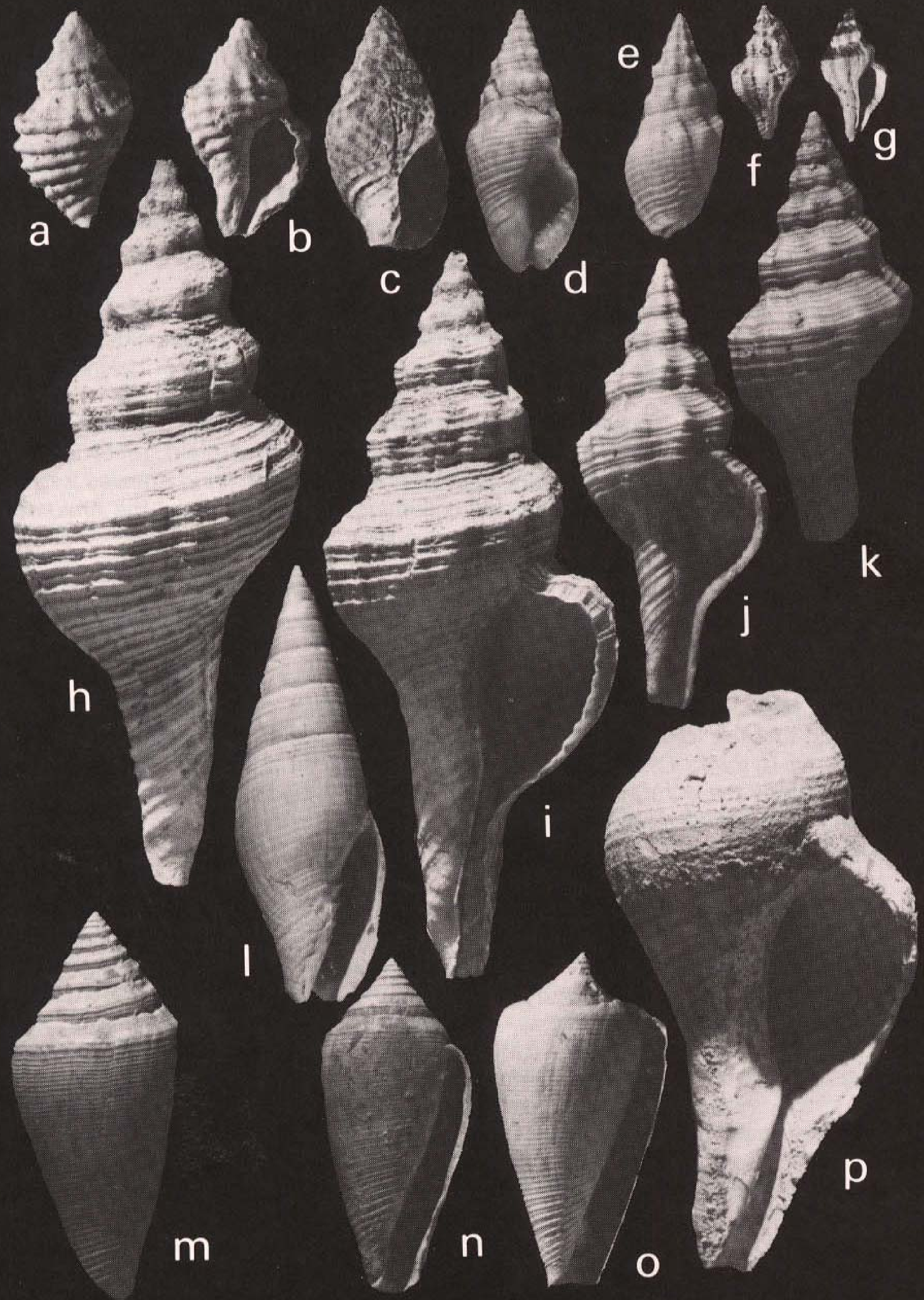
1924. Howchin described the older of the two raised beaches he had recognised at Glanville and occurring at Port Moorowie, on Kangaroo Island, on the West Coast and south of Ardrossan as varying lithologically from calcareous sand to limestone. He regarded both of these and the sediments laid down during the younger transgression as of Recent age, but distinguished material from the older (*'Anadara'*) transgression as subfossil, using the term first introduced by Verco.

1929. Howchin, as for 1918.

1932. Cotton & Godfrey under *Pyrene bidentata* quoted without acknowledgement the record by Verco (1910) of *P. versicolor* from Murat Bay.

1933. Tindale summarised the distribution of the *Anadara* beds (*'Arca* zone') on a 6.1 m terrace which he compared with the Pamlico (Mid-Wisconsin) terrace of the United States and the 20-foot London terrace.

Fig. 66 Glanville Formation—Late Pleistocene. All x1 a,b. *Lepsiella flindersi;* c. *Cominella lineolata;* d,e. *Cominella eburnea;* f,g. *Microcolus dunkeri;* h,i. *Fusinus australis;* j,k. *Fusinus undulatus;* l. *Mitra (Eumitra) glabra;* m,n. *Conus (Floraconus) compressus* o. *Conus (Floraconus) anemone;* p. *Pleuroploca australasia.*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1935. Howchin published notes on the sections and faunas in several bores west of Adelaide including the Glanville (Government) Bore. He assumed that, from its proximity to Fletcher's Dock, the first 17 m passed through the section in Fletcher's Dock, although the amount of material he had was very limited.

1946. Crocker recorded an outcrop at Brown Point on Yorke Peninsula with *Euplica ('Columbella') bidentata* and *Marginopora vertebralis*. This has now been identified as a thin bed within the Bridgewater Formation at the jetty at Brown Point.

1946. Crocker reported a raised shell bed containing water-worn pebbles and molluscs including *Anadara trapezia* near South Hummocks at 5 to 6 m above sea level. The bed is capped with 'some inches' of calcrete.

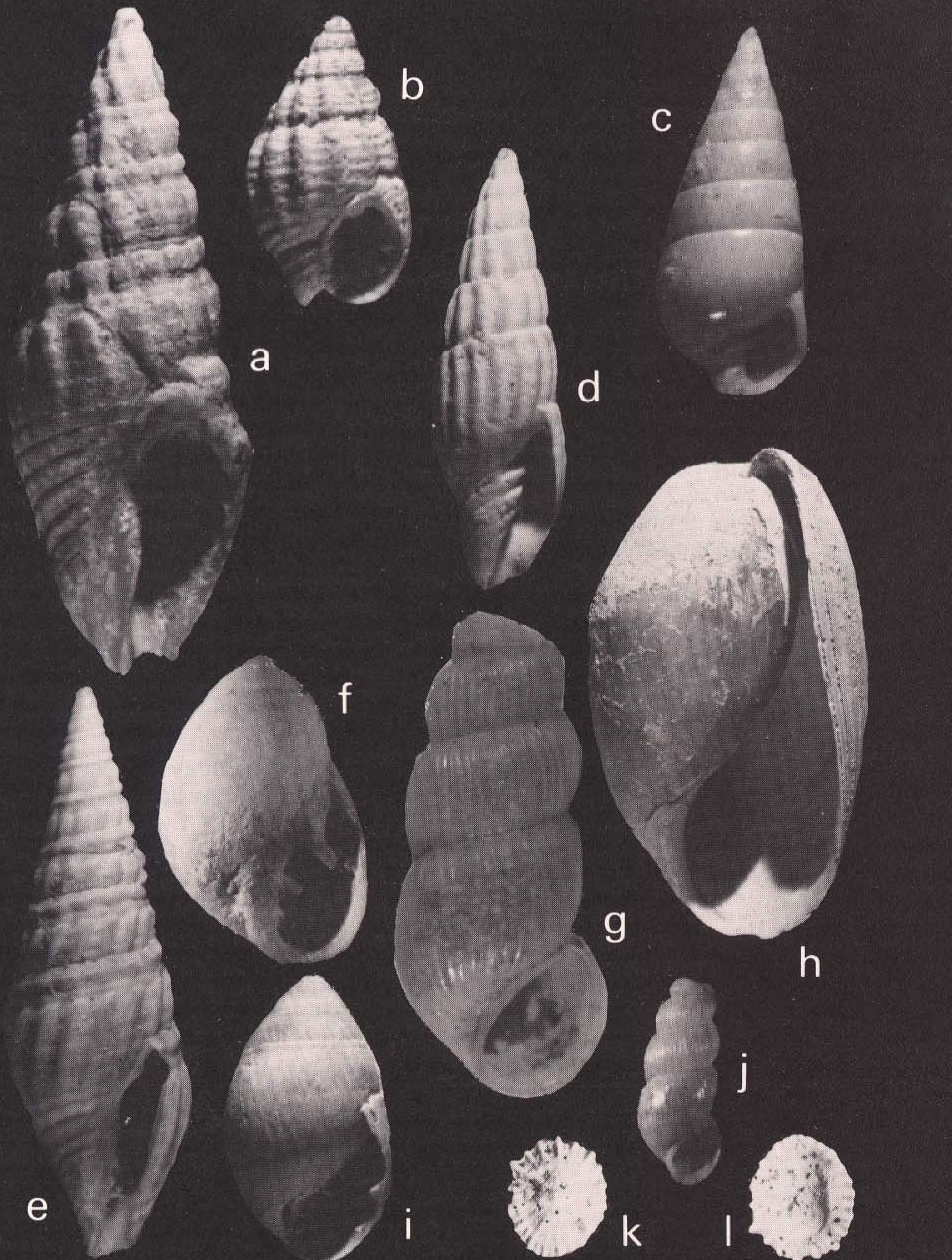
1946. Crocker & Cotton, citing the localities at Murat Bay, Port Augusta, Yorke Peninsula, Fowlers Bay, Dry Creek and Port Wakefield, recorded as subfossil *Anadara trapezia* associated with several gastropod species which have not been confirmed by recent collecting. They discussed the *Anadara* beaches and suggestions of climatic changes.

1952. Sprigg published his 'Geology of the South-East Province . . . 'and referred to the inundation of the present Woakwine Range during the *Anadara* high sea level.

1952. Miles, in discussing the subsurface geology of the Adelaide Plains, stated that the 'older Recent' marine sediments are probably nowhere more than 1.5 m thick. They carry a fossil fauna characteristic of subtropical seas, particularly the common pelecypod *Anadara*. The bed is capped by calcrete, marking a period of widespread recession and emergence under arid climatic conditions.

1954. Aitchison, Sprigg & Cochrane gave a stratigraphic succession in the Adelaide region. They included in the Recent sequence marine sands and clays of the Osborne high sea level, maximum thickness 3 m, and marine sands and clays of *Anadara* high sea level, maximum thickness 4.57 m. The *Anadara* high sea level was considered the maximum encroachment corresponding to the climatic optimum in the mid-Recent warm stage. This was the Great Australian Arid Period of Crocker, when the deserts of Australia were at their peak development. Desert sand dunes and clay pans were present on the Adelaide Plains at least as far south as Roseworthy. A pronounced marine regression followed the *Anadara* high sea level, permitting extensive development of calcrete on the exposed shell bed seaward far beyond the present coastline.

Fig. 67 Glanville Formation—Late Pleistocene a. *Josepha tasmanica* x4.5; b. *Hinia (Reticunassa) paupera* x5; c. *Cossmannica* sp. x6; d. *Austromitra lincolnensis* x4.3; e. *Splendrillia harpularia* x4.5; f. *Marinula xanthostoma* x5.7; g. *Acme scalarina* x10; h. *Bulla botanica* x1; i. *Laemodonta ciliata* x6; j. *Acme vincentiana* x5; k,l. *Siphonaria (Hubendickula) baconi* x1.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1957. Cotton discussed the species *Anadara trapezia* —'the dominant bivalve of our Mid-Recent stranded beaches'.

1961. Cotton published a revised (second) edition of Cotton & Godfrey (1938).

1965. Firman repeated the suggestion of Aitchison, Sprigg & Cochrane that a strong regression of the sea occurred after the deposition of the *Anadara*-bearing limestone of which one of the features was the development of a lime-cemented crust on the shelly limestone.

1966. Ward suggested that the *Anadara* beds at Dry Creek were of late Pleistocene age.

1966. Firman named the Glanville Formation as the ' "Pleistocene (marine) . . . older raised sea-bed with many shells locally extinct" of Howchin 1935. The name is derived from the suburb of Glanville where the original section described by Howchin (1888) is located'.

It is Bed No. 5 of Howchin (1935) but Bed No. 7 of Howchin (1888). It is the type subsurface section.

1969. Firman considered that the *Anadara*-bearing shell beds in the South-East were probably laid down at the same time as the dunes of the upper member of the Bridgewater Formation, both of which he placed in the Middle Pleistocene. He gave a date of 'more than 45 000 years' for *Anadara* beds at Port Wakefield and Port Adelaide.

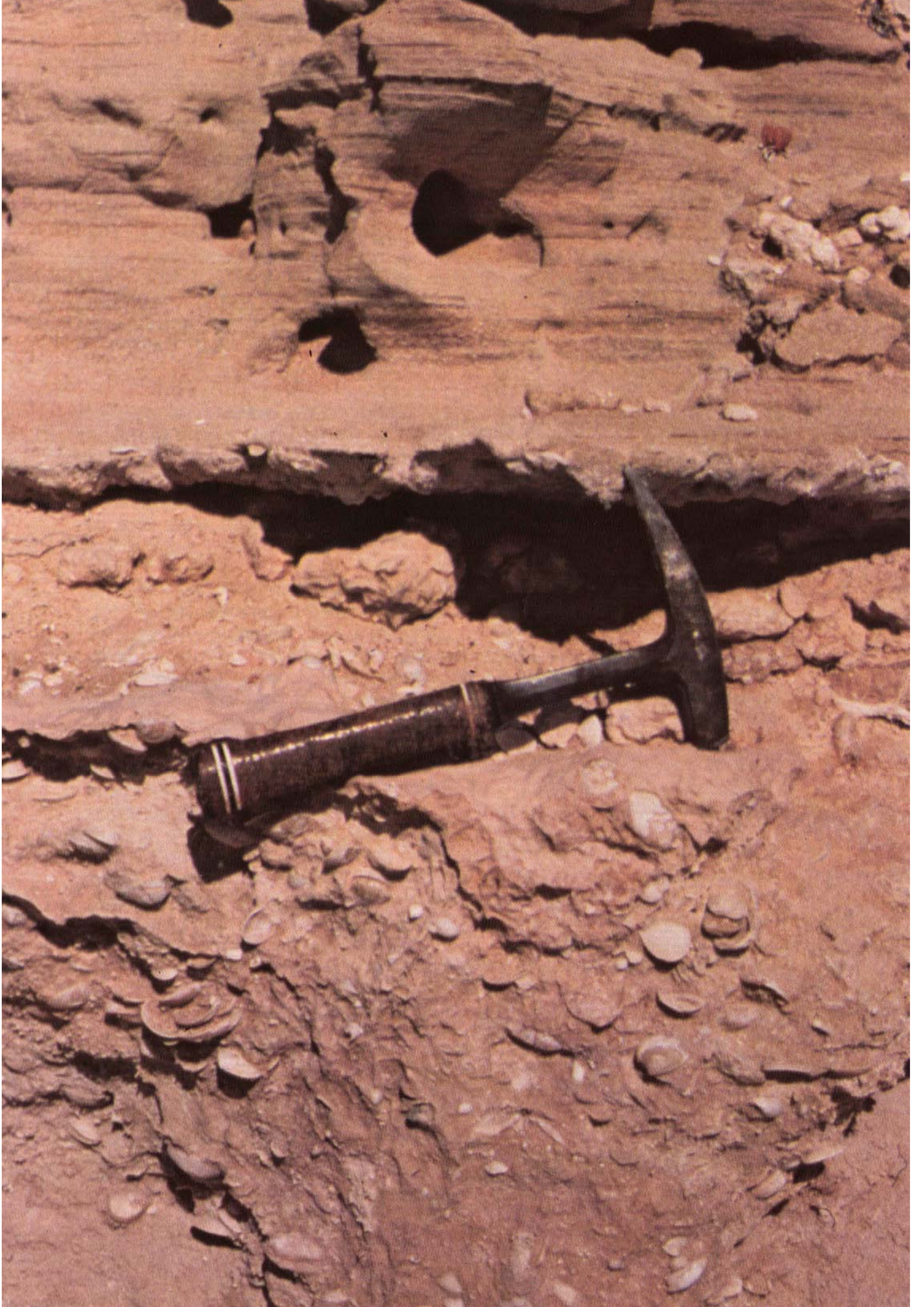
1976. Ludbrook published a photograph of and commentary on Fletcher's Dock during excavation as it was seen by Howchin before being flooded.

1978. Cann designated a reference section of the Glanville Formation in a trench at the ICI works at Dry Creek which is exposed during the summer months.

1978. Ludbrook included the Glanville Formation in a correlation table and quoted an age derived from the La Jolla Radiocarbon Laboratory as 'tens of thousands rather than hundreds of thousands of years old'.

1983. Belperio et al. cite a late Pleistocene age of about $110\,000 {}^{+\,19\,000}_{-\,7\,000}$ years obtained from amino acid racemization of fossil *Anadara trapezia* from the Mambray Formation of Spencer Gulf which correlates with the Glanville Formation and the uppermost component of the Woakwine Range sequence. Thermoluminescence measurements at the same level as one of the *Anadara* shells yielded age estimates of 96 000 $\pm$ 24 000 and 90 000 $\pm$ 15 000 years.

PLATE 16 Glanville Formation, overlain by calcarenites of the Bridgewater Formation. NUYTS 1:250 000 sheet. Photo R.B. Flint 015-024. (Trans. 24549)



The extent of the Late Pleistocene Glanville Formation and its equivalents (Fig. 60)

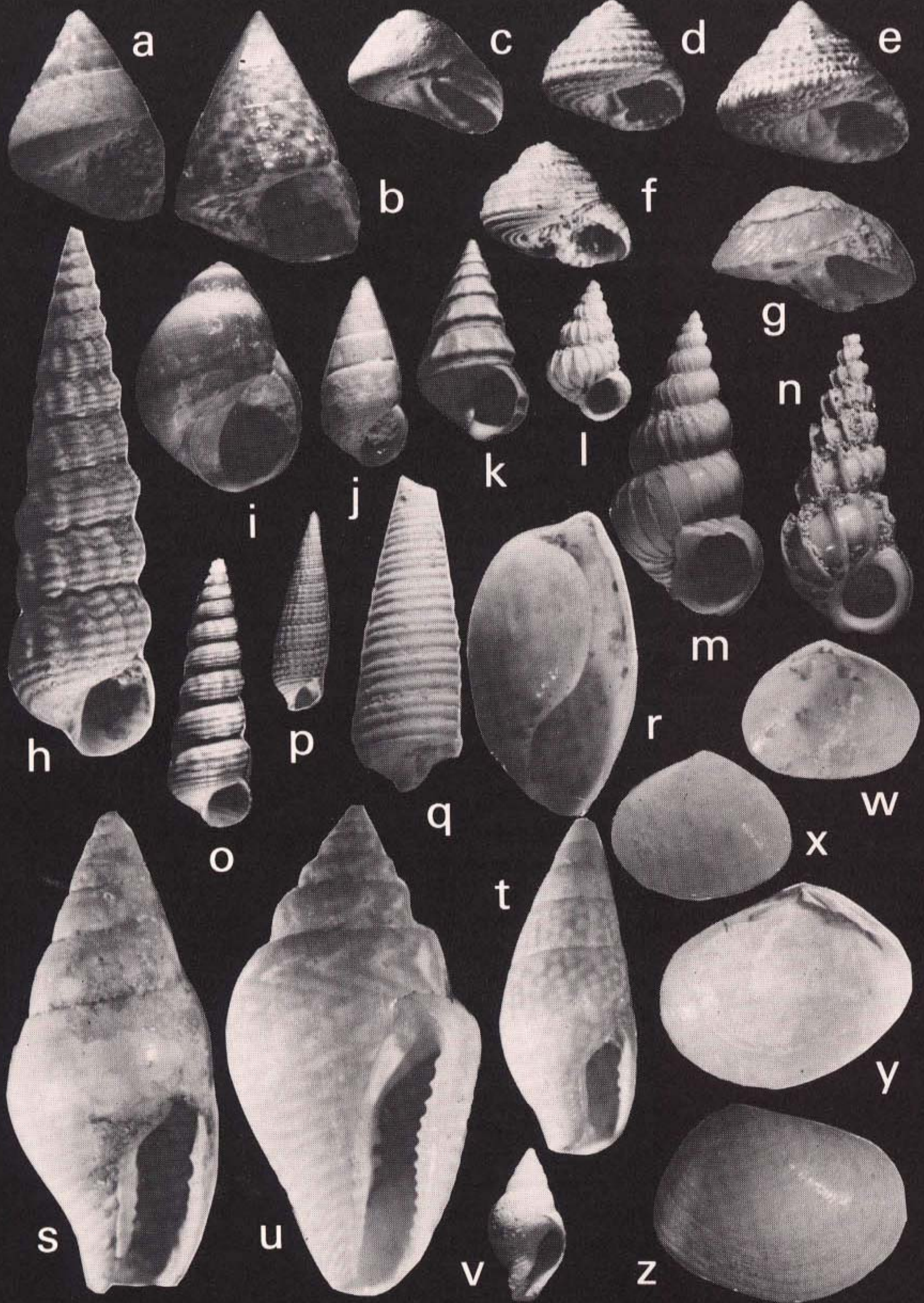
Most of the Late Pleistocene marine deposits and their constituent molluscs of southern Australia were deposited in low-lying areas adjacent to the present coastline during high sea level periods. The richest faunas are to be found in the indented area of shallow bays between Fowlers Bay and Elliston, on the NUYTS, STREAKY BAY and ELLISTON 1:250 000 geological map sheets, and on southern Yorke Peninsula in the wide corridor between Hardwicke Bay and Sturt Bay, particularly near Warooka on the MAITLAND 1:250 000 sheet.

When the Glanville Formation was deposited the water was warmer and species now living at lower latitudes formed part of the fauna. It includes, some abundantly, *Anadara trapezia, Pinctada carchariarum, Mactra eximia, Euplica bidentata*, together with the foraminifer *Marginopora vertebralis*. It was not until the Holocene that these disappeared from the South Australian fauna. On land the epoch was one of erosion and terrestrial deposition.

The shelly deposits are usually covered by calcrete and are exposed mainly in roadside scrapes after the calcrete has been removed (Pl.17). For this reason, it is difficult to present a map showing the precise extent of the transgression during the high sea level. Figure 60 illustrates the principal localities from which collections have been made, extending from Fowlers Bay east to Beachport and on the eastern part of Kangaroo Island from Kingscote around to Vivonne Bay.

The assemblage usually contains one at least of the diagnostic species mentioned above, together with species which live gregariously in the littoral or intertidal zone of sheltered sandy beaches. The most common of these are species of *Katelysia—K. peronii, K. rhytiphora* and *K. scalarina—Fulvia tenuicostata* (in local concentrations), *Eubittium lawleyanum, Diala lauta, Niotha pyrrhus* and *Cominella eburnea*. Apart from species which have been introduced after death, rock-dwelling species are present only where the environment was that of a rocky coast, such as that at Brown Point. This is in marked contrast to the Early Pleistocene fauna of the Point Ellen Formation.

Fig. 68 Glanville Formation—Late Pleistocene a. *Calliostoma (Fautor) legrandi* x3; b. *Calliostoma (Fautor) rubiginosum* x1.25; c. *Diloma (Fractarmilla) rudis* x1.25; d. *Clanculus (Isoclanculus) dunkeri* x1.75; e. *Clanculus (Isoclanculus) philippi* x2.25; f. *Clanculus (Mesoclanculus) plebeius;* x2; g. *Astraea (Bellastraea) squamifera* x2.1; h. *Batillaria (Batillariella) estuarina* x4; i. *Littorina (Austrolittorina) unifasciata* x2.1; j. *Diala lauta* x3; k. *Hypotrochus monachus* x5; l. *Epitonium (Pomiscala) perplicata* x1.75; m. *Epitonium (Limiscala) helicornuum* x2.25; n. *Acutiscala minora* x2.5; o. *Eubittium lawleyanum* x2; p. *Bittium (Semibittium) granarium* x1; q. *Seila (Notoseila) crocea* x10; r. *Haminoea (Liloa) brevis* x3.5; s. *Mitrella (Dentimitrella) semiconvexa;* x4; t. *Mitrella (Dentimitrella) lincolnensis* x2.25; u. *Euplica bidentata* x4; w,x. *Melliteryx acupunctum* x10 LV; y,z. *Abra (Syndosmysa) exigua* RV x2.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Owing to the selective nature of most of the collecting, any attempt to indicate the relative abundance of each species must be inaccurate. In recording foraminifera from a sequence of samples from a single boring, the following order of abundance is used:

v = very rare (1-2 specimens)

r = rare (3-5 specimens)

f = frequent (6-10 specimens)

c = common (11-25 specimens)

a = abundant (25+specimens)

For both the Glanville and St Kilda molluscs a roughly similar system has been used as an indication only, taking into account also the number of localities from which the species was collected. An abundant and ubiquitous species occurs in considerable numbers at most localities. 'Common' indicates that both the number of individuals and the number of localities is less abundant—say, 20 or so at several localities—'uncommon' species occur in small numbers at few localities; while 'not common' species are perhaps a little more frequent than 'uncommon'. 'Rare' species are represented by one or two specimens only. The record is intentionally imprecise because the method of collecting was so. It is in no way a kind of population study, but it is useful to know how many specimens one has for examination, and which species are dominant.

Species so far collected from the Glanville Formation are:

GASTROPODA

HALIOTIDAE

Haliotis (Padollus) scalaris Leach p. 43 Figs 12e,63f

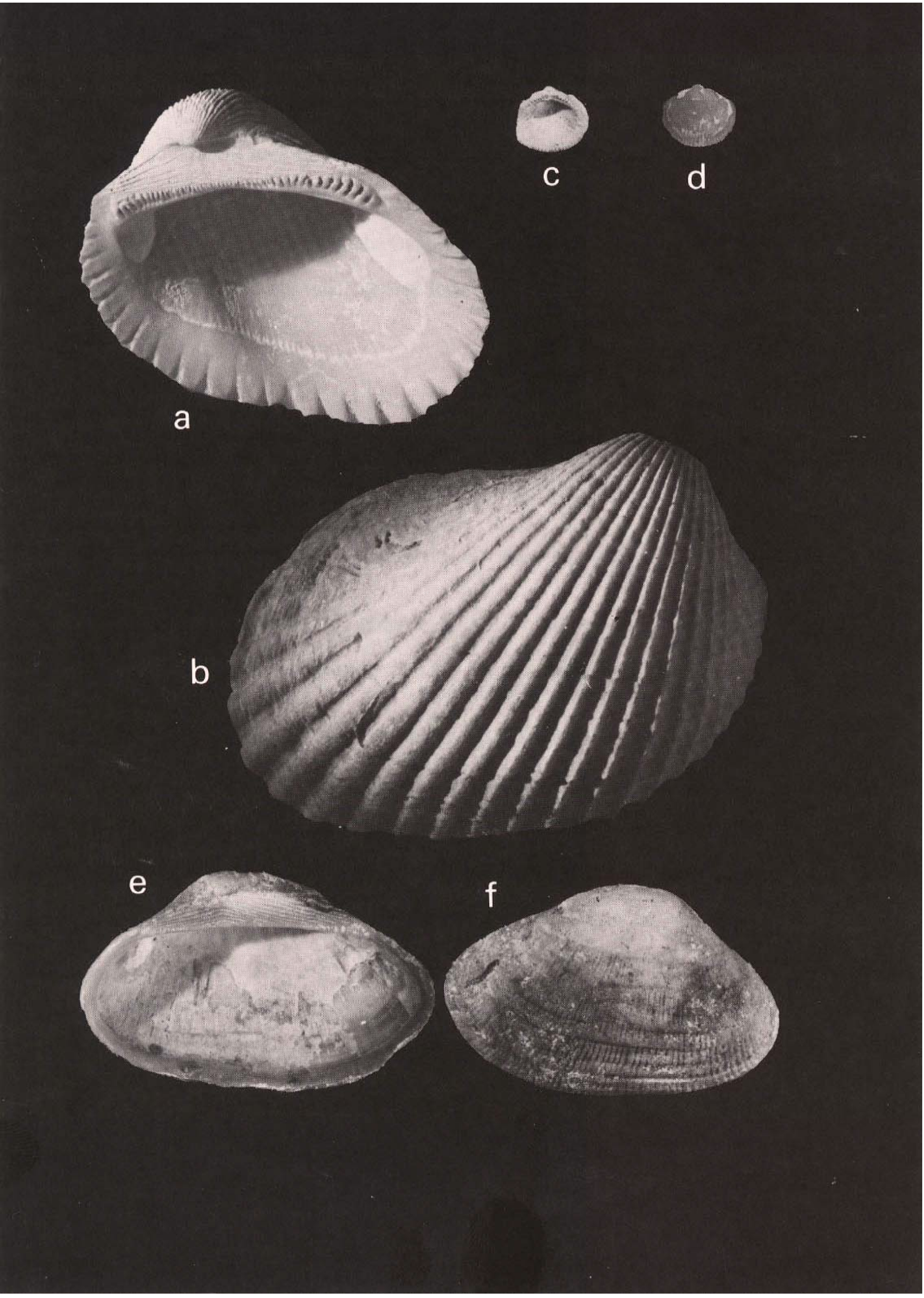
A single specimen from Rocky Point, K.I.

FISSURELLIDAE

Notomella candida (A. Adams)

A single specimen from Brown Point, Y.P.

Fig. 69 Glanville Formation—Late Pleistocene All x1 a,b. *Anadara trapezia;* c,d. *Glycymeris (Tucetilla) mayi;* e,f. *Barbatia pistachia.*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PATELLIDAE

Patella (Scutellastra) laticostata Blainville p. 48 Figs 15a,f,j

Rare; single specimens from Tourville Bay, Kingscote and Rocky Point.

ACMAEIDAE

Patelloida nigrosulcata (Reeve) p. 48 Figs 15d,e;63g,h

Not common; collected from near Point Sinclair, Tourville Bay and from Rocky Point K.I.

TROCHIDAE

Thalotia conica (Gray) p. 57 Figs 16s, 63i; Pl.10f

Not common; collected only from Tourville Bay and Rocky Point.

Cantharidus (Phasianotrochus) irisodontes (Quoy & Gaimard) p. 56 Figs 16o, p;63j,k Pl.10,e

Fairly widely distributed: near Point Sinclair, Tourville Bay, Warooka and Brownlow Beach K.I.

Monodonta (Austrocochlea) constricta Lamarck p. 53 Figs 16c,d;63l; Pl. 1f

Found at several localities on the west coast between Ceduna and Elliston, at Point Brown Y.P. and Rocky Point K.I.

Calliostoma (Fautor) legrandi (Tenison Woods) Fig. 68a

Not uncommon in the basalt conglomerate at Brownlow Beach.

Calliostoma (Fautor) rubiginosum (Valenciennes) Fig. 68b

Not common, found only at Outer Harbor Channel and near Point Sinclair.

Diloma (Chlorodiloma) adelaidae (Philippi) p. 56 Figs 16g-i; Pl.1i

Rare; two specimens collected at Rocky Point K.I.

Diloma (Fractarmilla) concamerata (Wood) p. 56 Figs 16e,f; 57d,e;63m,n

Recovered only from Tourville Bay, Point Brown and Rocky Point.

Diloma (Fractarmilla) rudis (Gray) p. 56 Figs 57f;68c

Rare; collected only at Rocky Point.

PLATE 17 Roadside scrape in Glanville Formation, Vivonne Bay road, K.I. KINGSCOTE 1:250 000 sheet. (Trans. 24550)

PLATE 18 *Bothriembryon barretti* within calcarenite of the Bridgewater Formation west of Point Sinclair. NUYTS 1:250 000 sheet. Photo R.B. Flint 015-030. (Trans. 24551)

Clanculus (Isoclanculus) dunkeri (Koch) p. 60 Figs 17h-j;68d

Almost ubiquitous in the Glanville Formation.

Clanculus (Isoclanculus) philippi (Koch) p. 60 Figs 17k-m;68e

Collected only at Warooka.

Clanculus (Mesoclanculus) plebeius Philippi p. 58 Figs 17n-p;68f

Common at Boree Swamp N of Fowlers Bay.

TURBINIDAE

Turbo (Ninella) torquatus Gmelin p. 61 Figs 16l,m; 64a,b

Rare; collected from Ceduna, near Point Sinclair and at Brown Point.

Turbo (Subninella) undulatus Solander p. 61 Figs 18c,d; Pl.1g

Also rare; collected only from the basalt conglomerate at Kingscote K.I.

Astraea (Bellastraea) squamifera (Koch) p. 62 Figs 68g; Pl.8k

Rare; a single specimen from N of Point Sinclair.

Astraea (Micrastraea) aurea (Jonas) p. 62

Not common; found at Kingscote and Rocky Point K.I.

Astraea (Micrastraea) rutidoloma (Tate) p. 62 Figs 64c,d

CYCLOSTREMATIDAE

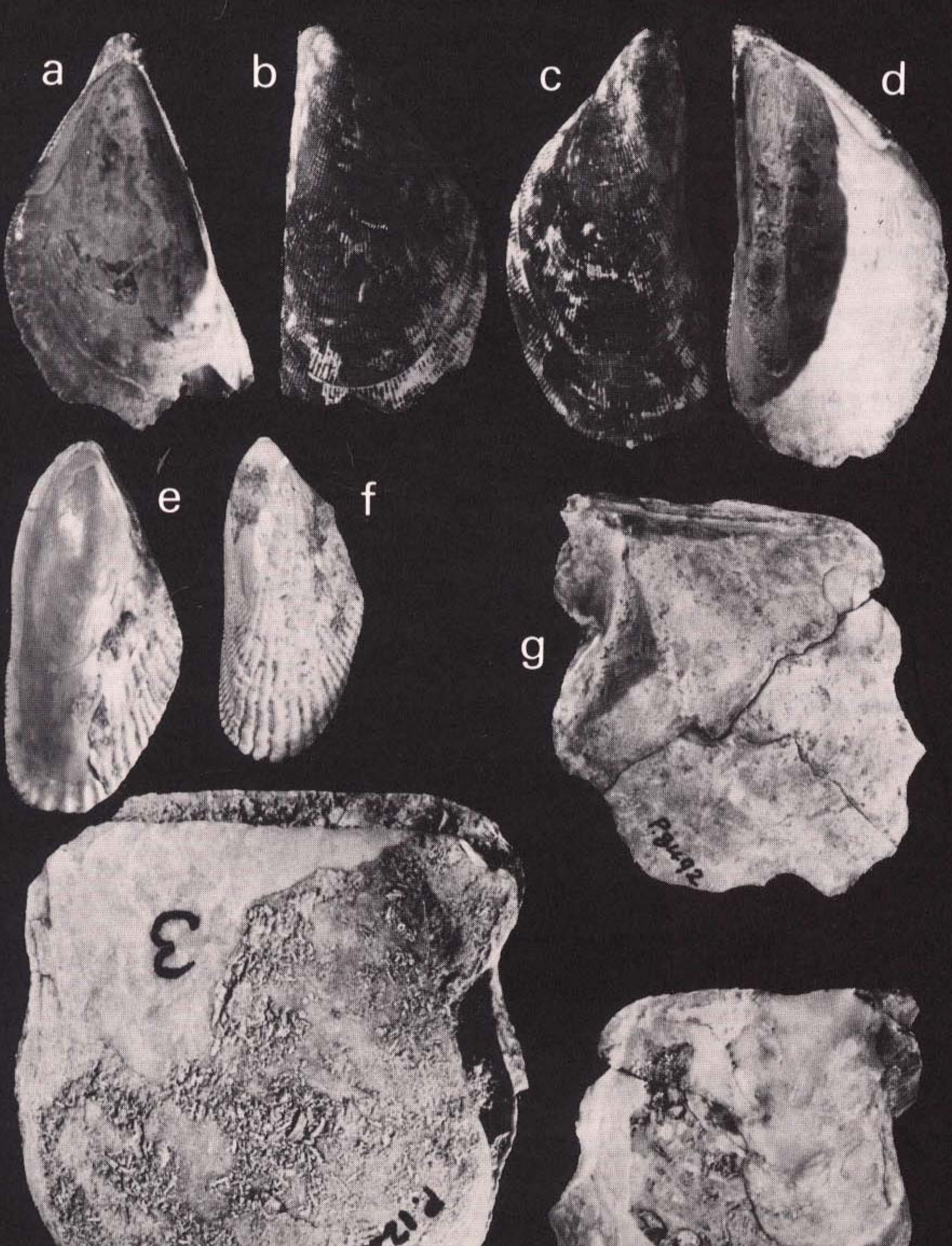
Munditia subquadrata (Tenison Woods) p. 62 Figs 78a,b

Rare, collected only from New Lake K.I.

Elachorbis tatei (Angas) p. 64 Figs 78c-g

Rare in the Glanville Formation, 2 specimens from Tourville Bay where it is living today.

Fig. 70 Glanville Formation—Late Pleistocene All x1 a-d. *Brachidontes (Austromytilus) rostratus* a,b LV, c,d. RV; e,f. *Brachidontes (Brachidontes) erosus* LV; g-i. *Pinctada carchariarum.*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NERITIDAE

Nerita (Melanerita) atramentosa Reeve

p. 65 Figs 18e,f;64i,j; Pl.1o

Common at Tourville Bay and on Kangaroo Island, abundant at Brown Point.

PHASIANELLIDAE

Phasianella australis (Gmelin) p. 64 Figs 20a,57l,64k; Pl.10p

Not common; collected from N of Point Sinclair, Brownlow Beach K.I. and from Outer Harbor Channel.

LITTORINIDAE

Littorina (Austrolittorina) unifasciata Gray p. 68 Figs 20j,k; 68i; Pl.1m

Uncommon; Coffin Bay, Brown Point and Rocky Point.

Bembicium auratum Quoy & Gaimard p. 68 Figs 20c-e

Uncommon, Elliston area.

Bembicium melanostoma (Gmelin) p. 68 Figs 20f-h;57m,n; Pl.10j

Uncommon; found north of Fowlers Bay and in the basalt conglomerate at Kingscote.

Bembicium nanum (Lamarck) p. 68 Figs. 20i; Pl.1l

Not uncommon at Rocky Point K.I.

ACICULIDAE

Acme scalarina Cox p. 70 Figs. 67g

Collected from near Point Sinclair and at Tourville Bay.

Acme vincentiana Cotton p. 70 Fig. 67j

Occurs with *A. scalarina* and is probably a variety of that species.

TURRITELLIDAE

Gazameda iredalei Finlay p. 74 Figs. 21e,64f; Pl.8m

Widespread: Point Sinclair and Tourville Bay, Warooka and Peesey Swamp, Rocky Point and Outer Harbor Channel.

PLATE 19 *Bothriembryon barretti* within calcarenite of the Bridgewater Formation west of Point Sinclair. NUYTS 1:250 000 sheet. Photo R.B. Flint 015-029. (Trans. 24552)

PLATE 20 Cliffs about 100 m high, Bridgewater Formation, west of Lake Hamilton. KIMBA 1:250 000 sheet. Photo R.B. Flint 012-241. (Trans. 24553)

POTAMIDIDAE

Batillaria (Batillariella) estuarina (Tate)

p. 78 Figs 21h,i;64e; Pl.11c

Single specimens from Point Sinclair and W of Calca, not uncommon W of Talia, Eyre Peninsula, and Rocky Point K.I.

Batillaria (Zeacumantus) diemenensis (Quoy & Gaimard)

p. 77 Figs 21f,g;57q,64g,78p; Pl.11b

Ubiquitous and abundant.

Eubittium lawleyanum (Crosse) p. 78 Figs 21j,68o,78m; Pl.11f

Not common; collected Rocky Point and Outer Harbor Channel.

SILIQUARIIDAE

Tenagodus weldii Tenison Woods p. 76 Fig. 64h

A single specimen from ENE of Point Sinclair.

CERITHIIDAE

Bittium (Semibittium) granarium (Kiener) p. 79 Figs 21n, 68p

Fairly ubiquitous, in small numbers.

Diala lauta A. Adams p. 78 Figs 21k,l;68j,78k; Pl.11e

Ubiquitous and locally abundant.

Hypotrochus monachus (Crosse & Fischer) p. 79 Figs 21p,q;68k,78l, Pl.11d

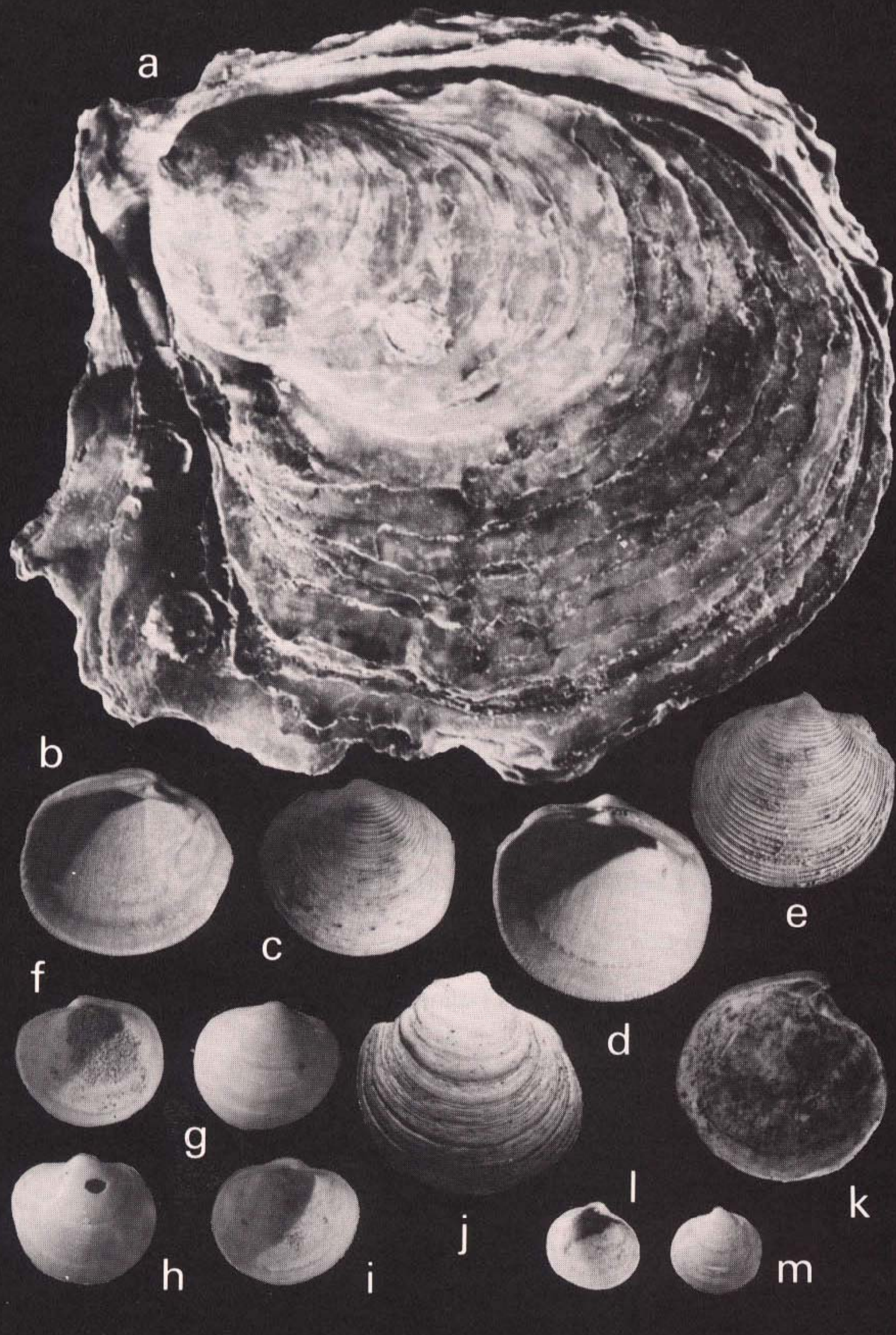
Collected from Tourville Bay, Rocky Point and New Lake.

CERITHIOPSIDAE

Seila (Notoseila) crocea (Angas) p. 80 Figs 68q,79f

Rare, collected only from ENE of Point Sinclair.

Fig. 71 *Glanville Formation—Late Pleistocene All x1 a. Ostrea angasi;* b-e. *Callucina lacteola* b,c. LV, d,e. RV; f-i. *Anodontia (Cavatidens) perplexa* f,g. RV, h,i. LV, j,k. *Loripes* sp. LV; l,m. *Wallucina assimilis* LV.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EPITONIIDAE

Epitonium (Pomiscala) perplicata (Iredale) p. 81 Fig. 68l

Rare; collected only from N of Point Sinclair.

Epitonium (Limiscala) helicornuum (Iredale) p. 81 Fig. 68m

Rare; collected only from ENE of Point Sinclair and at Tourville Bay.

Acutiscala minora Iredale p. 80 Fig. 68n

Collected from spoil from shallow well NE of Slade Point, Eyre Peninsula.

HIPPONICIDAE

Hipponix (Sabia) conicus (Schumacher) p. 82 Figs 20o,p;57t,64l; Pl.5h

Uncommon; collected from S of Talia, Warooka and Rocky Point.

Hipponix (Antisabia) erma Cotton p. 234 Fig. 64m

Rare; from Tourville Bay

NATICIDAE

Polinices (Conuber) conicus (Lamarck) p. 88 Figs 24a,64n; Pls 8j,10c

In small numbers from Coorabie, the Elliston area, Tourville Bay, Warooka and Rocky Point.

Notocochlis gualteriana (Recluz) p. 89 Figs 60o,p

A single specimen from Tourville Bay.

Sinum (Ectosinum) zonale (Quoy & Gaimard) p. 89 Figs 24b,c; Pl.5g

Rare; collected at Rocky Point

CASSIDAE

Cassis (Hypocassis) fimbriata Quoy & Gaimard p. 91 Figs 24d,e; 65l,m+s 2c,8l

A single specimen from ESE of Coorabie.

PLATE 21 Cliffs about 60 m high, Bridgewater Formation, Cape Spencer, Yorke Peninsula. Photo A.R. Milnes. (Trans. 24554)

CYMATIIDAE

Cymatiella gaimardi Iredale p. 93 Figs. 24l,m;65j,k; Pl.10i

Uncommon; collected from Tourville Bay, Coorabie, and Brownlow Beach, K.I.

Cymatiella verrucosa (Reeve) p. 93 Figs 24h,i;57z

Collected only at Brown Point.

MURICIDAE

Pterynotus triformis (Reeve) p. 98 Figs 27a,b;65a,b; Pl.5a,b

Collected only on Yorke Peninsula near Warooka.

Bedeva paivae (Crosse) p. 98 Figs 27e,f;65d,e; Pl.10k

Not common; from Tourville Bay, and from Kingscote and Rocky Point.

Thais orbita (Gmelin) p. 100 Figs 27p,65c; Pl.2d

Rare; collected only at Kingscote.

Lepsiella flindersi (Adams & Angas) p. 100 Figs 27h,i;66a,b; Pl.1p,q

Rare; collected at Tourville Bay and Kingscote.

COLUMBELLIDAE

Mitrella acuminata (Menke)

Rare; collected at Warooka and Rocky Point

Mitrella (Dentimitrella) lincolnensis (Reeve) p. 102 Figs 27g; 68t; Pl.10m

Fairly ubiquitous in small numbers.

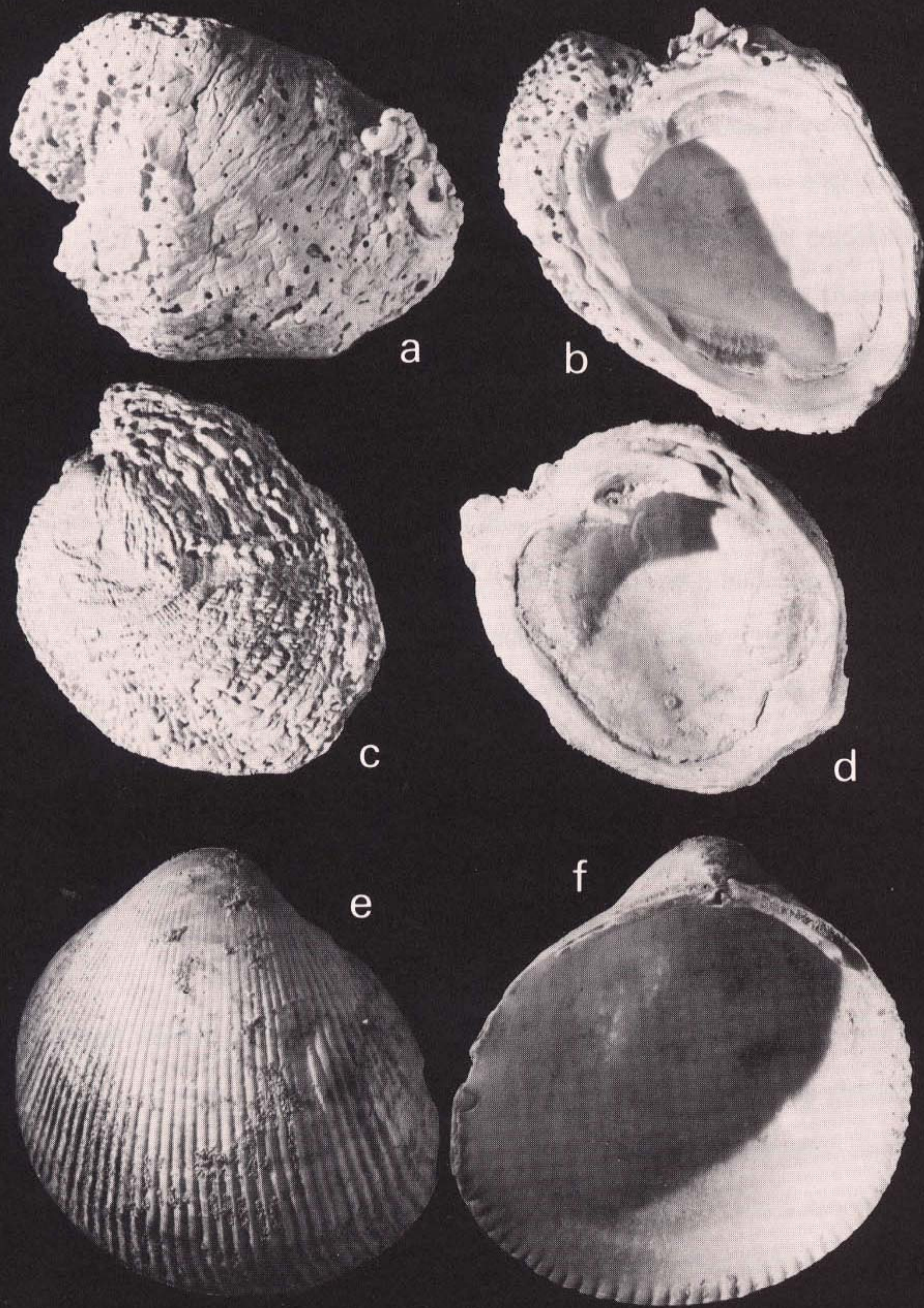
Mitrella (Dentimitrella) semiconvexa (Lamarck) p. 102 Fig. 68s Pl.10n

Rare, collected only at Brownlow Beach, K.I.

Euplica bidentata (Menke) p. 102 Fig. 68u

One of the characteristic fossils of the Glanville Formation and usually present in small numbers.

Fig. 72 Glanville Formation—Late Pleistocene All x1 a-d *Chama ruderalis* a,b. LV, c,d. RV; e,f. *Fulvia tenuicostata* RV.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BUCCINIDAE

Cominella eburnea (Reeve) p. 104 Figs 20x,y;57x;66d,e

Common; usually present in small numbers.

Cominella lineolata (Lamarck) p. 104 Figs. 20v,w;66c; Pl.5d

Collected from Tourville Bay and Kingscote.

Josepha tasmanica Tenison Woods p. 110 Fig. 67a

Rare; collected only from ESE of Coorabie.

NASSARIIDAE

Niotha (Tavaniotha) munierana (Crosse)

Rare; collected from the Elliston area W of Calca Hill and NE of Slade Point.

Niotha pauperata (Lamarck) p. 106 Figs 27n,o;65h,i; Pl.11i

Not common; present in small numbers at several localities.

Niotha pyrrhus (Menke) p. 106 Figs 27l,m;65f,g; Pl.11h

Common and ubiquitous.

Hinia (Reticunassa) paupera (Gould) p. 106 Fig. 67b

Rare; collected only ENE of Point Sinclair.

FASCIOLARIIDAE

Fusinus (Propefusus) undulatus (Perry) p. 108 Figs 28b,66j,k

Rare; collected at Tourville Bay, Coorabie, Warooka and Brownlow Beach.

Fusinus australis (Quoy & Gaimard) p. 107 Figs 28c,66h,i

Rare; collected N of Point Sinclair, Coorabie and Kingscote.

Pleuroploca australasia (Perry) p. 107 Figs 10,28a,66p

Rare; collected only at Tourville Bay.

PLATE 22 Bridgewater Formation: reddish-brown soil horizons and fawn, crossbedded calcarenite, 2 km west of Elliston. Photo R.B. Flint 012-145. (Trans. 24555)

Microcolus dunkeri (Jonas) p. 110 Figs. 66f-g

Collected only from the Elliston area.

MITRIDAE

Mitra (Eumitra) glabra Swainson p. 112 Figs 28i,66l; Pl.10l

Rare; collected from ENE of Point Sinclair and Warooka.

Austromitra lincolnensis (Angas) p. 112 Fig. 67d

Rare; two specimens only from ENE of Point Sinclair.

Austromitra schomburgki (Angas)

A juvenile only from Tourville Bay.

Proximitra pica (Reeve) p. 112

Rare; a single specimen from Tourville Bay.

TURRIDAE

Splendrillia harpularia (Desmoulins) p. 118 Fig. 67e

Rare; collected only ENE of Point Sinclair and at Tourville Bay.

CONIDAE

Conus (Floraconus) anemone Lamarck p. 118 Figs 25a,66o; Pl.2b

Not common; collected from Coorabie, the Elliston area, Kingscote and Rocky Point.

Conus (Floraconus) compressus Sowerby p. 118 Figs 66m,n

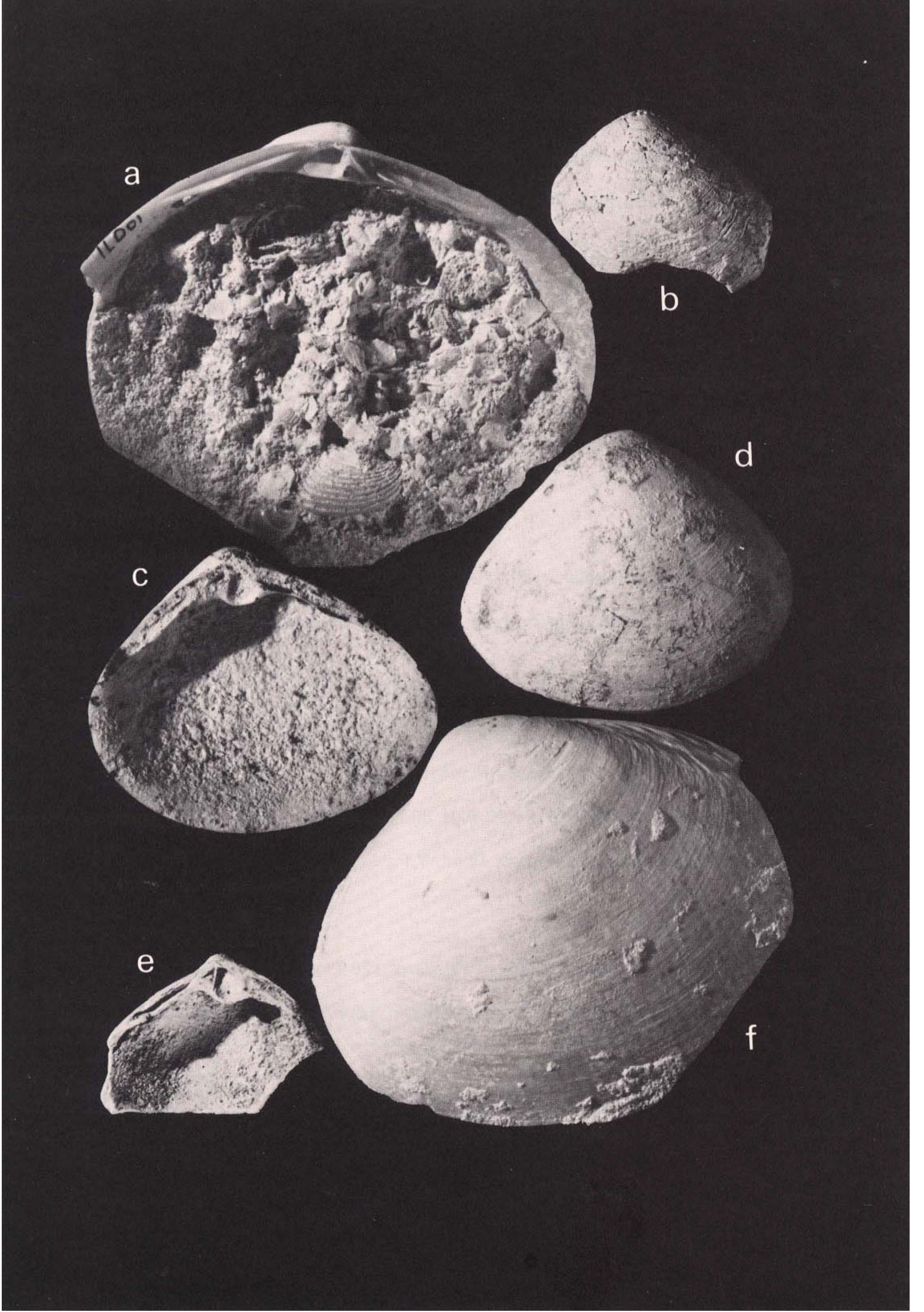
Not common, but fairly well distributed between Ceduna and Elliston, Warooka, Outer Harbor Channel.

PYRAMIDELLIDAE

Cossmannica sp. Fig. 67c

A single specimen from Tourville Bay

Fig. 73 Glanville Formation—Late Pleistocene All x1 a,f. *Mactra eximia* LV; b,e. *Mactra australis* LV; c,d. *Mactra pura* LV.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ATYIDAE

Haminoea (Liloa) brevis (Quoy & Gaimard) p. 119 Fig 68r

Rare; specimens from Tourville Bay and near Fowlers Bay.

Cyclichna arachis (Quoy & Gaimard) p. 119

Rare; from Slade Point, Elliston District.

BULLIDAE

Bulla botanica Hedley p. 119 Fig 67h; Pl.10q

Fairly ubiquitous from Fowlers Bay to Elliston, near Warooka and at Rocky Point K.I.

AMPHIBOLIDAE

Salinator fragilis (Lamarck) p. 122 Figs 30f,g

West of Calca in the Elliston area and at Vivonne Bay, K.I.

ELLOBIIDAE

Marinula xanthostoma H. & A. Adams p. 122 Figs 30b,c;67f

A single specimen from Rocky Point K.I.

Laemodonta ciliata (Tate) p. 122 Figs 30d,e;67i

A single specimen from Brown Point, Y.P.

SIPHONARIIDAE

Siphonaria (Hubendickula) baconi Reeve p. 126 Figs 30j,k;57a 67k,l

Rare; single specimens from Point Sinclair, Tourville Bay and Kingscote.

Fig. 74 Glanville Formation—Late Pleistocene All x1 a-d *Anapella cycladea* a,b. LV; c,d. RV; e-h. *Spisula (Notospisula) trigonella* e,f. LV; g,h. RV; i-k. *Amesodesma angusta* i. RV, j,k. LV; l. *Amesodesma cuneata* LV; m. *Solen vaginoides* RV; n-q. *Tellina (Macomona) deltoidalis* n,o. LV, p,q. RV; r-t. *Tellina (Macomona) mariae* r,s. LV, t. RV.

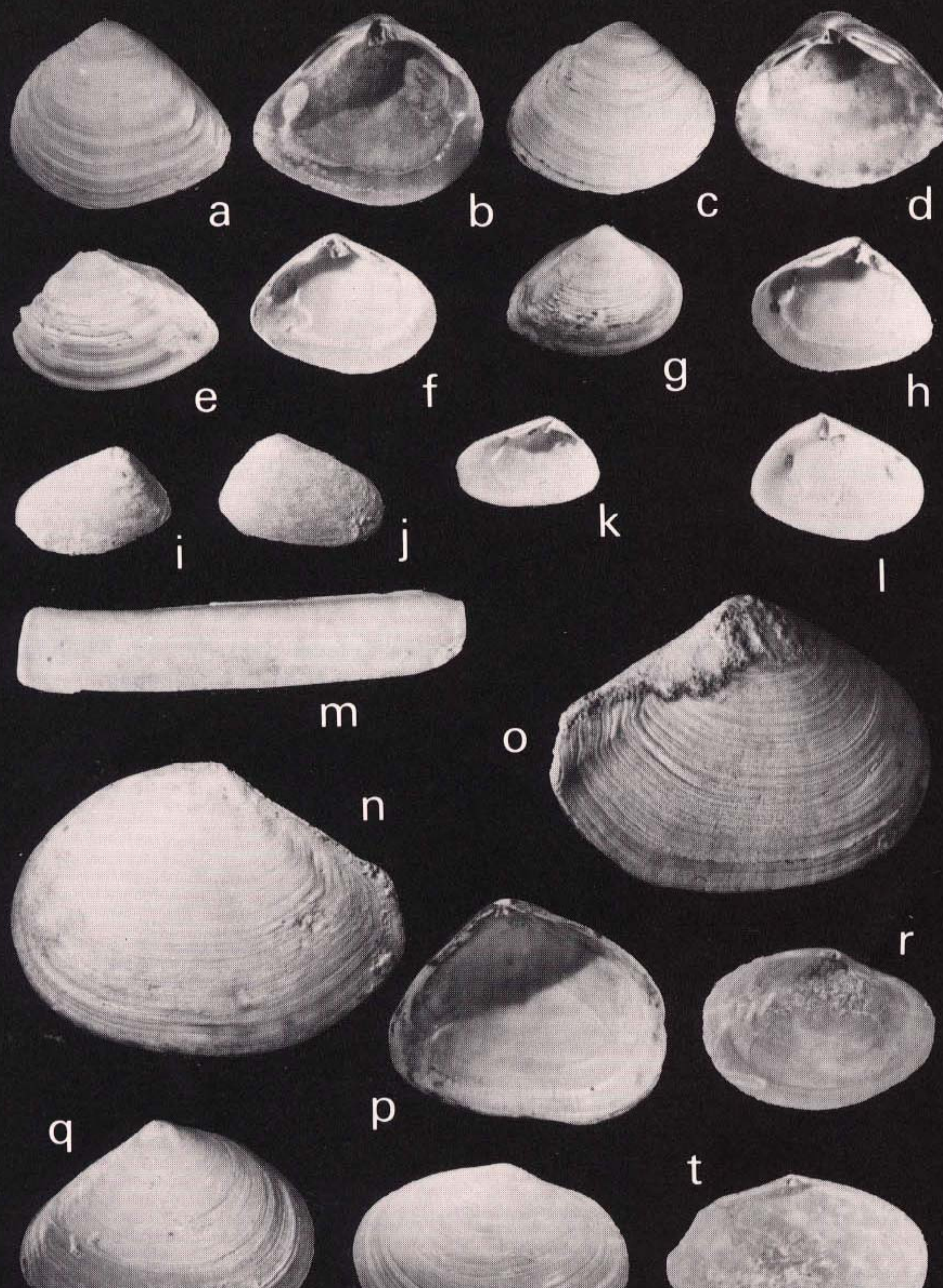
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PLATE 23 St Kilda Formation, road cutting, southern shore of Bay of Shoals, Kangaroo Island, west of The Bluff. KINGSCOTE 1:250 000 sheet. Photo A.R. Milnes. (Trans. 24556)

PECTINIDAE

Pecten benedictus albus Tate p. 162 Fig. 40a

A poor specimen found with *Fulvia tenuicostata* below the gypsum at New Lake in the hundred of Dudley, K.I.

OSTREIDAE

Ostrea angasi Sowerby p. 167 Figs 40b,71a

Widespread in the Glanville Formation from Fowlers Bay to Warooka and K.I.; collected mostly from bulldozer scrapes.

LUCINIDAE

Callucina lacteola (Tate) p. 171 Figs 71b-e Pl.9j,k

So far, found only near Warooka.

SCAPHOPODA

DENTALIIDA

Dentalium (Paradentalium) flindersi Cotton & Ludbrook p. 129 Fig. 63d

Rare; collected from N of Point Sinclair.

Antalis hyperhemileuron (Verco) p. 129 Figs 30q,63a

Also rare; from N of Point Sinclair.

BIVALVIA

ARCIDAE

Barbatia pistachia (Lamarck) p. 142 Figs 35g,h;69e,f; Pl.50o,p

Found at Rocky Point, K.I.

Anadara trapezia (Deshayes) p. 144 Figs 61, 69a,b

The species from which the '*Anadara* high sea-level' was named. Abundant at most localities with very large specimens from N of Point Sinclair.

GLYCYMERIDIDAE

Glycymeris (Tucetilla) mayi Cotton p. 146 Figs 69c,d

Found in the Glanville Formation in the Port River.

MYTILIDAE

Brachidontes erosus (Lamarck) p. 150 Figs 37a,b;70e,f; Pl.3b,c

Found ENE of Point Sinclair and on K.I.

Brachidontes (Austromytilus) rostratus (Dunker)

p. 150 Figs 37c,d;70a,d

Found ENE of Point Sinclair, at Tourville Bay and on K.I.

PTERIIDAE

Pinctada carchariarum (Jameson) p. 156 Figs 62;70g-i

Found at Ceduna, 'near Whyalla', St Kilda and east of Warooka, Y.P.

Anodontia (Cavatidens) perplexa (Cotton & Godfrey)

p. 171 Figs 71f-i

Recovered from spoil from a shallow well south of Streaky Bay, from N of Point Sinclair and near Warooka.

Wallucina assimilis (Angas) p. 171 Figs 71l,m

Collected from Tourville Bay and west of Ceduna and New Lake, K.I.

Loripes sp Figs 71j,k

A species not so far identified from Rocky Point, K.I.

CHAMIDAE

Chama ruderalis Lamarck p. 172 Figs 43e,g;72a-d

From two localities north of Fowlers Bay.

CARDIIDAE

Fulvia tenuicostata (Lamarck) p. 176 Figs 44f-h;72e,f; Pls 8b,9l,m

Collected from Point Sinclair W of Ceduna of Slade Point S of Streaky Bay, from near Warooka, and abundantly *in situ* at New Lake, K.I.

ERYCINIDAE

Melliteryx acupunctum (Hedley) p. 172 Figs 68w,x

Not common, among shell debris from Boree Swamp N of Fowlers Bay and from New Lake, K.I.

MACTRIDAE

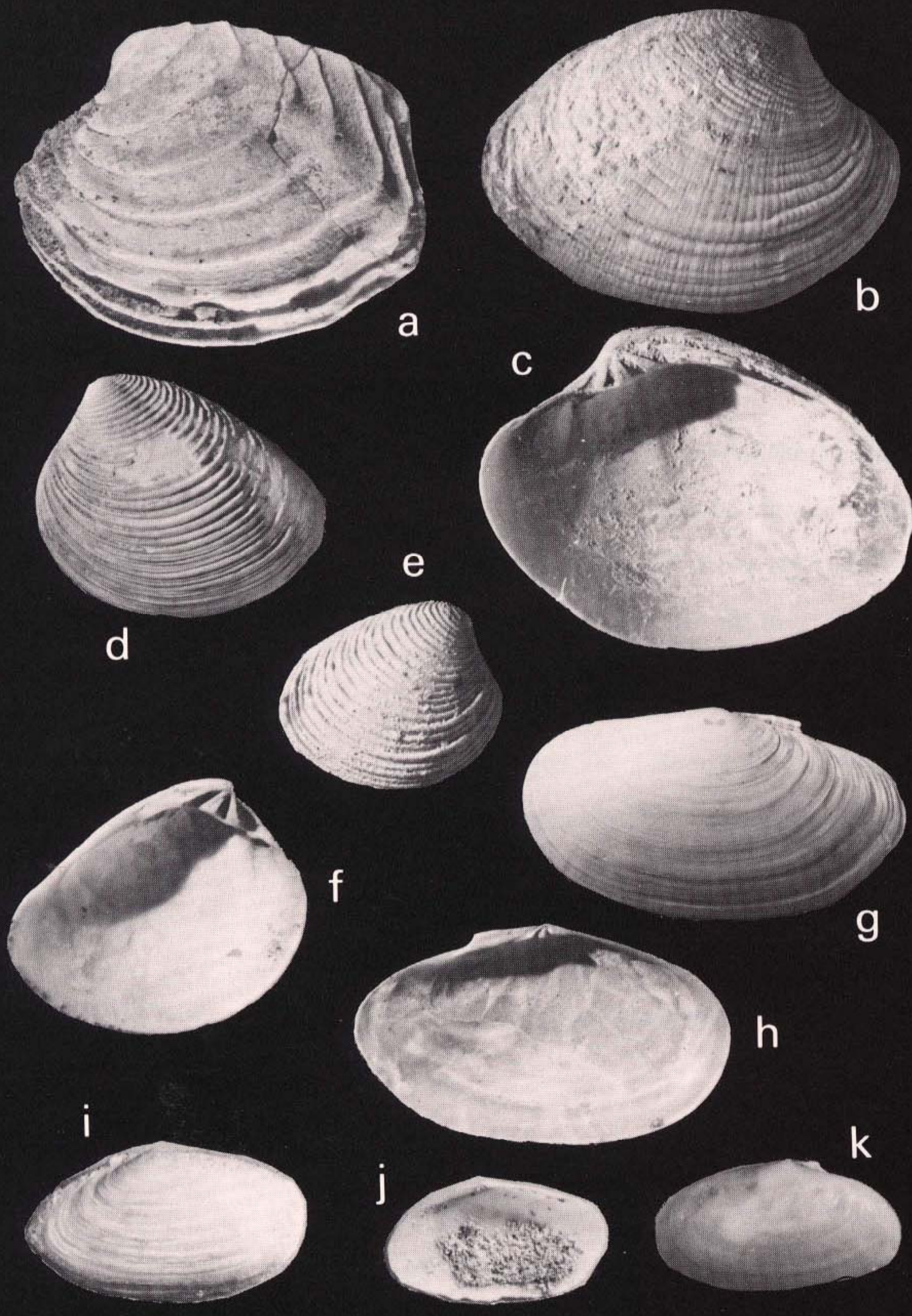
Mactra australis Lamarck p. 177 Figs 45e,f;73b,e; Pl.6i-l

Rare, found only in the basalt conglomerate at Kingscote, K.I.

Mactra eximia Reeve p. 177 Figs. 73a,f

A single valve was collected at Warooka. This is a rare find as it is an eastern Australian species living today from southern Queensland to New South Wales.

Fig. 75 Glanville Formation—Late Pleistocene All x1
a. *Circomphalus disjecta* LV; b,c. *Katelysia rhytiphora* RV; d-f. *Katelysia scalarina* d,g. LV, e,f. RV; g,h. *Sanguinolaria (Psammotellina) biradiata* LV; i-k *Sanguinolaria (Psammotellina) donacioides* i. both valves, j,k. LV.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Mactra pura Deshayes p. 177 Figs 45a,b;73c,d

From ENE of Point Sinclair.

Anapella cycladea (Lamarck) p. 182 Figs 74a-d

Abundant in the roadside scrape on Vivonne Bay road, K.I.

Spisula (Notospisula) trigonella (Lamarck)

p. 177 Figs 45m-o;74e-h; Pl.11p

Not common, but collected from ENE of Point Sinclair, south of Talia on Eyre Peninsula and from near Warooka.

MESODESMATIDAE

Amesodesma angusta (Reeve)

p. 180 Figs 46d,e; 58g; h; 74i-k; Pl.9c,d,g,h

Common in the Glanville Formation at certain localities such as at Rocky Point, K.I., also at Tourville Bay and ENE of Point Sinclair.

Amesodesma cuneata (Lamarck)

p. 180 Figs 46f-h; 58i-j; 74l; 80g-l; Pl.9a,b,e,f

Found in the Glanville Formation on Kangaroo Island.

SOLENIDAE

Solen vaginoides Lamarck p. 182 Figs 46c,74m

A single specimen recovered from north of Point Sinclair.

TELLINIDAE

Tellina (Macomona) deltoidalis Lamarck p. 184 Figs 48c-e; 74n-q; 80m-o; Pl.8i

Almost ubiquitous in the Glanville Formation.

Tellina (Macomona) mariae Tenison Woods p. 184 Figs 74r-t

Rare; collected from Peesey Swamp, Y.P.

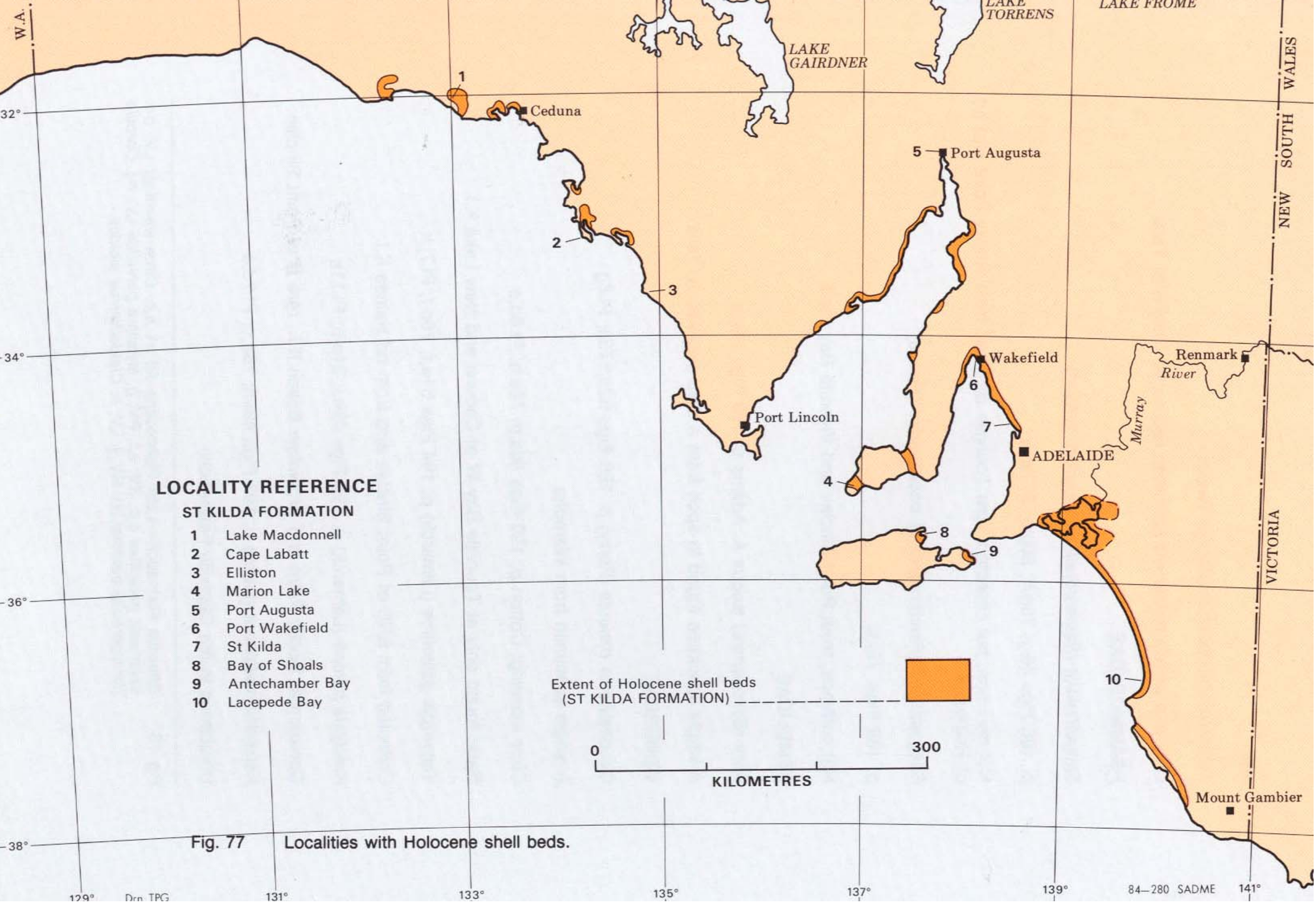


Fig. 77 Localities with Holocene shell beds.

Tellina (Eurytellina) ensiformis Reeve

Only one poorly preserved specimen recovered from S of Talia.

PSAMMOBIIDAE

Sanguinolaria (Psammotellina) biradiata (Wood)

p. 188 Figs 46i,j; 75g,h; 80p,q; Pl.7m,n

Not common, but collected from Tourville Bay and from Rocky Point and hd of Haines, K.I.

Sanguinolaria (Psammotellina) donacioides (Reeve)

p. 188 Figs. 75i-k

Not common, from Point Sinclair and Vivonne Bay road.

SEMELIDAE

Abra (Syndosmya) exigua A. Adams p. 189 Figs 68y,z

A single specimen found in spoil from a dam excavation, Talia.

VENERIDAE

Circomphalus disjecta (Perry) p. 198 Figs 52e,f;75a; Pl.8g

A single specimen from Warooka.

Circe weedingi Cotton p. 190 Figs 50a,b; 76a,b; Pl.8d,e

Rare; found only at Tourville Bay W of Ceduna and New Lake K.I.

Venerupis galactites (Lamarck) p. 194 Figs 51e,f; 76c-f; Pl.7j,k

Collected from ENE of Point Sinclair and from hd Haines K.I.

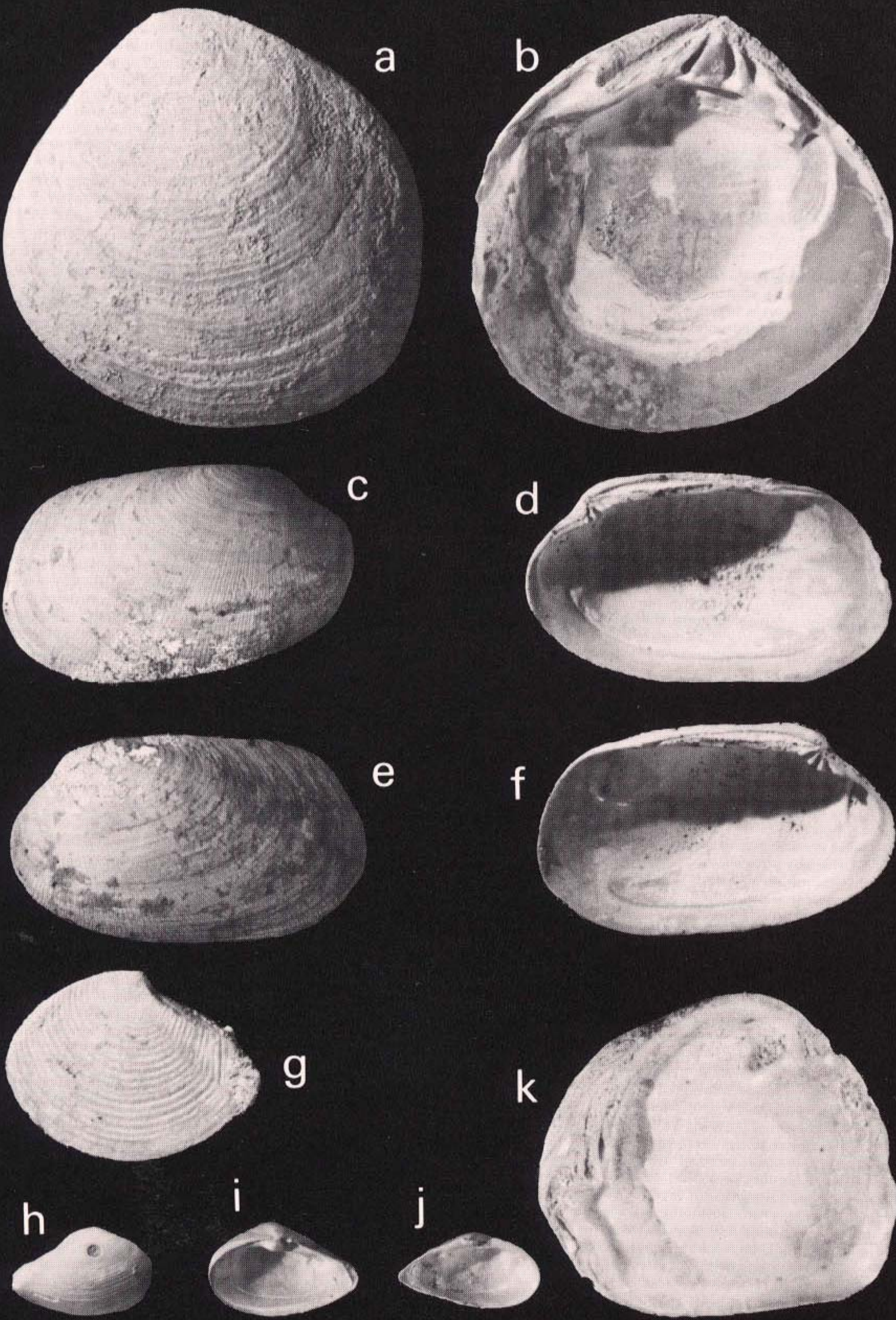
Katelysia peronii (Lamarck) p. 193 Figs 49h,i; 81e-h; Pl.11k

Common at Rocky Point and Brownlow Beach K.I., rare N of Point Sinclair.

Katelysia rhytiphora (Lamy) p. 193 Figs 49l-n; 75b,c; Pl.7d,e

Ubiquitous in the Glanville Formation.

Fig. 76 Glanville Formation—Late Pleistocene All x1 a,b. *Circe weedingi* LV; c-f. *Venerupis galactites* c,d. RV, e,f. RV; g. *Myadora pervalida* LV; h-j. *Corbula (Notocorbula) flindersi* h,i. RV, j. LV; k. *Cleidothaerus albidus*.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Katelysia scalarina (Lamarck) p. 193 Figs 49j,k; 75d-f; Pl.7f

Ubiquitous and abundant in the Glanville Formation.

CLEIDOTHAERIDAE

Cleidothaerus albidus (Lamarck) p. 207 Figs 55c-e; 76k

A single valve found in the basalt conglomerate at Brownlow Beach K.I.

CORBULIDAE

Corbula (Notocorbula) flindersi Cotton p. 201 Figs 76h-j

Rare; collected from Tourville Bay and Kingscote.

MYOCHAMIDAE

Myadora pervalida Cotton Fig. 76g

A single valve from Warooka.

4. HOLOCENE EPOCH

The end of the Pleistocene and beginning of the Holocene (formerly called Recent) is considered to have taken place about 10 000 years ago. According to Fairbridge (1982), the boundary is marked by strong oscillations in magnetic declination and inclination with a periodicity of 2 700 years. Melting of glacier ice occurred at about the same time and throughout the world there was a substantial rise in sea level.

St Kilda Formation

Most of the sediments deposited in South Australia during the Holocene are terrestrial, but there is a narrow fringe of coastal marine deposits around much of the present coastline which give varying evidence of a sea level slightly higher then at present (Pl. 23). Belperio, Hails & Gostin (1983) consider that in northern Spencer Gulf this transgression reached its peak from 6 600 to 6 400 years ago and that the sea level remained at least 2.5 m above present sea level until 1 600 years ago. Howchin (1888, 1912) and Greenway & Phillips (1902) recognised littoral shell deposits which they attributed to this transgression. Similar deposits were mapped by Sprigg on the *Adelaide* 1 inch to 1 mile geological sheet (1951) as 'Osborne marine sands and clays' and at Antechamber Bay, on the KINGSCOTE 4-mile geological sheet (1953) as 'stranded beach ridge dunes of the Mid-Recent high sea-level'. In 1954, Aitchison, Sprigg & Cochrane included them in the stratigraphy of the Adelaide area as 'Marine sands and clays of the Osborne high sea level'.

Firman (1966) named them the St Kilda Formation. The name has continued to be applied to unconsolidated shell beds and samphire and tidal flat deposits which are regarded as of Holocene age. They can be seen in coastal areas mostly in shallow excavations as a thin bed with samphire material and tidal flat molluscs some 2 to 3 metres above the Glanville Formation.

The richest shell beds are at Dry Creek, NW of Port Wakefield, N of Wallaroo, in a cobble conglomerate on the W side of Spencer Gulf opposite the Thomas Playford Power Stations and in the Bay of

Shoals and Antechamber Bay on Kangaroo Island. Species of *Katelysia* and *Batillaria, Tellina (Macomona) deltoidalis, Munditia subquadrata* and *Anapella cycladea* are abundant. While the foraminifer *Marginopora vertebralis* occurs commonly in the Glanville Formation, it is absent from the St Kilda Formation where it is replaced by *Peneroplis planatus.*

Most of the species live gregariously in estuaries or sheltered bays or in the littoral or sublittoral of sand flats and beaches. All of the species so far identified from the St Kilda Formation can be collected from South Australian beaches today.

Localities are shown on Fig. 77

GASTROPODA

ACMAEIDAE

Patelloida nigrosulcata (Reeve) p. 48 Figs 15d,e;63g,h

Rare; found only at Bay of Shoals.

TROCHIDAE

Cantharidus (Phasianotrochus) apicinus (Menke) p. 54 Fig 78h

Rare; Tickera.

Cantharidus (Phasianotrochus) irisodontes (Quoy & Gaimard)

p. 56 Figs 16o,p;63j,k; Pl.10e

Not uncommon at Tickera

Monodonta (Austrocochlea) constricta Lamarck

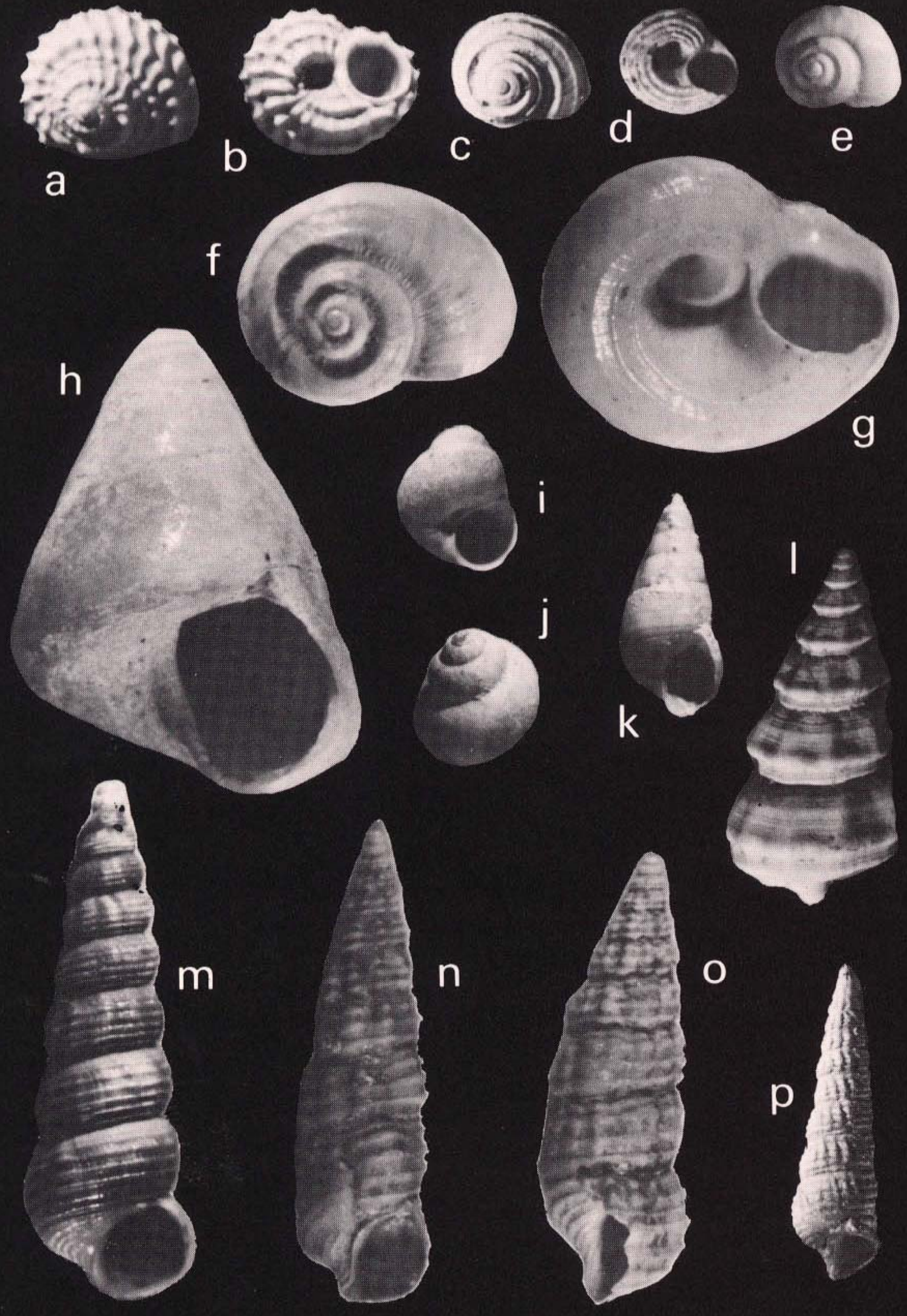
p. 53 Figs 16c,d;63l; Pl.1g

Found only at Port Augusta and Bay of Shoals.

Calliostoma (Fautor) rubiginosum (Valenciennes) Fig 68b

Found only at Tickera.

Fig. 7.8 St Kilda Formation—Holocene
a,b. *Munditia subquadrata* x6.5; c-g. *Elachorbis tatei* c,d. ribbed variety x9, e,f. x9, g x20, smooth or with few ribs; h. *Cantharidus (Phasianotrochus) apicinus* x20; i,j. *Hydrococcus brazieri* x7; k. *Diala lauta* x6; l. *Hypotrochus monachus* x6; m. *Eubittium lawleyanum* x4; n,o. *Batillaria (Zeacumantus) bivaricata* x10; p. *Batillaria (Zeacumantus) diemenensis* x1.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Diloma (Fractarmilla) concamerata (Wood) p. 56 Figs 16e,f;57d,e;63m,n; Pl.1h

Not uncommon at Port Augusta

Clanculus (Isoclanculus) dunkeri (Koch) p. 60 Figs 17h-j;68d

Not uncommon at Port Wakefield and Tickera.

Clanculus (Isoclanculus) philippi (Koch) p. 60 Figs 17k-m;68c

Found only at Port Wakefield.

CYCLOSTREMATIDAE

Munditia hedleyi (Pritchard & Gatliff) p. 62

Rare; a single specimen from ICI borrow pit, Dry Creek.

Munditia subquadrata (Tenison Woods) p. 62 Figs 78a,b

Abundant at Antechamber Bay; common at ICI borrow pit, Dry Creek.

Elachorbis tatei (Angas) p. 64 Figs 76c-g

Abundant ICI borrow pit, Dry Creek, present at Tickera.

NERITIDAE

Nerita (Melanerita) atramentosa Reeve

p. 65 Figs 18e,f;64i,j Pl.1o

Rare; found only at Tickera.

LITTORINIDAE

Bembicium nanum (Lamarck) p. 68 Figs 20i; Pl.1l

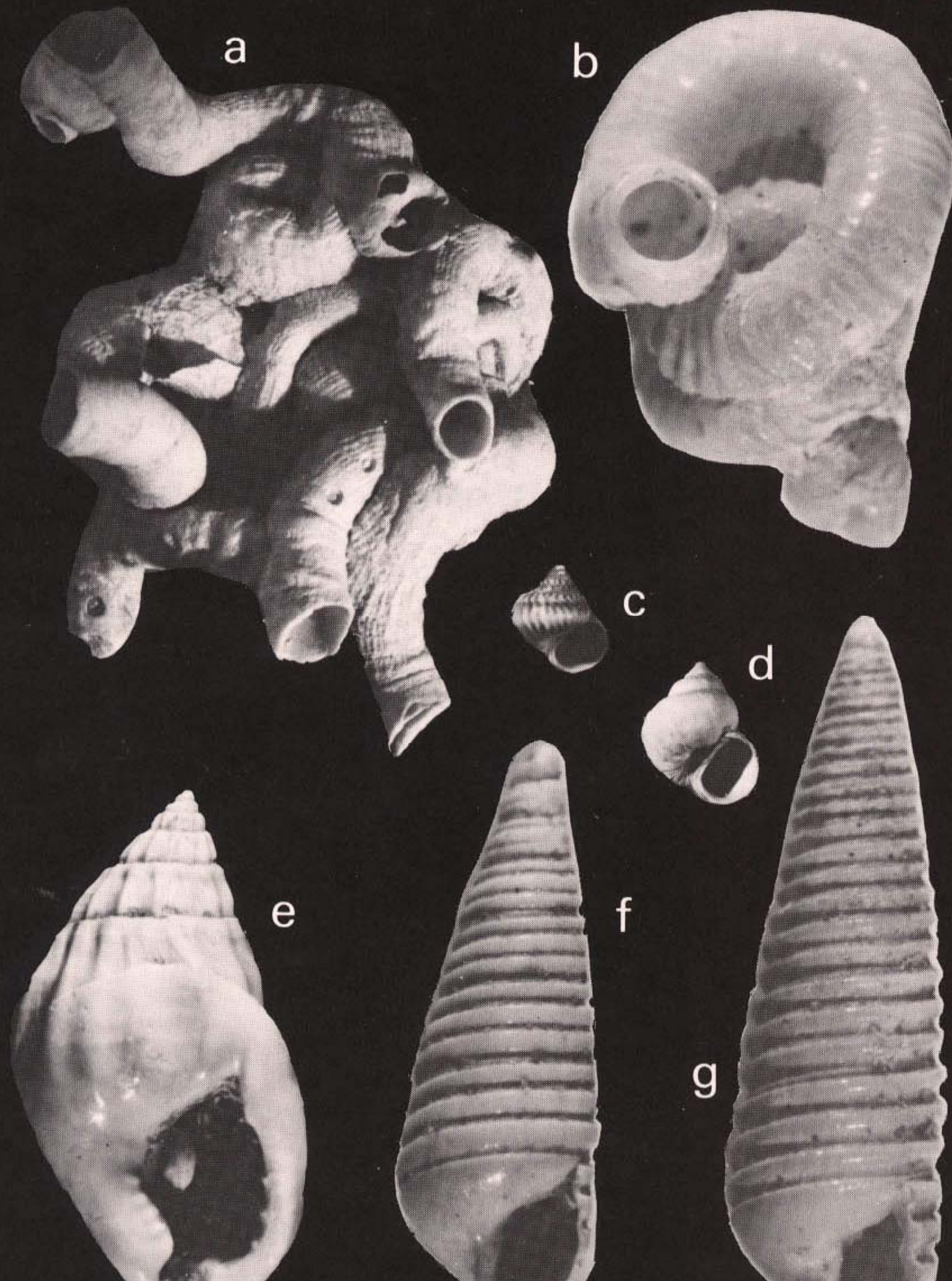
Rare; Bay of Shoals only.

HYDROCOCCIDAE

Hydrococcus brazieri (Tenison Woods) p. 71 Figs 21b;78i,j

Abundant at ICI borrow pit, Dry Creek, and Tickera.

Fig. 79 St Kilda Formation—Holocene
a. *Serpulorbis sipho* x1; b. *Dendropoma caperata* x12; c,d. *Salinator solidus* x1; e. *Plicarcularia burchardi* x4; f. *Seila (Notoseila) crocea* x20; g. *Seila (Notoseila) triplanicincta* x20.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POTAMIDIDAE

Batillaria (Batillariella) estuarina (Tate) p. 78 Figs 21h,i;64e

Not common; Port Wakefield and Tickera.

Batillaria (Zeacumantus) bivaricata Ludbrook

Figs 78n,o

Not uncommon, ICI borrow pit, Dry Creek.

Batillaria (Zeacumantus) diemenensis (Quoy & Gaimard)

p. 77 Figs 21f,g;57q;64g;78p; Pl.11b

Abundant and ubiquitous.

Eubittium lawleyanum (Crosse) p. 78 Figs 21j,68o,78m; Pl.11f

Common.

VERMETIDAE

Serpulorbis sipho (Lamarck) p. 75 Figs 21r,79a

Rare, found at Port Augusta and Tickera.

Dendropoma caperata (Tate & May) p. 75 Fig. 79b

Rare, ICI borrow pit, Dry Creek, and Tickera.

CERITHIIDAE

Diala lauta A. Adams p. 78 Figs 21k,l;68j;78k; Pl.11e

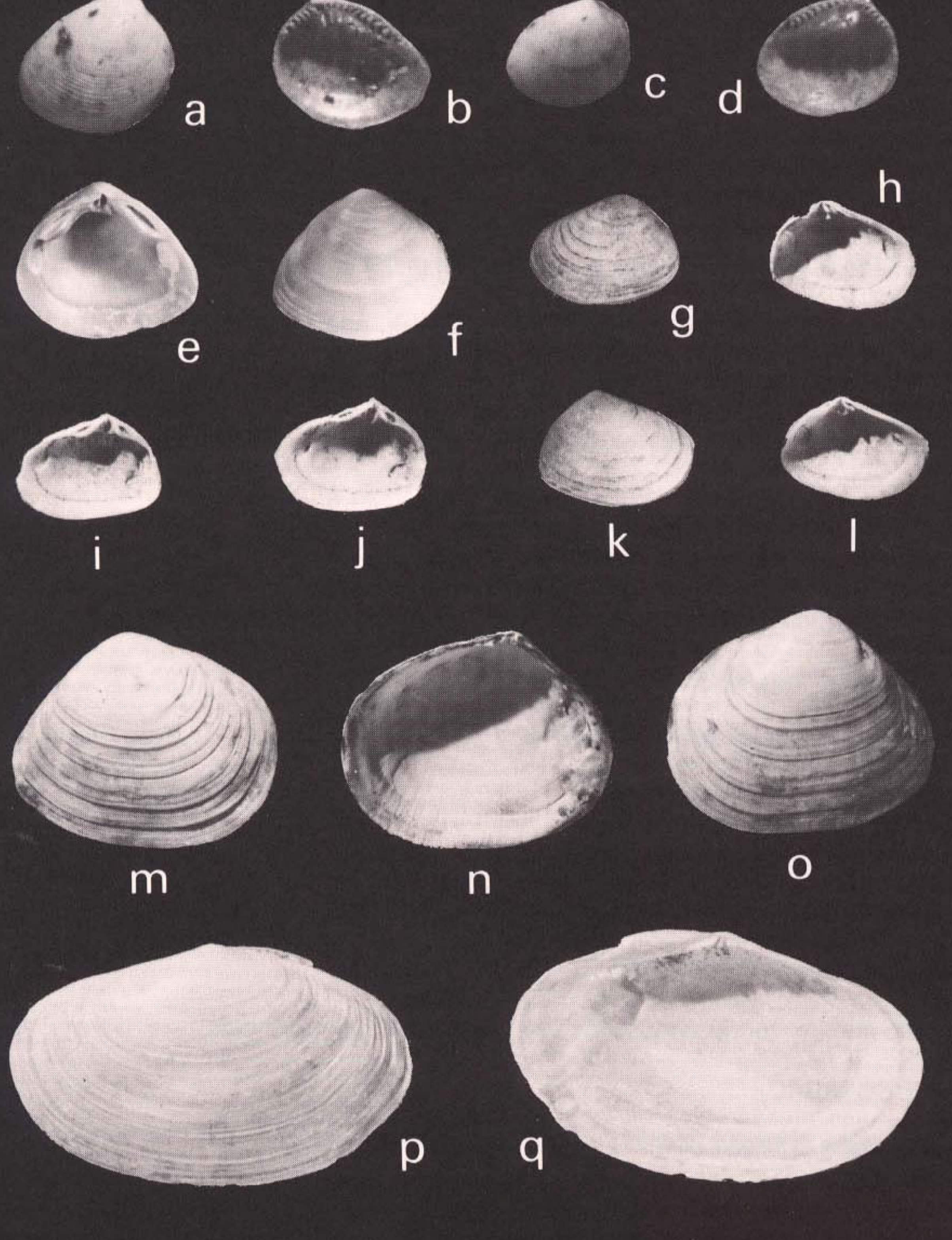
Ubiquitous and usually abundant.

Hypotrochus monachus (Crosse & Fischer)

p. 79 Figs 21p,q;68k;78l; Pl.11d

Common at Tickera, rare Port Wakefield, ICI borrow pit, Bay of Shoals.

Fig. 80 St Kilda Formation—Holocene All x1
a-d *Nucula pusilla* a,b,c. LV, d. RV; e,f. *Anapella cycladea;* g-l. *Amesodesma cuneata* g,h,l. LV, i,j. k. RV; m-o. *Tellina (Macomona) deltoidalis* m. RV, n,o. LV; p,q. *Sanguinolaria (Psammotellina) biradiata* LV.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CERITHIOPSIDAE

Seila (Notoseila) crocea (Angas) p. 80 Figs 68q,79f

Rare at ICI borrow pit, Dry Creek.

Seila (Notoseila) triplanicincta Ludbrook Figs 79g

Also rare, only ICI borrow pit, Dry Creek.

CYMATIIDAE

Cymatiella gaimardi Iredale p. 93 Figs 24l,m;65j,k; Pl.10i

Rare, found only at ICI borrow pit, Dry Creek, and Port Wakefield.

Cymatiella verrucosa (Reeve) p. 93 Figs 24h,i;57z

Rare, found only at Bay of Shoals.

MURICIDAE

Bedeva paivae (Crosse) p. 98 Figs 27e,f;65d,e; Pl.10k

Common, ICI borrow pit, Dry Creek, and Bay of Shoals.

Lepsiella flindersi (Adams & Angas)

p. 100 Figs 27h,i;66a,b; Pl.1p,q

Found only at Port Augusta.

COLUMBELLIDAE

Mitrella (Dentimitrella) lincolnensis (Reeve)

p. 102 Figs 27g,68t Pl.10m

Uncommon, found only at ICI Dry Creek and Bay of Shoals.

BUCCINIDAE

Cominella eburnea (Reeve) p. 104 Figs 20x,y;57x;66d,e

In small numbers at ICI Dry Creek and Port Wakefield.

Cominella lineolata (Lamarck) p. 104 Figs 20v,w;66c; Pl.5d

Found only at ICI Dry Creek.

NASSARIIDAE

Niotha pauperata (Lamarck) p. 106 Figs 27n,o;65h,i; Pl.11i

Not uncommon, ICI Dry Creek, Tickera, Port Augusta and Bay of Shoals.

Niotha pyrrhus (Menke) p. 106 Figs 27l,m;65f,g; Pl.11h

Widespread, locally common.

Plicarcularia burchardi (Dunker) p. 106 Fig 79e, Pl.11j

Abundant at Antechamber Bay, found also at Port Wakefield.

FASCIOLARIIDAE

Microcolus dunkeri (Jonas) p. 110 Figs 66f,g

Rare, ICI Dry Creek.

CONIDAE

Conus (Floraconus) compressus Sowerby p. 118 Figs 66m,n

Found at Port Wakefield and Tickera.

AMPHIBOLIDAE

Salinator fragilis (Lamarck) p. 124 Figs 30f,g

Single specimens collected at Tickera, Bay of Shoals and Antechamber Bay.

Salinator solidus (von Martens) Figs 30h,i;79c,d

SIPHONARIIDAE

Siphonaria (Hubendickula) baconi Reeve

p. 126 Figs 30j,k;57a,67k,l;79c,d

Rare, Tickera only.

BULLIDAE

Bulla botanica Hedley p. 119 Figs 67h, Pl.10q

Rare, Port Wakefield.

BIVALVIA

NUCULIDAE

Nucula pusilla Angas p. 139 Figs 80a-d

Not uncommon, ICI borrow pit, Dry Creek.

MYTILIDAE

Brachidontes erosus (Lamarck) p. 150 Figs 37a,b;70e,f; Pl.3b,c

Collected only from Bluff Road, Bay of Shoals.

Brachidontes (Austromytilus) rostratus (Dunker)

p. 150 Figs 37c,d;70a-d

Not uncommon, collected in small numbers from Port Wakefield, Bluff Road, Bay of Shoals, and Tickera.

MALLEIDAE

Vulsella spongiarum Lamarck p. 158 Figs 37f,g

Rare, Tickera only.

PECTINIDAE

Chlamys (Equichlamys) bifrons (Lamarck) p. 160 Figs 38a,b; Pl.8f

Single valves from ICI borrow pit, Dry Creek, and Tickera.

OSTREIDAE

Ostrea angasi Sowerby p. 167 Figs 41b,70a

Collected Tickera.

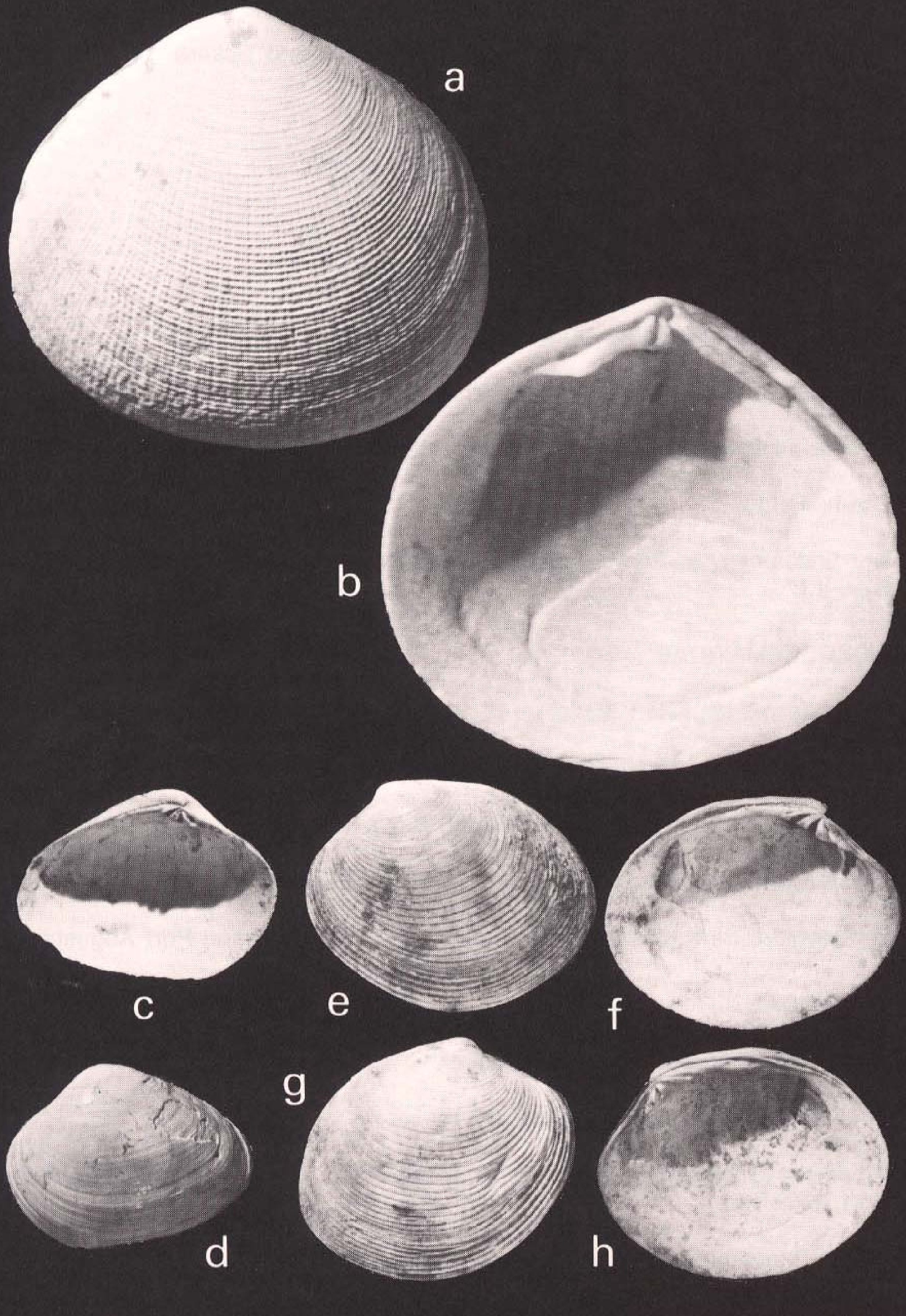
LUCINIDAE

Anodontia (Cavatidens) perplexa (Cotton & Godfrey)

p. 171 Figs 71f-i

Uncommon, ICI borrow pit, Dry Creek only.

Fig. 81 St Kilda Formation—Holocene All x1 a,b. *Tellina (Pseudarcopagia) victoriae* a. RV, b. LV; c,d. *Eumarcia fumigata* LV; e-h. *Katelysia peronii* e,f. LV, g,h. RV.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Loripes sp.

Not uncommon on Bluff Road, Bay of Shoals K.I. and Tickera.

CHAMIDAE

Chama ruderalis Lamarck p. 172 Figs 43e-g; 72a-d

Rare, collected only from Tickera.

MACTRIDAE

Anapella cycladea (Lamarck) p. 182 Figs 45j-l; 74a-d;80e,f

Abundant at Port Wakefield and Port Augusta.

Spisula (Notospisula) trigonella (Lamarck) p. 177 Figs 45m-o;

74e-h; Pl.11p

Not uncommon at Port Augusta, Port Wakefield, Tickera and Antechamber Bay, K.I.

MESODESMATIDAE

Amesodesma angusta (Reeve)

p. 180 Figs 46d,e;58g,h;74i-k; Pl.9c,d,g,h

Collected from Tickera and Bluff Road, Bay of Shoals

Amesodesma cuneata (Lamarck) p. 180 Figs 46f-h;58i-j;74l; 80g-l; Pl.9a,b,e,f

Widespread; Bluff Road, Bay of Shoals, Port Wakefield and Port Augusta.

TELLINIDAE

Tellina (Macomona) *deltoidalis* Lamarck

p. 184 Figs 48c,e; 74n-q; 80m-o; Pl.9i

Abundant in auger hole, Antechamber Bay Road, ICI borrow pit, Dry Creek, Port Wakefield.

Tellina (Macomona) *mariae* Tenison Woods p. 184 Figs 74r-t

Not common; found ICI borrow pit, Dry Creek, Port Wakefield.

Tellina (Pseudarcopagia) victoriae Gatliff & Gabriel

p. 184 Figs 48f,g;81a,b

Rare, Tickera only.

PSAMMOBIIDAE

Sanguinolaria (Psammotellina) biradiata (Wood)

p. 188 Figs 46i,j; 75g,h; 80p,q; Pl.7m,n

Port Wakefield only.

Sanguinolaria (Psammotellina) donacioides (Reeve)

p. 188 Figs 75i-k;

Not common, Antechamber Bay.

VENERIDAE

Circe weedingi Cotton

p. 190 Figs 50a,b;76a,b; Pl.8d,e

Rare, Tickera only.

Eumarcia fumigata (Sowerby)

p. 192 Figs 50j,k; 81c,d

Rare, Antechamber Bay.

Katelysia peronii (Lamarck)

p. 193 Figs. 49h,i; 81e,h; Pl.11k

Not uncommon, ICI borrow pit, Dry Creek, Tickera and Bay of Shoals, K.I.

Katelysia rhytiphora (Lamy) p. 193 Figs 49l-n; 75b,c; Pl.7d,e

Locally abundant, otherwise present in small numbers.

Katelysia scalarina (Lamarck) p. 193 Figs 49j,k;75d-f; Pl.7f

Common; ICI borrow pit, Dry Creek, Tickera, Port Augusta, Bay of Shoals.

5. TERRESTRIAL MOLLUSCS

The fossil land snails included in this book are desert snails of the same species as those living in western coastal areas and the Nullarbor Plain at the present time. Most of them come from within the Pleistocene Bridgewater Formation (Pls 18,19) but some were also collected from the Holocene Semaphore Sand.

The Bridgewater Formation was named from its outcrops in the Cape Bridgewater—Cape Nelson area of western Victoria. It consists of an extensive system of calcarenite dunes or aeolianites forming precipitous cliffs between western Victoria and the west of South Australia. Along the south coasts of Kangaroo Island, Yorke Peninsula and Eyre Peninsula (Pls 20,22) these cliffs are often more than 100 m high.

During Pleistocene high sea levels the dunes were breached in places allowing the sea to invade low lying areas and deposit the Glanville Formation which at localities such as Brown Point on western Yorke Peninsula, is interbedded with the Bridgewater Formation. Soil horizons occur within the Bridgewater Formation (Pl. 22) and *Bothriembryon barretti indictus* sometimes weathers out abundantly.

The Semaphore Sand forms the dunes of the modern coast. It is of Holocene age and contains *Bothriembryon barretti barretti* at Cape Labatt, 40 km south of Streaky Bay.

BULIMULIDAE

Bothriembryon barretti barretti Iredale Figs 82a-d

Shell of medium size, elongate-turbiniform, thin but solid, aperture equal in height to the spire, protoconch prominent, of two whorls with tip immersed, microscopically pitted and wrinkled although the initial whorl may be smooth and the wrinkles visible under the glassy surface, adult whorls four, moderately convex, sculptured with fine axial wrinkles crossed and weakly tuberculated by fine spiral threads particularly near the adapical suture; both axial and spiral sculpture weaker on the base; aperture subovate, outer lip thin, sharp, columella nearly straight, columellar lip reflected over the umbilical chink. Height 31.5, diameter 17.7 mm, average ratio height: diameter 1.784 :1.

Living on Nullarbor Plain, fossil in Semaphore Sand west of Cape Nuyts and at Cape Labatt.

Bothriembryon barretti indictus Iredale Fig. 82e.

The subspecies is, on the whole, less strongly ornamented than *B. b. barretti* with an average ratio of height: diameter 1.93:1.

Living on Nullarbor Plain, known range upper member of Bridgewater Formation (Pleistocene) to Holocene.

CAMAENIDAE

Angasella polypleura Tate Fig. 82j-l

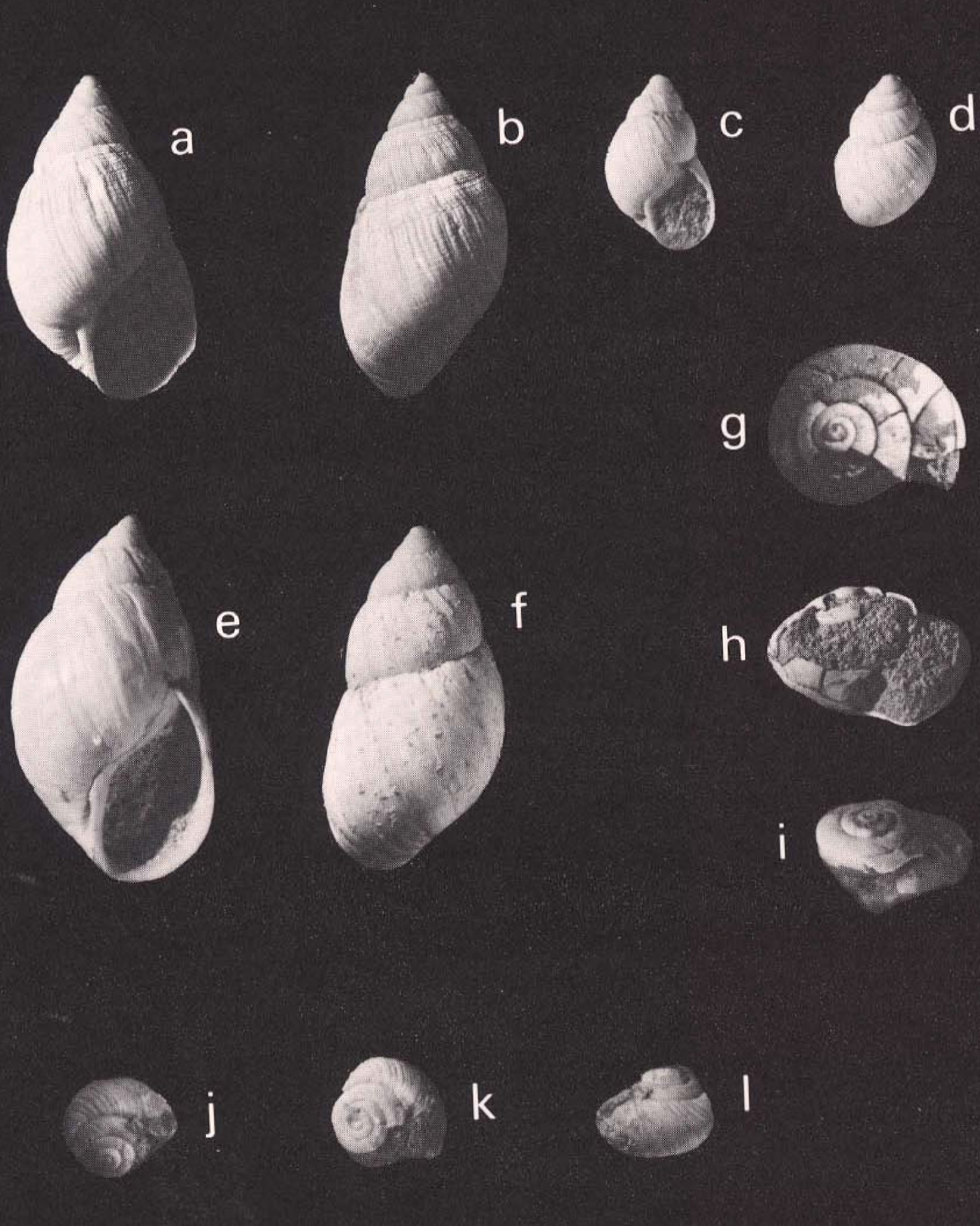
Shell subdepressed, flattened, but height of spire varying, umbilicate, with about 60 sigmoid threadlike axial ribs, the intercostal spaces coarsely granular, the granules having a tendency to coalesce to form rugae, outer lip reflected, parietal callus thick, columellar lip arched and broadly reflected over the umbilicus; the apex is large, flattish, with 1½ whorls with tip submerged, very finely microscopically pitted. Diameter 18, height 10.5 mm.

According to Tate, dead shells are strewn on the surface, but living shells are found in soil at the bases of shrubs. The specimen figured came from the Bridgewater Formation on Althorpe Island.

Exilibadistes sutilosa (Ferussac) Fig. 82g-i

The fragile specimens collected from St Francis Island are very likely topotypes of this species which was originally described from the Isles of St Peter and St Francis.

Fig. 82 Land shells All x1
a-d *Bothriembryon barretti barretti* a, b. Upper Member Bridgewater Formation, c,d. Semaphore Sand; e, f. *Bothriembryon barretti indictus* Bridgewater Formation; g,i. *Exilibadistes sutilosa* Bridgewater Formation; j-l. *Angasella polypleura* Bridgewater Formation.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