CHAPTER 16

BODY FOSSILS AND ROOT-PENETRATION STRUCTURES

BODY FOSSILS AND ROOT-PENETRATION STRUCTURES
RECORDED FROM THE STUDY AREA

16.1. INTRODUCTION

There are three major groups of body fossils that occur in the Triassic rocks of the study area, including the Hawkesbury Sandstone. The first group comprises fossil plant remains, which are abundant and previously well studied (e.g. Helby, 1969a,b & 1973; Retallack, 1976, 1977a, b, c, & 1980), and root-penetration structures. The second group comprises fossil animal remains which are extremely rare and, except for locally abundant fossil freshwater fish in shale lenses in the Hawkesbury Sandstone and the Gosford (=Terrigal) Formation (see Reggatt, in Packham 1969, p.407; and Branagan, in Packham 1969, p.415-416), include the bones of amphibians (e.g. Warren, 1972 & 1983; and Beale, 1985) and bivalve mollusc shells of mytilid affinity (Grant-Mackie et al., 1985). Additionally, the freshwater fossil pelecypod, Unio, the branchiopod Estheria, and a variety of insects have been recorded from the Hawkesbury Sandstone (cf. Branagan, in Packham 1969, p.417). The third group comprises microfossils (microfauna and microflora) (e.g. Helby, in Packham, 1969 p.404-405 and 417; Retallack, 1980; Grant-Mackie et al., 1985). The abundance of spores, megaspores, intact spore tetrads, and abundant quantities of other microscopic organic materials including acritarchs (possibility having been reworked) have been suggested as evidence that the palaeoenvironment of the Newport Formation was as marginal marine, possibly of lagoonal or estuarine character (Grant-Mackie et al., 1985).

16.2. TAXONOMY OF THE PLANT REMAINS AND
ROOT-PENETRATION STRUCTURES

16.2.1. Plant remains

Plate 54, Figs. a - e
Plate 75, Figs. c & e

The first systematic palaeobotanical studies on the rocks of the Sydney Basin were carried out by Helby (1969a,b & 1973) and Retallack (1976, 1977 & 1980). Their studies showed that elements of the Permian flora still persist into the Triassic, but with Dicroidium widespread throughout the Sydney Basin. During the late Sythian to early Anisian, the Permian coniferous forest elements were finally extinguished after the slow rise of the water table. The flora of the uppermost Bald Hill Claystone and Garie Formation (=Lower Newport Member) was probably dominated by a Dicroidium-Voltziopsis swamp woodland association (Retallack, 1977) as witnessed by the contained plant megafossils and coalified logs (Plate 54 Fig. e), and with Neocalamites (equisetalean).

The Bald Hill Claystone and lower part of the Lower Newport Member were eventually overlain by widespread coastal lagoonal or estuarine shales (Bunny & Herbert, 1971) containing Dicroidium and Pleuromeia (the latter being a lycopod). The distribution of the D. zuberi and P. longicaulis flora from the Newport Formation exposed in the sea-cliffs of the study area has been previously discussed by many authors, most notably : Walkom (1925); Burges (1935); Jacob & Jacob (1950); Helby & Martin (1965); Townrow (1966, 1967); and Retallack (1973, 1975 & 1980). The Dicroidium leaves from the Newport Formation are character-

ized by thick, tough cuticles and are commonly bipinnate. The other elements of the Newport Formation flora are: (1) Cyclostrobus sydneyensis (reproductive cone of P. longicaulis); (2) Neocalamites and Schizoneura (equisetaleans); (3) Cladophelbis (sterile fern); (4) "Todites" narrabeenensis (Gleichnia-like); (5) Asterotheca (fertile marattiaceous fern); (6) Lepidopteris madagascariensis (pteridosperm); (7) Odontopteris dubiae (Pachydermophyllum-like) and some leaves of uncertain origin.

This D. zuberi flora was later (in the Anisian, represented by the upper part of the Newport Formation) dominated by Taeniopteris lenticuliformis (forming a coastal scrub). This remarkable appearance of T. lenticuliforms in the upper part of the Newport Formation coincides approximately with the base of the Upper Newport Formation (=Upper Newport Member) when the environment comprised a broad coastal plain drained by braided and meandering streams (McDonnel, 1974; Retallack, 1977c).

Some of the plant remains (stems and leaves) recorded from the study area are illustrated in Plate 54 Figs. a - e, and Plate 75 Figs. c & e. The plant remains are normally present and abundant in silty shales interbedded with very fine sandstone units in all members of Newport Formation of the study area. The interpretation of the palaeoenvironmental affinities of the depositional environments on the basis only of the occurrence of the plant remains is not justified for several reasons. Firstly, the abundance of land-derived plant remains suggests only the proximity of a freshwater influx in a fluvially-dominated coastal lagoon or estuary (most of the plant remains from the study area

are not <u>in situ</u> except for roots and rootlets which will be discussed later in this chapter); in general the presence of the plant remains is not inconsistent with the idea of a marginal-marine type of coastal environment. Secondly, The plant remains may often occur in sediments indicative of a terrestrial origin (e.g., redbeds) and probably representing low-lying coastal areas, which areas can be inundated with brackish-marine water in trangressive episodes when the terrestrial environmental conditions give way to brackish-marine conditions and typical of all shallow intertidal marginal-marine areas. Thirdly, these marine environments (recognized on the basis of the trace fossils) and non-marine environments (recognized in the basis of the plant remains) can occur juxtaposed together practically, and are especially recognizable on the basis of the degree of stratigraphic extension or the vertical distribution of vertically orientated trace fossils (such as burrows of <u>Skolithos</u> and <u>Barrenjoeichnus mitchelli</u>) within the sedimentary sequence; in such situations a record of both marine and non-marine conditions may occur together in the same bed (Fürsich, 1981) which can be viewed as a kind of palimpsest deposit.

16.2.2. Root-penetration structures

The morphological features and internal structures of root-penetration structures made by plants and burrows made by organisms are in some cases quite similar, making it is very difficult to distinguish between them. However, generally the two can be separated on the basis of their shape, size, branching patterns, orientation, and external features (cf. Table 16.1).

TABLE. 16.1. Selected criteria for distinguishing rhizoliths from organism burrows (Summarised from Klappa (1980; Ekdale & et al., 1984; and Jones & Kwok-Choi Ng, 1958). However, the distinction between them is difficult in some cases and it is also advisable to study the associated features such as: palaeosols, and the relative diversity of associated trace fossils. See text for additional discussion.

Selected criter	Rhizoliths	Burrows
(1) Shape	Cylindrical to conical, circular in cross-section, normally tapering downwards	Highly variable morpho-logy and cross-section, tapering downward/upward or uniformly cylindrical
(2) Size	Length: few cm to several metres Diameter: 0.1 mm to 20 cm or more	Highly variable in length and diameter, but most of the burrows are less than a metre long and a few cm in diameter
(3) Branching	Mainly of downward bifurcation with decreasing diameter in 2nd- and 3rd-order branches	Downward/upward bifurcation with more or less uniform diameter
(4) Inter-penetration (cross-cutting)	Normally roots lack cross-cutting and interpenetration relationship	Interpenetration and cross-cutting relation-ships between burrows are quite common
(5) Orienta-tion	Variable but normally vertically branching system with or without 2nd-order ramifying horizontal network rootlets. In vertical cross-section, they show a preferred orien-tation of vertical main root with horizontal to inclined small root-lets	Highly variable, ranging from simple vertical shafts to highly pattern-ed horizontal networks; some even may have a pre-ferred orientation of lying parallel to each other, probably resulting from a prevaling current

TABLE 16.1 (continued)

Selected criteria	Rhizoliths	Burrows
(6) internal structures	The structure is in-filled with root material of carbonised film and if not flattened may be filled with whatever material lies above; normally enveloped with reduction halos	The burrow structure can either be actively or passively filled with result and meniscus pattern, spreiten, faecal-pellets etc.
(7) External Features	Few or no external features can be recognised	Annulation, striation, scratch marks (bioglyphs) etc.

The distinction may also be helped by circumstantial evidence involving other associated features such as the relative diversity of the associated trace fossils: in non-marine to marginal-marine settings these should be of low diversity and mainly of the _Scoyenia_ and _Teredolites_ ichnofacies; also characteristic of these habitats is an association of vertebrates trackways and dwelling-traces, lack of true feeding-burrows, and presence of true palaeosol horizons (see Table 16.1).

The root-penetration structures can be divided into two major categories (see Text-Fig. 16.1). To the first group belong rhizoliths or traces of roots and rootlets which are classified here as trace fossils; these can be defined by the nature of their external and internal features (Text-Fig. 16.1). There are five constituent zones (1 - 5) in a normal complete rhizolith structure (however, in practice most rhizoliths are incomplete in respect of these zones): zone (1) is an open tube, that was once occupied by a living root, commonly destroyed or filled-in during fossilization; zone (2) is normally formed as a cavity or entire core of the rhizolith; zone (3) is an indurated wall-layer comprising well-cemented sand; zone (4), the outermost zone, is less well-cemented and comprises relatively coarser-grained sand; zone (5) is really outside the root-penetrated structure and comprises chemically altered (reduced) host sediment which envelope the roots with variable thickness. The packing and density of the sand grains as well as the degree of induration of the sediment decreases towards the periphery of the whole root-penetration structure.
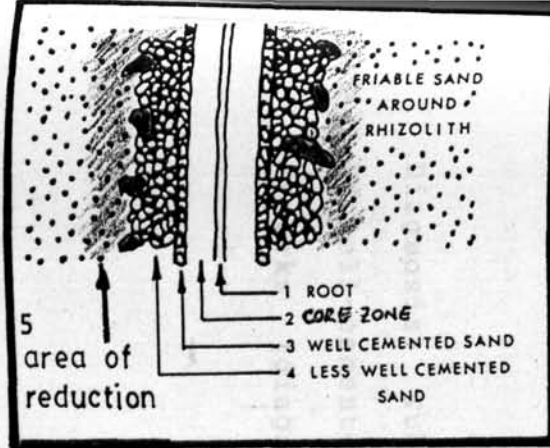
The rhizoliths can be further subdivided into four

TEXT-FIG. 16.1. Proposed classification scheme for root-penetration structures based partly on Klappa (1980), Jones & Kowk-Choi Ng (1988), and on examples observed in the present study area. The proposed classification contains two major types of root-penetration structures: firstly rhizoliths, which are considered to be trace fossils; secondly, roots/rootlet-petrification structures considered here to be body fossils. The definition and terminology of the first group is explained in the box at upper-left. There are five constituent zones (1 - 5): zone (1) is a central tube occupied by a root, but it is not invariably present for study; zone (2) is the central core zone of the rhizolith; zone (3) is the well-cemented wall-layer zone; zone (4) comprises coarser sand is and less well-cemented; zone (5) is the outermost zone, mainly occupied with host sediment, but with reduction overprints or other signs of chemical alteration.

The first group (rhizoliths) can be subdivided into four major categories: (1) type A, root-moulds, are simply tubular voids left after the root has decayed; (2) type B, root-tubules, comprise cement or cemented materials arranged in a cylindrical-shaped pattern around the root-moulds; (3) type C, root-casts, comprise infilling of the root-moulds, either by sediment, cement or both; and (4) type D, root-concretion or rhizoconcretion is a pedodiagenetic accumulation of mineral matter around the roots.

The other group, type E, root-petrifaction structures, are also considered to be root-penetration structures, defined by their petrifying processes which make it more appropriate to classify them as body fossils rather than as trace fossils. Root-petrification is a process which involves replacement, impregnation, encrustation, and void-filling of organic matter by mineral matter without total loss of the roots' anatomical features. Asterisks indicate the root-penetration structures observed in the present study area.

489

ROOT PENETRATION STRUCTURES

Branching (bifurcation) and tapering downward only

5 area of reduction

1 ROOT
2 CORE ZONE
3 WELL CEMENTED SAND
4 LESS WELL CEMENTED SAND

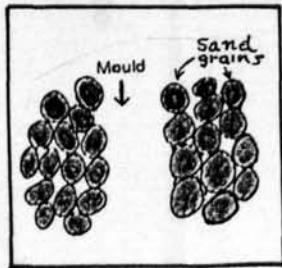FRIABLE SAND AROUND RHIZOLITH

RHIZOLITHS (trace fossils)
traces of roots and rootlets

ROOT/ROOTLETS. PETRIFACTION (body fossils)

*TYPE A
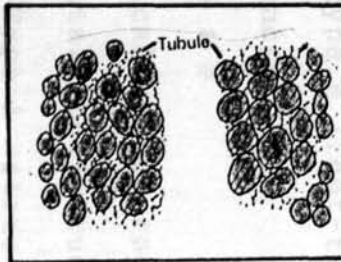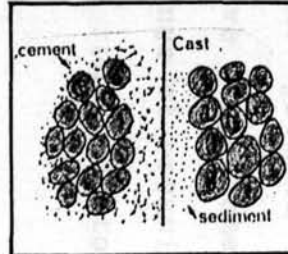
ROOT-MOULD

Tubular voids left after root decays

*TYPE B

ROOT-TUBULE

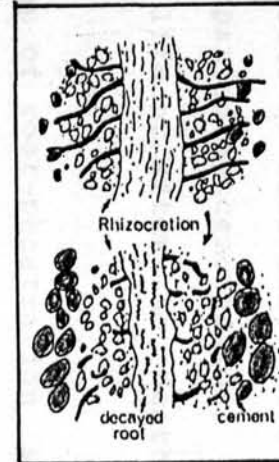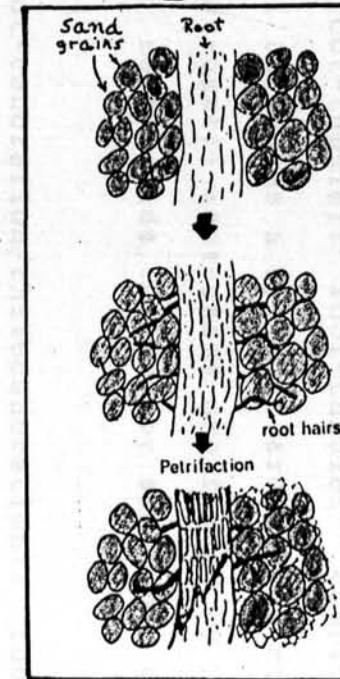Cylindrical-shaped zone of cemented sediment or cement surrounding root-mould

*TYPE C

ROOT-CAST

Infilling of root-mould, either by sediment or cement, or both

*TYPE D

ROOT-CONCRETION (RHIZOCONCRETION)

Pedodiagenetic mineral matter accumulated around roots

*TYPE E

Replacement of organic matter by mineral matter without total loss of root anatomical features

TEXT-FIG. 16.1.

489

categories (Text-Fig. 16.1):

Type A (root-mould): root-moulds are simply tubular voids left behind when roots have decayed.

Type B (root-tubule): root-tubules comprise cemented material formed as a cylinder around the root-moulds.

Type C (root-cast): root-casts are formed by the infilling of the root-moulds, either by sediment or cement or both.

Type D (root-concretion/rhizoconcretion): root-concretions can be described as pedodiagenetic accumulations of mineral matter around roots or root-casts. The accumulation, usually accompanied by cementation, may have occurred during the life or after the death of the plant.

The second major group of root-penetration structures are root/rootlet-petrifications (type E in Fig. 16.1), which are regarded as body fossils in the present classification. The root-petrifying processes involve replacements, impregnations, and encrustacions and void-fillings of organic matter by mineral matter without total loss of the roots' anatomical features.

Taxonomy

Type A (root-mould) with type B (root-tubules) and type D (root-concretion)

Plate 53, Figs. d & e

Diagnosis: Tubular- or cylindrical-shaped root-voids surrounded by well-cemented sand grains containing ferruginous cements.

Remarks (diagnostic features): Type A structures (root-moulds)

are about 0.5 cm to 1 cm in diameter (core zone 1) and are en-veloped with well-cemented relatively coarse sand and iron-oxide accumulation about 0.2 cm thick in zones 2 and 3 of the root-tubules (type B) or root-concretions (type D) (see Text-Fig. 16.1).

Description: The type A root-moulds with type B (root-tubules) and type D (root-concretion) are normally vertically orientated or steeply inclined, 10 cm to 15 cm in length and about 1.5 cm in diameter. The shape of the root-moulds is not entirely tubular or cylindrical, and some of the root-tubules and root-concretions are twisted or rope-like and all taper downwards with sporadic minor branching or bifurcation of second-order level rootlets at very acute angles to the primary root. No chemical alteration or reduction of roots are observed in these structures.

Comparison: In the present study the type A (and type B and type D) rhizoliths are somewhat comparable with the "tuberose rhizo-concretion" structures described by Klappa (1980) from aeolian-ites of Pleistocene age, at Call d'en Rabassa, Mallorca.

Distribution: The rhizolith structures occur mainly in palaeosol horizons of trace fossil subintervals ID1 and ID2 of the Lower Newport Member at St. Michaels Cave (area 5). Similar types of rhizoliths also occur in thin inextensive horizons in the Bald Hill Claystone and Middle Newport Member.

Studied material: None of the studied materials illustrated in Plate 53 have been retrieved from the field.

Preservation and association: The rhizoliths studied here are preserved as full-relief, vertically orientated or steeply in-

clined structures. They are well-defined by their zone 2 and zone 3 cemented sand grain layers (cf. Text-Fig. 16.1). These rhizoliths are associated with abundant other plant remains, but are not associated with other trace fossils of animal origin.

Ichnofacies and palaeoenvironmental affinities: The rhizoliths occur within thin palaeosol beds which were exposed to subaerial conditions, especially during regressive episodes associated with the proximal parts of a fluvially-dominated coastal lagoonal or estuarine environment. The rhizoliths probably belong to the _Scoyenia_ ichnofacies.

Type C (root-casts)
Plate 53, Figs. a & c

Diagnosis: Tubular- or cylindrical-shaped infilled structures of root-moulds or root-tubules, which are encased by a thin cemented layer (zone 3) surrounded in turn by a wide outermost zone of reduction halos .

Remarks (diagnostic features): Type C rhizoliths (root-casts) are normally of 5 cm to 15 cm in length and consist of a very thin infilled central core zone (less than 0.5 cm in diameter), enveloped by a very thin dark well-cemented wall-layer (zone 3). These root-cast structures are typically surrounded by a wide reduction zone. Some parts of the root-casts are flattened and some comprise root-petrifaction (type E) structures.

Description: Type C root-cast structures are normally developed in a vertical orientation, tapering downwards and invariably without branches. The entire core (mould and tubule) zone is normally filled with silty material identical to the host sedi-

ment and believed to be of palaeosol origin. These palaeosol host sediments comprise fine sand and silty sand and are well-laminated.

Comparison: Type C root-cast rhizolith structures are not comparable with the root-cast structures described by Klappa (1980), and differ from them by virtue of the former's more vertical orientation and downwards tapering shape, and typical presence of the surrounding reduction halos and lack of the less-cemented zone 3.

Distribution: The type C root-cast rhizolith structures illustrated in Plate 53 Figs. a & c are from trace fossil subinterval IF1 of the Upper Newport Member at south Palm Beach (area 4b). Similar types of root-cast structures are also observed in some palaeosol horizons of the underlying Middle Newport Member in other areas to the south.

Studied material: The root-casts illustrated in the Plate 53 Figs. a & c have not been retrieved from the field.

Preservation and association: The root-casts are commonly preserved as _in situ_ vertical, downward-tapering structures in well-laminated very fine sandstone and siltstone beds that are thought to represent palaeosols and are associated with other plant remains.

Ichnofacies and palaeoenvironmental affinities: Same as for type A rhizoliths.

Type E (root- and rootlet-petrifications)

Plate 53, Fig. b

Diagnosis: Small vertically orientated straight to slightly

curved, compressed or flattened petrified root penetration structures composed of highly carbonaceous materials.

Remarks (diagnostic features): The root-petrifications are very well preserved suggesting replacement of the plant material by mineral matter without total loss of the roots' anatomical features. The roots are small, about 0.5 to 1 cm in diameter, and 5 cm to 7 cm in length. The structural zones of the roots are not well defined and reduction zones around the roots are also lacking.

Description: These small vertically orientated small petrified plant roots or rootlets are well preserved including even the thin woody tissues (evident as small striations parallel to the longitudinal axis of the roots) and can still be examined. The roots lie almost parallel to each other and most of them are compressed or flattened. Most of these structures are straight, but some are curved and bifurcate downwards. The downwards-tapering structure is readily discernible in some terminal parts of the roots.

Comparison: The small petrified (carbonized) root structures are comparable with the root remains of plants that have grown in silty or muddy sediments of swamps and marshes.

Distribution: The root-petrifications illustrated in Plate 53 Fig. b are from trace fossil subinterval IE7 of the Middle Newport Formation at Little Head (area 7). Such petrifications probably aoour at other stratigraphic levels within the Bald Hill Claystone and Newport Formations but their distribution has been studied here in detail.

Studied material: The root-petrifications illustrated in Plate 53

Fig. b occur in sample 706b/MU.44412 collected from trace fossil subinterval IE7 of the Middle Newport Member at Little Head (area 7).

Preservation and association: These root-petrifications are preserved as full-relief, vertically orientated root-penetration structures and are associated with many other types of plant remains.

Ichnofacies and palaeoenvironmental affinities: Same as type A and type C rhizoliths.

16.3. ANIMAL REMAINS

Fossil animal remains in the study area are extremely rare, the known examples comprising amphibian bones in the Bald Hill Claystone at Long Reef Point (Beale, 1986), a few bivalves from the lower Newport Member at Warriewood Beach (Grant-Mackie et al., 1985); and numerous freshwater fish, an incomplete skull of a capitosaur amphibian and a variety of insects from a shale lens within the Hawkesbury Sandstone at the former Beacon Hill Quarry, Brookvale (cf. Branagan, in Packham, 1969, P.415-416). Fossil amphibian bones have been discovered at several sites and from several different formations in the Triassic of the Sydney Basin. The Lower and Middle Triassic Gosford subgroup (upper Narrabeen Group) contains the brachyopid Blinasaurus, the capito-saurid Parotosaurus and a femur of a very large capitosaurid (Warren, 1972). The Middle Triassic Hawkesbury Sandstone contains bones of the capitosaurid Parotosaurus, and ?Mastodonsaurus. The overlying Wianamatta Group contains a similar fauna including the brachiopid capitosaurid amphibian Paracyclotosausus davidi Wat-
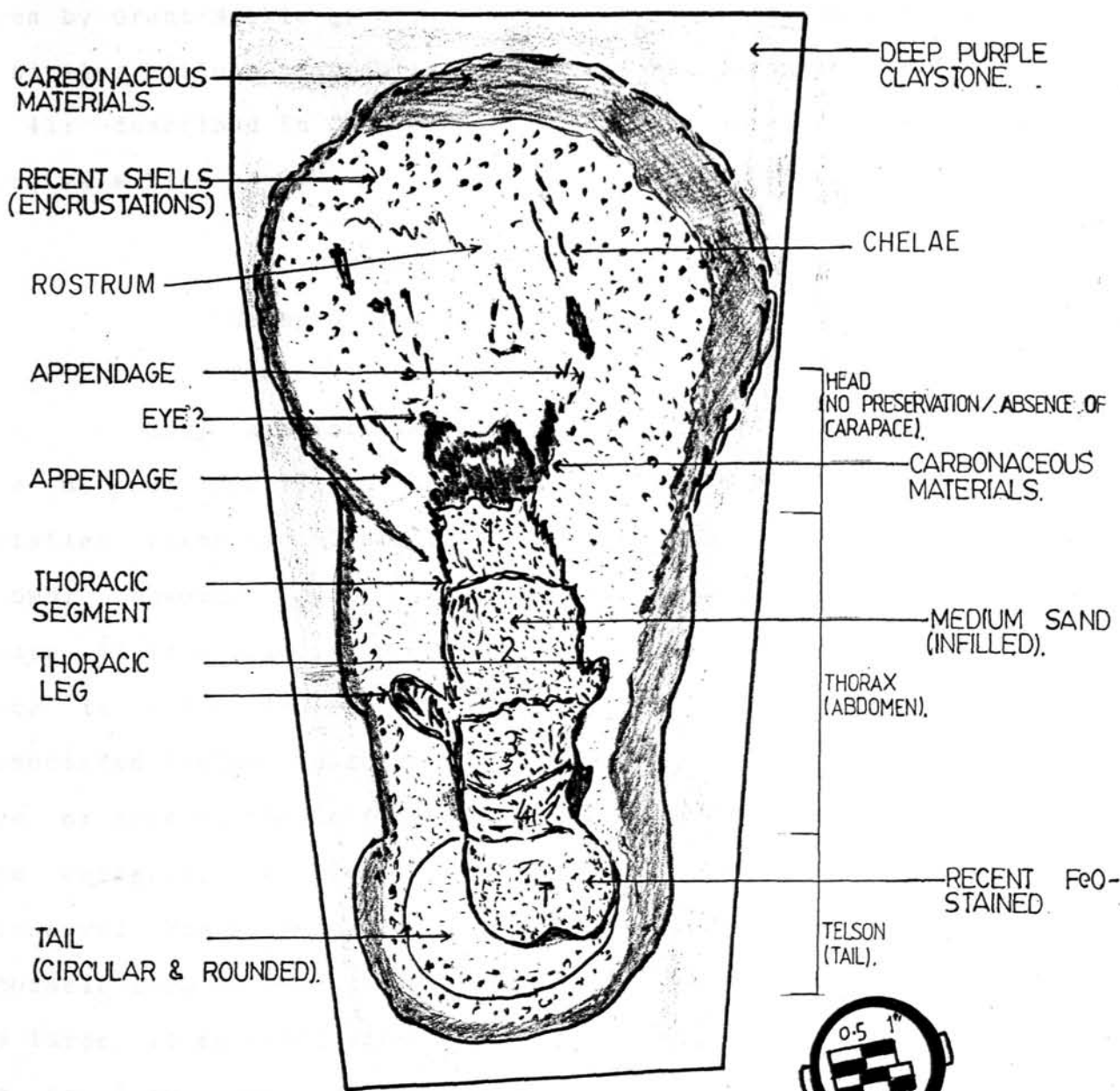
son, 1958 (Warren, 1972). But, both reptilian and amphibian (especially labyrinthodont) trackways are present in all formations of the upper Narrabeen Group, in the Hawkesbury Sandstone, and in the Wianamatta Groups (Fletcher, 1948; Sherwin, 1969; Pepperell & Grigg, 1973).

A large fossil crustacean was discovered in a shale lens of the Hawkesbury Sandstone at the Beacon Hill Quarry (Brookvale) (Chilton, 1928). This crustacean was identified as belonging to the Anaspidacea (Anaspides) which are extant in freshwater lakes and streams in the highlands of Tasmania. During the present study a large decapod crustacean was discovered for the first time in the Narrabeen Group, within trace fossil subinterval IC3/4 of the Bald Hill Claystone (Plate 74 Figs. a & b, and Text-Fig. 16.2). This fossil crustacean was discovered at Long Reef Point where it was associated with burrows of the new ichnogenus Turimettichnus conaghani, believed to have been produced by these same crustaceans (see Chapter 6 for details). Previously, the record of decapod crustaceans was thought to extand back only as far as the end of the Mesozoic. The present discovery extends the record of decapod crustaceans back towards the Devonian (cf. Schram et al., 1978), beyond the previously oldest known Mesozoic decapod crustacean fossil from the Upper Triassic of the USA (Miller & Ash, 1988; and Hastiotis & Mitchell, 1989).

The Pelecypod bivalve shells have been discovered from two localities during the present study. The first of these is in the Garie Formation (Lower Newport Member) at Warriewood

TEXT-FIG. 16.2. Sketch of the body fossil of the decapod crusta-
cean illustrated in Plate 74 Figs. a and b, that is associated
with burrows of the new ichnotaxon <u>Turimettichnus conaghani</u>. The
drawing is a dorsal view of the crustacean in which can be seen
partly-preserved cephalon parts (rostrum, chelae, and carapace),
and well-preserved thoracic and telson parts. The taxonomic
identity of the decapod crustacean is unknown.

CARBONACEOUS MATERIALS.

RECENT SHELLS (ENCRUSTATIONS)

ROSTRUM

APPENDAGE

EYE ?

APPENDAGE

THORACIC SEGMENT

THORACIC LEG

TAIL (CIRCULAR & ROUNDED).

DEEP PURPLE CLAYSTONE.

CHELAE

HEAD (NO PRESERVATION / ABSENCE OF CARAPACE).

CARBONACEOUS MATERIALS.

MEDIUM SAND (INFILLED).

THORAX (ABDOMEN).

RECENT FeO-STAINED.

TELSON (TAIL).

DORSAL VIEW.
(INTERNAL CAST OF FOSSIL SHRIMP).

0.5   1"
1   2   3"
SCALE.

TEXT-FIG. 16.2

497

Beach; similar bivalves were previously described from the same area by Grant-Mackie et al., (1985). The second discovery was of a bivalve mollusc trapped inside its own escape-burrow (Plates 40 & 41; described in Chapter 14) in the Lower Newport Member at Mona Vale Head.

Taxonomy

Decapod crustacean

Plate 74, Figs. a & b

Only a brief taxonomic identification can be given to the decapod crustacean because of its poor preservation (the detailed taxonomic identification and assignment are still unknown). However, it is clear that the specimen illustrated in Plate 74 is a crayfish or decapod crustacean. The head or carapace is not well-preserved, but parts of a broken rostrum and associated chelae, subchelae and pereiopods are evident. The left eye or area of the left eye is preserved and protrudes out from the carapace. The abdomen or thoracic part is moderately well-preserved. The segmentation joints are well-preserved with short thoracic legs on both sides of the body. The tail or telson part is large, is extended laterally (to both left and right) about 2 cm to 3 cm, and has a somewhat rounded outline. The length of the crustacean is about 20 cm from head to tail and the width 5 cm at the thorax. The fossil is preserved as a convex epirelief form on the surface of a bed of silty clay within the Bald Hill Claystone. The fossil is associated with burrows of comparable size to the animal and which are believed to have been produced by them.

The fossil was found immediately adjacent to a burrow of the new ichnogenus _Turimettichnus conaghani_ (Plate 74 Fig. a), and it is believed that crustaceans of this kind produced these burrows. Unfortunately, no trace of the hard parts of such crustaceans have been found inside the burrows, suggesting that they may have made these burrows for temporary residence (see more detailed discussion in Chapter 6). A similar decapod crustacean was found _in situ_ in a burrow in the Upper Triassic Chinle and Dolores Formations of the Colorado Plateau, USA (Hasiotis & Mitchell, 1989), such burrows having previously been interpreted to have been made by lungfish (Dubial et al., 1987).

Bivalve Molluscs: Category A (parautochthonous)
Plate 74, Fig. c

These fossil bivalve molluscs occur in small numbers, commonly as isolated valves and not as articulated individuals, in trace fossil subinterval ID1 of the Lower Newport Member at Warriewood Beach (area 6). A similar or identical kind of bivalve mollusc was described from the same area and stratigraphic level by Grant-Mackie et al. (1985) According to them these bivalves belong to the subfamily Modiolinae of the family Mytilidae, most of which groups are marine. This important discovery provides support for the idea of Bunny & Herbert (1971) that the lower part of the Newport Formation is of a trangressive, marine-influenced nature, possibly involving shallow deltaic or salt-marsh facies. The bivalve mollusc fossils are associated with the vertically orientated trace fossil _Tigillites_ (=_Skolithos_). The present additional documentation of a trace fossil assemblage

from this same stratigraphic level provides further support for this notion of marine influence.

Bivalve Mollusc: Category B (autochthonous - trapped inside the escape-burrow)

Plate 40.
Plate 41, Figs. a & b

This fossil bivalve mollusc occurs as a solitary artic-ulated specimen completely trapped within its escape-burrow. The bivalve is well-articulated and is exposed in a natural section which cuts through the anterior portion of the infilled cast of the shell. Faint growth lines on the shell are still evident. The beak is not very strong. The dentition and musculature are not visible and so hinder identification. A relatively long hinge-line is evident but the presence of posteriodorsal wings is not clear. The margins of the shell are smooth. No corrugation of the shell enclosure is evident. The mollusc's taxonomic identity is not known but it is believed to belong to the Mytilidae (as in the case of the category A bivalves) described by Grant-Mackie et al., (1985) from Warriewood Beach. This bivalve occurs in the same trace fossil subinterval (i.e., subinterval ID1) of the Lower Newport Member as the molluscs described from Warriewood Beach in the immediately foregoing section, and at the same stratigraphic level within this subinterval but occurs at Mona Vale Head (2 km north of Warriewood). The mollusc is trapped inside its escape-burrow and is believed to have lived in a brackish-marine to intertidal shallow-marine palaeoenvironment.

16.4. MICROFOSSILS

Micropalaeontological studies on rocks of the study area are very limited, and are restricted to a publications. The first mention of microfossils was from red siltstone and claystone from the upper portion of the Narrabeen Group by Connoly (1969). He claimed, without documentation, that most of his thin-sections showed the presence of ostracodes and foram tests which still retained their original shell structure. But he concluded that their preservation was not particular good because they were partly replaced by iron minerals. The first palynological study was carried out by Helby (1973) in which he reviewed the whole Late Permian and Triassic of the Sydney Basin. This was followed by palaeobotanical studies by Retallack (1973, 1975, 1977a, b, c, 1980), and more recently by Grant-Mackie et al., (1985). The palynological work of Grant-Mackie et al., (1985) from the horizon of the bivalve molluscs at Warriewood Beach demonstrated the presence of very rare acritarchs and abundant spores/pollens and megaspores. Grant-Mackie et al. (1985) suggest that the palaeoenvironmental affinities of the sediments on the basis of this palynoflora is marginal-marine, possibly a logoonal or estuarine situation which was of limited access to marine acritarchs. Micropalaeontological studies by J. Crowley (Macquarie University, in progress, 1990) on the trace fossil rich mudrock units of the Newport Formation from the present study area confirm this interpretation (Crowley, 1990).