Tech. Rep. Aust. Mus. Online
Number 39, pp. 1–52, 2023
https://doi.org/10.3853/j.1835-4211.39.2023.1819

Technical Reports of the Australian Museum Online
a peer-reviewed open-access journal
published by the Australian Museum, Sydney
communicating knowledge derived from our collections
ISSN 1835-4211 (online)

The Sydney Basin in the Triassic—A Review of the Geology, Flora and Fauna, and Ecosystems. The Narrabeen Group

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Abstract. The aim of this report is to provide a framework within which future earth science researchers of the Sydney Basin in the Triassic Period can work to rapidly access information relevant to their particular field of study. Information on the geology, flora and fauna and ecosystems has been extracted and summarized from an extensive range of papers published from the late 1800s to present day. In many cases the taxonomic classification of specimens has changed over the years as more data has come to light. The history of these changes has been noted. This information is backed by specimen lists and illustrated by images of selected specimens sourced from the extensive palaeontological collection of the Australian Museum, augmented by additional images from the collection of the Geological Survey of New South Wales. The major Triassic geological structures of the Sydney Basin are the Narrabeen Group, the Hawkesbury Sandstone and the Wianamatta Group. This report provides a consolidated review of data presently available for the Narrabeen Group. Future reports will cover the Hawkesbury Sandstone and the Wianamatta Group in a similar manner.

Introduction

As early Australian European settlement first occurred in the Sydney Basin there has been considerable work carried out in earth sciences in this area since the 1800s. The opening up of industries such as quarrying, and the construction of railways and roads, required geological investigations and revealed evidence of the life forms that existed during the formation of the Sydney Basin geological structures. This work peaked during the period between the 1930s and the 1980s and contributed to the understanding of the formation of Gondwana, tectonic movement, ancient climate and the Triassic ecosystem of the Sydney Basin.

The major Triassic geological structures of the Sydney Basin are the Narrabeen Group, the Hawkesbury Sandstone and the Wianamatta Group. This review draws together work in the earth sciences carried out on the Narrabeen Group. To do this, a brief discussion of the geology of the Narrabeen Group is set out while the fossil evidence is described in detail. At the conclusion of this report there is a discussion of the ecosystems that can be deduced from the accumulation of the fossil data described.

The Narrabeen Group consists of formations laid down in the Early Triassic Period, immediately after the Permian mass extinction. It comprises a range of shales, sandstones, claystones, siltstones and conglomerates produced over a lengthy period during which delta deposition occurred from the north, intermittent marine incursions occurred and sedimentary deposits from the Gerringong Volcanics spread from the east. The result was a complex series of formations up to 800 m thick of lithic conglomerate, quartz-lithic sandstone, and red, green, and grey shale (Herbert, 1980a).

The core section of this report, "Flora and Fauna", is a summary description of every taxon described or identified in the Narrabeen Group. The history of their taxonomic nomenclature and their changes is set out with the reasons for

Keywords: Sydney Basin, Triassic, Narrabeen Group, fossil sites, fossil fish, fossil plants, temnospondyl, archosaur, Crustacea
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Received: 27 October 2021 **Accepted**: 19 October 2022 **Published**: 18 October 2023 (online only)
Publisher: The Australian Museum, Sydney, Australia (a statutory authority of, and principally funded by, the NSW State Government)
Citation: McLean, Graham. 2023. The Sydney Basin in the Triassic—a review of the geology, flora and fauna, and ecosystems. The Narrabeen Group. *Technical Reports of the Australian Museum, Online* 39: 1–52. https://doi.org/10.3853/j.1835-4211.39.2023.1819

any change. The "Flora and Fauna" section is further divided into sites. Within the sites the content is grouped by taxa.

The palaeontology collection of the Australian Museum has been used as the basis for the description and images of flora and fauna. This is an extensive collection dating from the 1840s and contains later contributions of large sections of the collections of the University of Sydney, the University of New England, the University of Newcastle and the former Mining and Minerals Museum of NSW. Although the Australian Museum collection forms the basis of this document, information on relevant specimens still held in the collections of the Geological Survey of New South Wales (Londonderry) and the Natural History Museum (London) has been accessed and presented. An image or a drawing of every taxon described has been provided.

A quarry associated with railway construction produced some fine examples of the freshwater fish populations, while erosion of the headlands of the Northern Beaches of Sydney and the Central Coast provided a valuable account of the plant life during the formation of the Narrabeen Group. Other minor sites produced fossils that indicated the extent of the spread of plant and animal taxa across the Sydney Basin in the Triassic.

This review can be used by scientists and educators as a reference guide to the geology, life and conditions that existed during the initial formation of the Sydney Basin in the Triassic.

Future reports will cover the Hawkesbury Sandstone and the Wianamatta Group in a similar manner.

Explanation of abbreviations

AM—Australian Museum.
AM F.nnnn—Australian Museum fossil specimen registration number; a slash denotes part/counterpart specimen registration numbers.
AMGC—Australian Museum General Collection (Palaeontology).
AMTC—Australian Museum Type Collection (Palaeontology).
DS nnn—Dan Scully collection specimen number.
Fig., Figs—figures in this publication.
fig., figs—figures in other publications.
GSNSW—Geological Survey of New South Wales, Londonderry.
GSQ—Geological Survey of Queensland.
MF nnn—transfer specimen registration number for transfer between the Mining and Minerals Museum and the Australian Museum.
MM—Mining and Minerals Museum (now absorbed into the GSNSW collection at Londonderry).
MMF nnnn—Mining and Minerals Museum fossil specimen registration number (specimens now in Geological Survey of New South Wales collection at Londonderry).
MV P nnnn—Museum Victoria fossil specimen registration number.
NHMUK—Natural History Museum, United Kingdom.
pl.—plate.
QM—Queensland Museum.
QMF nnnn—Queensland Museum fossil specimen registration number.
SUP nnnn—Sydney University Palaeontology specimen registration number.
USGD nnnn—University of Sydney Geology Department specimen registration number.
#—specimen registration number not yet matched to figured specimen in collection records.
¿—specimen number unable to be matched to mentioned specimen as no identification is evident in collection records.

Taxonomic conventions used

The naming and placement of individual fossils from the Sydney Basin within a taxonomic structure has, in many cases, been subject to multiple changes and many are still under periodic discussion. This is often apparent within the Plantae. In this review the origin of each change and the reason is discussed in the description of the specimen.

Synonym lists include only the papers where taxonomic names have been emended. They do not include any papers where authors have used the nominated taxonomy without change.

In this study an attempt is made to provide all names that have been applied over the years and to use the name most recently considered valid. It is not the intention in this study to offer any new taxonomic interpretations, new names, new combinations, new spellings, or new synonymies.

Where taxonomic emendments have been made to the genus and/or species of similar specimens from another region, this has usually been noted within the description of the relevant species. Unless the author promoting the change in the other region specifically noted that it applied to the Sydney Basin species also, the change is not applied to the Sydney Basin species binomial taxonomic description in this document. For higher taxonomic levels the most recent worldwide agreement has been chosen.

Type material conventions

Type material includes nominated types (holotype, paratype etc.) as well as specimens figured or mentioned in the relevant peer reviewed journal paper. This follows the convention used in the AMTC where nominated types, figured and mentioned specimens are held within the Type Collection.

Nominated types in this paper include specimens from any site, but specimens figured or mentioned are only from the nominated site under discussion.

GEOLOGY

The Sydney Basin structure

The Sydney Basin extends from Durras in the south to the Hunter Valley in the north, and its western edge runs along the western side of the Blue Mountains. Its total area is approximately 52,000 square kms, of which 15,000 square kms is offshore (Alder *et al*., 1998) (Fig. 1a). The Sydney Basin is the southern part of a longitudinal chain of basins stretching through the Gunnedah Basin to the Bowen Basin in Queensland. Shallow basement at the Mt Coricudgy Anticline is believed to divide the Sydney and Gunnedah Basins, although rocks typical of the northern Sydney Basin are present to the north of the anticline. The Lachlan Fold Belt is positioned west of the southern end of the Sydney Basin, the New England Orogen lies to its north, while a chain of volcanic stubs, the Gerringong Volcanics, are positioned offshore at the southern end near Kiama (this structure is now entirely sub-marine) (Herbert, 1980a).

Late Carboniferous rifting and subduction initially formed foredeep structures associated with the New England Orogen and the Lachlan Fold Belt. Permian sedimentation developed in this foredeep depression. Sedimentation was initially marine, but Late Permian freshwater deposition was derived from the New England Fold Belt. Sediments were also periodically obtained from the Lachlan Fold Belt to the southwest. During the Late Permian *Glossopteris* forests thrived in the basinal marshes and laid down the eastern Australian coal deposits. Significant uplift at the end of the Permian Period resulted in the Triassic sediments being dominated by fluvial deposits and a marine retreat to the east. A line of volcanoes formed along the eastern edge in the south during the Permian, but were inactive and eroding during the Triassic (Herbert, 1980a).

The Triassic rocks of the Sydney basin are classified into three basic geological structures, marking major changes in sediment deposition. The earliest is the Narrabeen Group which shows evidence of marine influences due to subsidence and sea level changes, and many cycles of fluvial deposition from both the north and the southwest. This Group contains many interbedded shales, claystones and sandstones. After the Narrabeen Group deposition, massive quartzite sediments derived mainly from the Lachlan Fold Belt and delivered through an extensive braided river system formed the Hawkesbury Sandstone. Within these massive deposits shale lenses formed which preserved fossils that revealed evidence of the prevailing ecosystems. The Mittagong Formation is a thin intermediary deposit laid down between the Hawkesbury Sandstone and the Sydney Basin Triassic rocks which occur in the Wianamatta Group. The Wianamatta Group formed during a single marine regressive episode, and contains shales, sandstones, siltstones and claystones. These three main geological units were laid down within the first 15 million years of the Triassic (Fig. 1b).

Presently, all exposed rock surfaces in the Sydney Basin are Triassic. It is likely that Jurassic deposits existed above these Triassic rocks but have been completely eroded away without trace (Herbert, 1980a; Alder *et al*., 1998). Today, the Sydney Basin has an irregular "saucer" structure extending from the western Blue Mountains to the sub-marine east, from Durras in the south to the Hunter Valley in the north. This "saucer" contains the geological layers of Permian coal measures, the Triassic sediments of the Narrabeen Group formations, the Hawkesbury Sandstone, the Mittagong Formation and the Wianamatta Group formations. These geological layers surface in successive rings from the edge of the basin structure, with the youngest being the Wianamatta Group occupying the central area.

The Lapstone Monocline is a major geological feature of the Sydney Basin, running north/south over a distance of 160 km, to the west of which are the Blue Mountains. Basalt overlay dated at 45 Ma indicates it was formed later than the Mesozoic, sometime after 45 Ma (Fergusson & Hatherley, 2019). Sinking of the easterly section of the Sydney Basin along a number of hinges on a north/south line of this monocline led to a difference in levels of up to 600 m, producing a low-lying section of the Sydney Basin to the east and an elevated plateau, the Blue Mountains, to the west (Fig. 1c).

Sediment deposition

The deposition of the Narrabeen Group commenced at the end of the Permian Period, although there is still some discussion about the Permian/Triassic boundary in these sediments. Up to 800 m of lithic conglomerate, quartz-lithic sandstone and shale were deposited during this episode (Herbert, 1980a).

Initially, uplift in the New England Fold Belt to the north resulted in coarse detritus being deposited by alluvial fans in the Hunter Valley area. These alluvial fans developed south-westwards across the Sydney Basin, finally covering estuarine deposits left by Late Permian transgressions with finer claystone and siltstone sediments. The lower Narrabeen Group therefore displays an upward gradation from basal estuarine and fine-grained alluvial sediments to braided alluvial coarse-grained sediments, deposited during an overall regression from the northeast to the southwest. This process produced the Munmorah Conglomerate, the Stanwell Park Claystone, Wombarra Claystone and Dooralong Shale, among others (Herbert, 1980a).

Deposition continued uninterruptedly during the middle Narrabeen episode, but in the north low gradient meandering streams swung to flow in a south easterly direction. Fine grained sediments were deposited in floodplains producing the Tuggerah Formation and the Patonga Claystone (Herbert, 1980a). Increasing quartzose sedimentation came from the western margin (Ward, 1972b). At the same time in the south volcanic sediment derived from the Gerringong Volcanics in the east was being deposited westwards and northwards to form the Bulgo Sandstone, one of the thickest of the formations in the Narrabeen Group (Ward, 1972a). The Sydney Basin at this time was entirely fluvial (Crook, 1957).

Diminishing sediment supply and continued subsidence during the upper Narrabeen episode caused minor marine transgressions over some fluvial deposits. New England Fold Belt sediments did not reach the southern or western basin. Instead, claystone and siltstone red beds were deposited over the central and southern areas of the basin, possibly as a result of southern uplift. The mineralogy of the Bald Hill Claystone overlaying the Bulgo Sandstone indicates that the clays were obtained from volcanic rock weathering, probably derived from the Permian Gerringong Volcanics positioned in the Kiama area east of the present coastline. General subsidence exceeded the rate of sedimentation in the south and the Bald Hill Claystone Member was gradually transgressed. The Garie Formation to the east of this region was formed in an estuarine environment by marine erosion of the Bald Hill Claystone during this time (Herbert, 1980a). The Terrigal Formation (formerly the Gosford Formation) and the Newport Formation were the uppermost Narrabeen Group formations laid down in a fluvial freshwater lake environment. The Terrigal Formation exhibits at least six

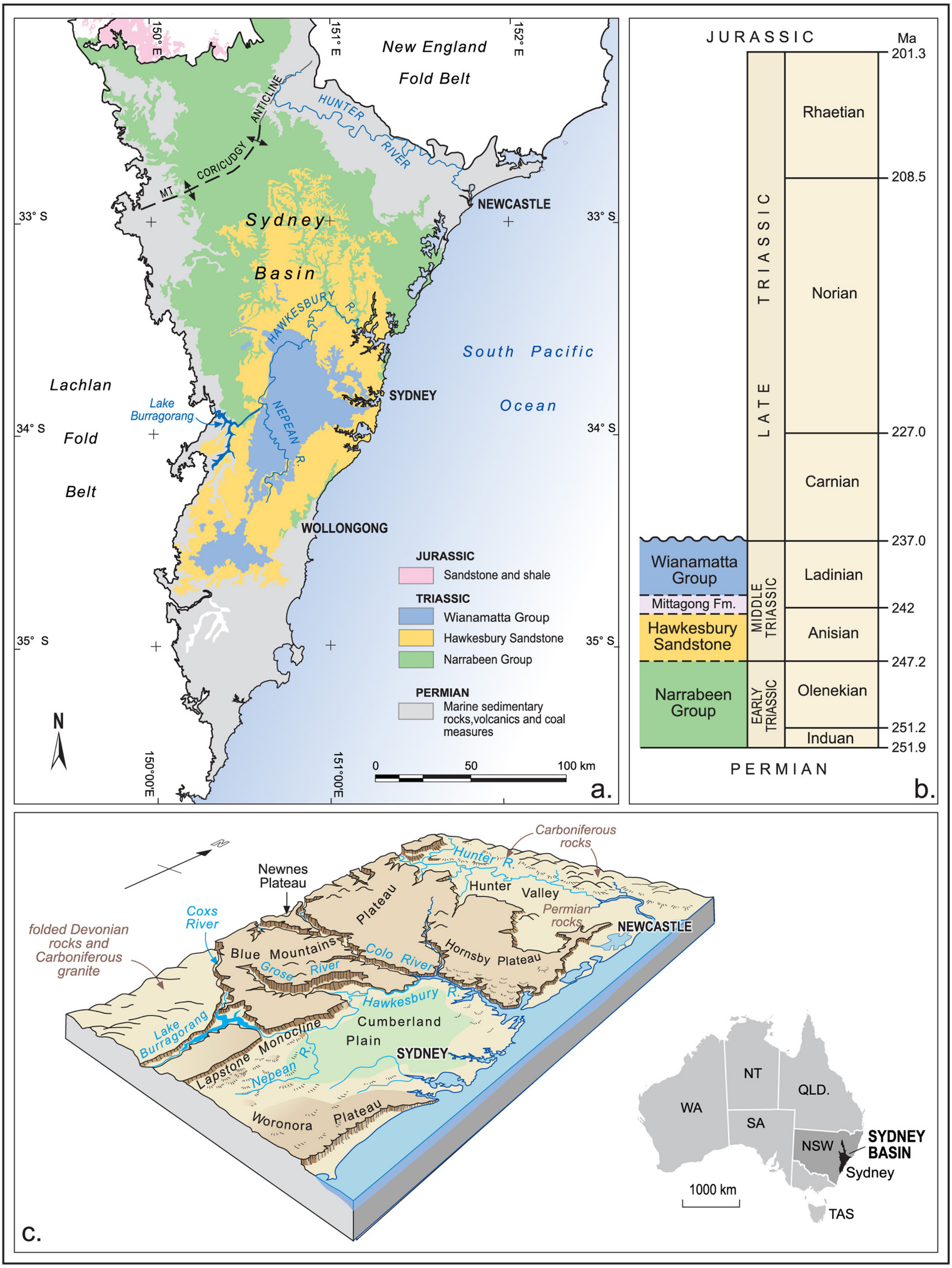

Figure 1. Sydney Basin structure. (*a*) Outcropping exposure of the three geological groups of Triassic rocks in the Sydney Basin. (*b*) Stratigraphic position of the three geological groups within the Triassic of the Sydney Basin. (*c*) Simplified topographic diagram of the central and northern sections of the Sydney Basin. Artwork by Dean Oliver.

stages of fluvial deposition (McDonnell, 1980).

Herbert (1993) also proposed that further sea-level changes affected sedimentation throughout the north-eastern area of the entire Narrabeen Group. Crossbedding in the Tuggerah Formation indicated tidal influence, foraminifera and bioturbation in the Patonga Claystone suggested a marine bay environment, point bar sandstones in the Terrigal Formation were interpreted as barrier islands and tidal deltas. Sedimentary cycles were created by a combination of sea level changes and sediment subsidence and uplift.

In the west, sandstone that is now exposed in the Blue Mountains was deposited by a fluvial system entering the Basin from the northwest via the Gunnedah Basin from the new England Fold Belt (Herbert, 1993).

Today, Narrabeen Group rocks are exposed in an arc encompassing the Blue Mountains, running north to the edge of the Hunter Valley, curving east then south down the coast along the Northern Beaches to Long Reef (Fig. 2). They are also evident in the Illawarra escarpment.

Palaeotopography

The Narrabeen Group is exposed in a number of regions, including the cliff lines of the Blue Mountains and particularly the headlands of the present east coast (Fig. 3a–d). These exposures provide clues to the topography of the Sydney Basin during this time.

Retallack (1977b) described a series of palaeosols exposed in the Northern Beaches headlands and some southern headlands of Sydney. The Bald Hill Claystone exposed at Long Reef Headland exhibits up to 8 palaeosols, as does the Bald Hill Claystone of Garie Beach Headland in the south. The minerals in these soils indicated they were well drained. The Turimetta Headland palaeosol constituents indicated the palaeosol was wet most of the yearly cycle and probably developed on a swampy, alluvial plain. The Avalon Headland palaeosols were probably soils of low lying areas. The Warriewood Headland palaeosols were similar to modern soils that develop around lakes and rivers that have a high water table. The St. Michaels Cave palaeosols probably developed on levees and point bar ridges. The South Head palaeosol series compare favourably with modern soils that form on levees (Retallack, 1977b).

Based on the palaeosol types and fossil plant evidence Retallack (1977b) reconstructed a topography that formed during the laying down of the Narrabeen Group in the area now known as the Northern Beaches headlands. This showed freshwater rivers running through low-lying lacustrine areas feeding through deltas into a large coastal lake, intermittently blocked from the open sea by a volcanic ridge, which occasionally gave access to maritime transgressions.

Naing (1993) studied the trace fossils found in the Bald Hill Claystone, the Garie Formation and the Newport Formation of the upper Narrabeen Group. Naing identified four assemblage zones within the Newport Formation which confirmed the presence of brackish, shallow marine conditions and the occurrence of four marine tongues along the Northern Beaches headlands between Long Reef and Broken Bay. Trace fossil assemblages in these tongues indicated the presence of a brackish to shallow marine, low energy coastal lagoon with a sand barrier which experienced periodic fluvio-lacustrine episodes, suggesting a presence of short-lived marine transgressions in the early to Middle Triassic.

In the west, sediment deposited via the Gunnedah Basin formed a sandy alluvial plain which graded into intermittent marine transgressions from the east (Herbert, 1993).

Stratigaphy

Formations within the Narrabeen group are exposed at sites along the Sydney Basin coast (Fig. 3a,b), inland at quarries and escarpments, and spectacularly on the faces of the Blue Mountains cliffs (Fig. 3c,d).

On the headlands from Long Reef north to Palm Beach on the Northern Beaches of Sydney the Bulgo Sandstone, Bald Hill Claystone, Garie Formation and Newport Formation are exposed (Fig. 3e). Further north the Terrigal Formation dominates the headlands with excellent exposure at The Skillion, Terrigal. This formation was also exposed in the Ballast Quarry near Gosford during the construction of the northern railway line in the 1890s (Fig. 3e).

In the Blue Mountains the western stratigraphy of the Narrabeen Group is exposed on many clifflines. The Three Sisters structure reveals the sequence of Burra-Moko Head Sandstone, a Mount York Claystone bench, then the Banks Wall Sandstone which forms the Three Sisters (Bembrick, 1980) (Fig. 3e).

A complete sequence of the southern Narrabeen Group can be seen on the Illawarra coast at the Seacliff Bridge where the Coal Cliff Sandstone, Wombarra Claystone, Scarborough Sandstone, Stanwell Park Claystone, Bulgo Sandstone, Bald Hill Claystone, Garie Formation and Newport Formation can be observed (Martyn, 2018) (Fig. 3e).

Fossiliferous deposits

Fossil specimens have been preserved in the fine muddy sediments of the successive fluvial deposits of the Narrabeen Group. Plant fossils are dominant in the strata exposed on the Northern Beaches headlands, and are often found in rockfalls from the cliff faces. Shales exposed during quarrying, mining or road and rail construction also contain specimens. Shales on coal mine roofs have revealed animal footprints and plant fossils, while shales quarried for railway ballast have contributed a range of fish specimens.

FLORA AND FAUNA

Fossil specimens from the Narrabeen Group have been recovered from two major sites and a number of minor sites (Fig. 2). The major sites were Gosford Ballast Quarry which produced temnospondyls, a range of fishes and some plants, and the Northern Beaches headlands in which many plant species (and one fish) were found. The minor sites included colliery roof shales, boreholes, some quarries and railway cuttings and tunnels. Most specimens were preserved in fine grained shales. The quarries and cuttings accessed surface strata, headlands provided naturally exposed stratigraphic columns, but the collieries allowed deep access to buried preservation sites around the edge of the Narrabeen sediments otherwise inaccessible to searchers.

Gosford Ballast Quarry

Gosford Ballast Quarry was opened to provide railway ballast for the northern railway being driven through the Hawkesbury River area of New South Wales. The quarry accessed shale from the local Narrabeen Group of rocks and was situated just west of the Gosford railway station. The quarry accessed a 1.8 m thick layer of purplish grey, sandy shale and laminated mudstone within the formerly named Gosford Formation (now known as the Terrigal Formation). Wade (1940) stated that the fossiliferous horizon was about 15 cm thick.

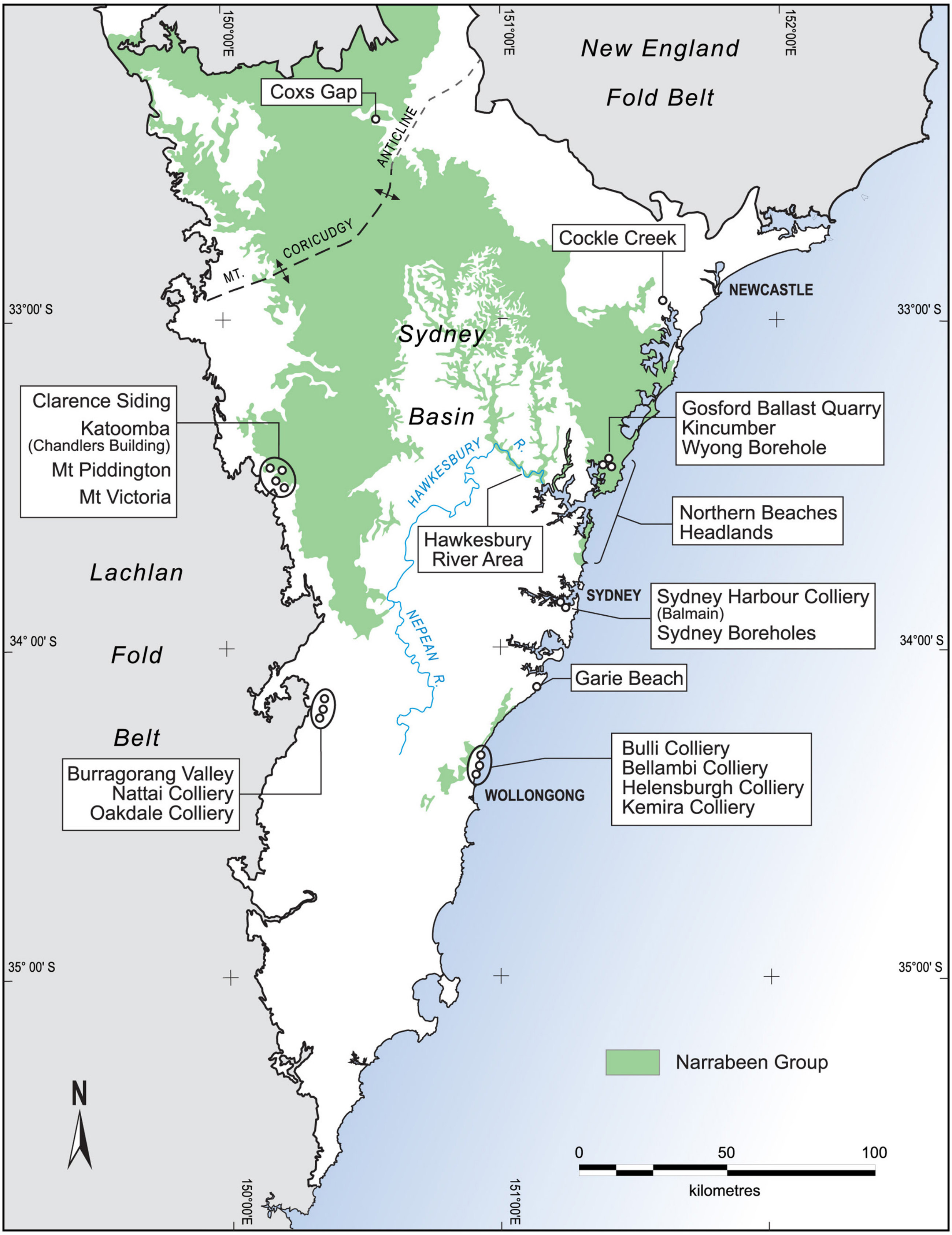

Figure 2. Narrabeen Group outcrops and fossil sites. Artwork by Dean Oliver.

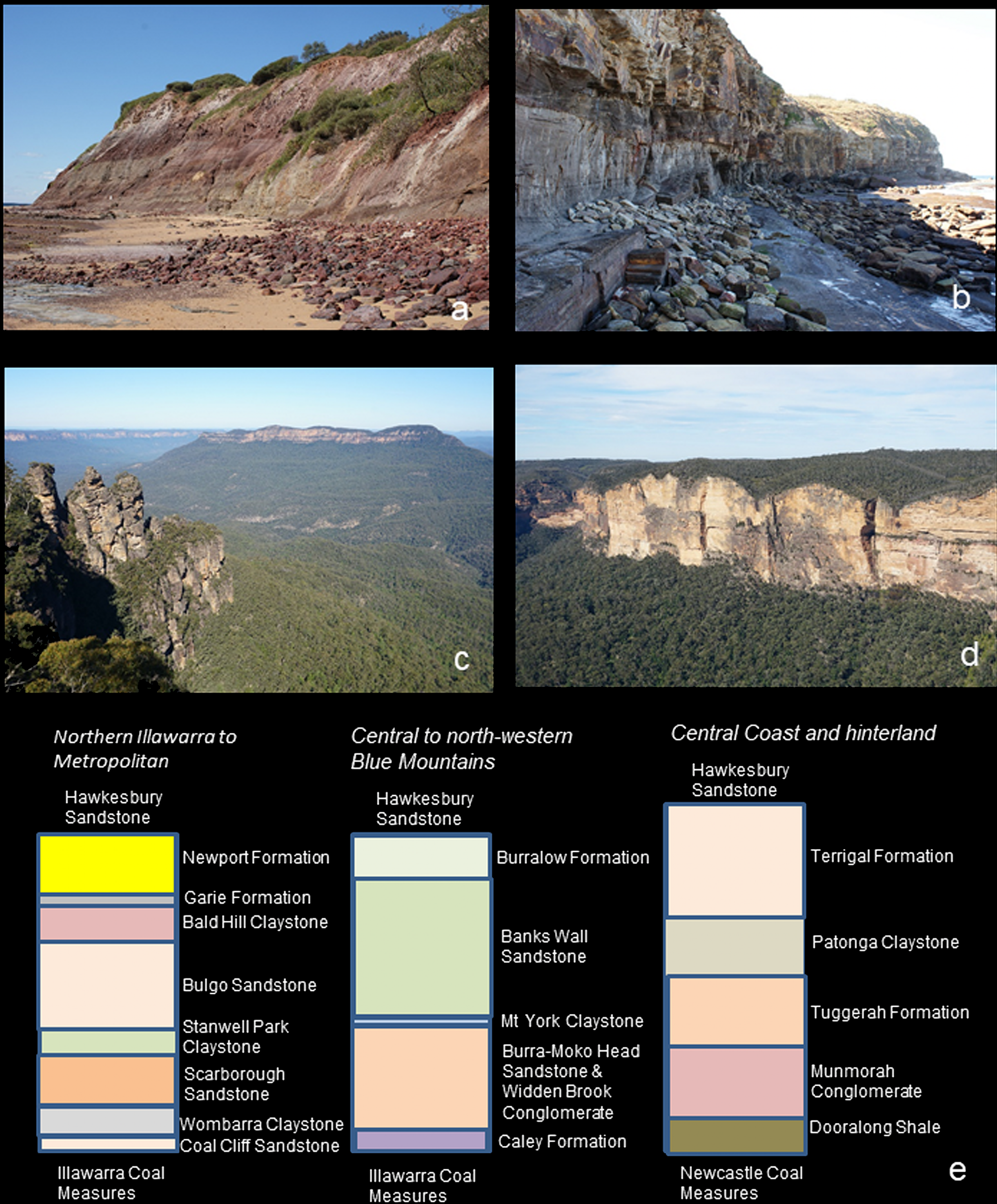

Figure 3. Narrabeen Group cliffline exposures and lithostratigraphic columns. (*a*) Long Reef Headland. (*b*) Turimetta Headland. (*c*) The Three Sisters, Katoomba, with Mt Solitary in the background. (*d*) Cliffline opposite Evans Lookout, Blackheath. (*e*) Cliffline exposure lithostratigraphic columns for the southern, western and northern areas of the Sydney Basin.

The quarry was only used for a brief period in the mid 1880s before being closed after the railway construction moved on. During this period, however, a significant range of fossils were discovered. Specimens of temnospondyls, fishes and plants were recovered in 1886 and 1887. C. S. Wilkinson (in Woodward, 1890) identified Mr Blunt, a railway contractor, as the finder, and the specimens were passed through a Mr Lambert to Wilkinson. Wilkinson, the Geological Surveyor-in-Charge in the Geological Survey of NSW, then sent Mr Cullen to Gosford to collect specimens.

Class Amphibia

Two species from the Gosford Ballast Quarry have been named and described, and a third specimen awaits description.

Order Temnospondyli
Superfamily Brachyopoidea
Family Brachyopidae

Platycepsion wilkinsoni (Stephens, 1887)

Fig. 4a,b

Platyceps wilkinsonii Stephens, 1887: 1118, pl. 22.
Bothriceps wilkinsoni [sic].—Lydekker, 1890: 172.
"Platyceps" wilkinsoni.—Watson, 1956: 338, text fig. 11, pl. 39.
Platycepsion wilkinsoni.—Kuhn, 1961, p. 79.
Blinasaurus wilkinsoni.—Cosgriff, 1969: 68, fig. 3.
Platycepsion wilkinsoni.—Warren & Marsicano, 1998: 333, fig. 2.

Type: MMF 12572 (Fig. 4a,b)—held in the GSNSW collection.

Stephens (1887c) described a "Baby Labyrinthodont" unearthed during work on a railway cutting in the Terrigal Formation near Gosford. It was found in a shale lens exposed in a ballast quarry and comprised a head, thoracic plates with vertebrae and ribs. Close examination showed that the back of the animal had been removed with the lost counterpart, exposing the ribs and ventral plates. Stephens named this specimen *Platyceps wilkinsonii* (Stephens, 1887c).

Lydekker (1890) listed this specimen in a British Museum catalogue as *Bothriceps wilkinsoni* [sic].

The taxonomy of this specimen was reviewed by Watson (1956) who cited it as "*Platyceps" wilkinsoni,* as the genus *Platyceps* was pre-occupied within snake taxonomy.

Kuhn (1961) then erected a new genus *Platycepsion* and placed this species within it.

Cosgriff (1969) was unaware of the genus reclassification of "*Platyceps"* to *Platycepsion* by Kuhn (1961) and nominated this specimen as a synonym "*Platyceps" wilkinsoni* within his new genus *Blinasaurus*, due to its close relationship to a Western Australian form.

Warren & Marsicano (1998: 334) noted typical juvenile characteristics in the type specimen and redescribed it as "*Platycepsion wilkinsoni*, a small, immature temnospondyl". They recommended the name *Platycepsion* be restricted to *Platycepsion wilkinsoni* "as it was a juvenile specimen with a single autapomorphy" (Warren & Marsicano, 1998: 336).

Two further finds from the Gosford Ballast Quarry were described by Stephens (1888). He tentatively identified both as *Platyceps wilkinsonii.* However, both Cosgriff (1972) and Damiani & Warren (1997) placed these specimens in the Capitosauridae (see *Parotosuchus wadei* below).

Superfamily Mastodonsauroidea
Family Mastodonsauridae
Parotosuchus wadei (Cosgriff, 1972)

Fig. 4c–e

Platyceps wilkinsonii Stephens, 1888: 158.
Parotosaurus wadei Cosgriff, 1972: 546, text fig. 1, pl. 1.
Parotosuchus wadei.—Damiani & Warren, 1997: 282, figs 1,2.

Holotype: AM F.55341 (MF 165) (Fig. 4d)—held in the AMTC under "Cosgriff 1972".
Paratype: MMF 12696 (Fig. 4c,e)—held in the GSNSW collection.
Other specimens: 4 casts of AM F.55341 held in the AMGC under "Amphibia/Labyrinthodontia".

Stephens (1888) described two further temnospondyl specimens obtained from the Gosford Ballast Quarry during the construction of the railway. He tentatively identified them as *Platyceps wilkinsonii*. The specimens were not numbered, no photographs or diagrams were published, but dimensions were tabled. He noted that both specimens were coated with "a kind of black Japan" (Stephens, 1888: 157).

Cosgriff (1972) described two specimens of temnospondyls, one from the collection of the Australian Museum (AM F.55341 (MF 165)), transferred from the Geological and Mining Museum in 1935, and the other from the Geological and Mining Museum of NSW collection (MMF 12696). AM F.55341 comprised a nearly complete external impression of a skull roof. MMF 12696 comprised an internal impression of bones forming part of the skull roof, an external impression of the shoulder girdle and a carbonized impression of the trunk and tail. He named them *Parotosaurus wadei* within the Capitosauridae, unaware that Ochev and Shishkin (in Kalandadze *et al*., 1968) had reclassified *Parotosaurus* as *Parotosuchus*.

However, Damiani and Warren (1997) state that these two specimens were actually those described tentatively by Stephens (1888) as being *Platyceps wilkinsonii* (a brachyopid), a fact about which Cosgriff was unaware. Damiani and Warren went on to re-interpret these specimens as *Parotosuchus wadei* nomen dubium, as they exhibit immature morphology and significant allometric changes occur during the growth stages of Capitosauridae.

After a revised phylogenetic analysis, Damiani (2001) placed all previously nominated Capitosauridae in Mastodonsauridae.

Pisces

Original taxonomic work on the Gosford fish specimens was carried out by Woodward (1890) of the British Museum (Natural History Branch), London (now the Natural History Museum, London). Later, Wade (1940) reviewed the work of Woodward and updated the taxonomy of five genera.

All the specimens described by Woodward (1890) were first held in the GSNSW collection. In 1935 and 1939 some of these specimens were transferred to the Australian Museum as a result of an exchange agreement. Some of the transferred specimens had been registered in the GSNSW collection and were numbered (e.g., MMF 186) and some were unregistered. Every specimen transferred was given a sequential "MF transfer number" by the Australian Museum, starting at "MF 1" (e.g., MF 191). Subsequently the Australian Museum progressively accessioned the MF specimens into their registration system (e.g., AM F.85958). This process has been indicated below (e.g., AM F.85958 (MF 191) (MMF 186)).

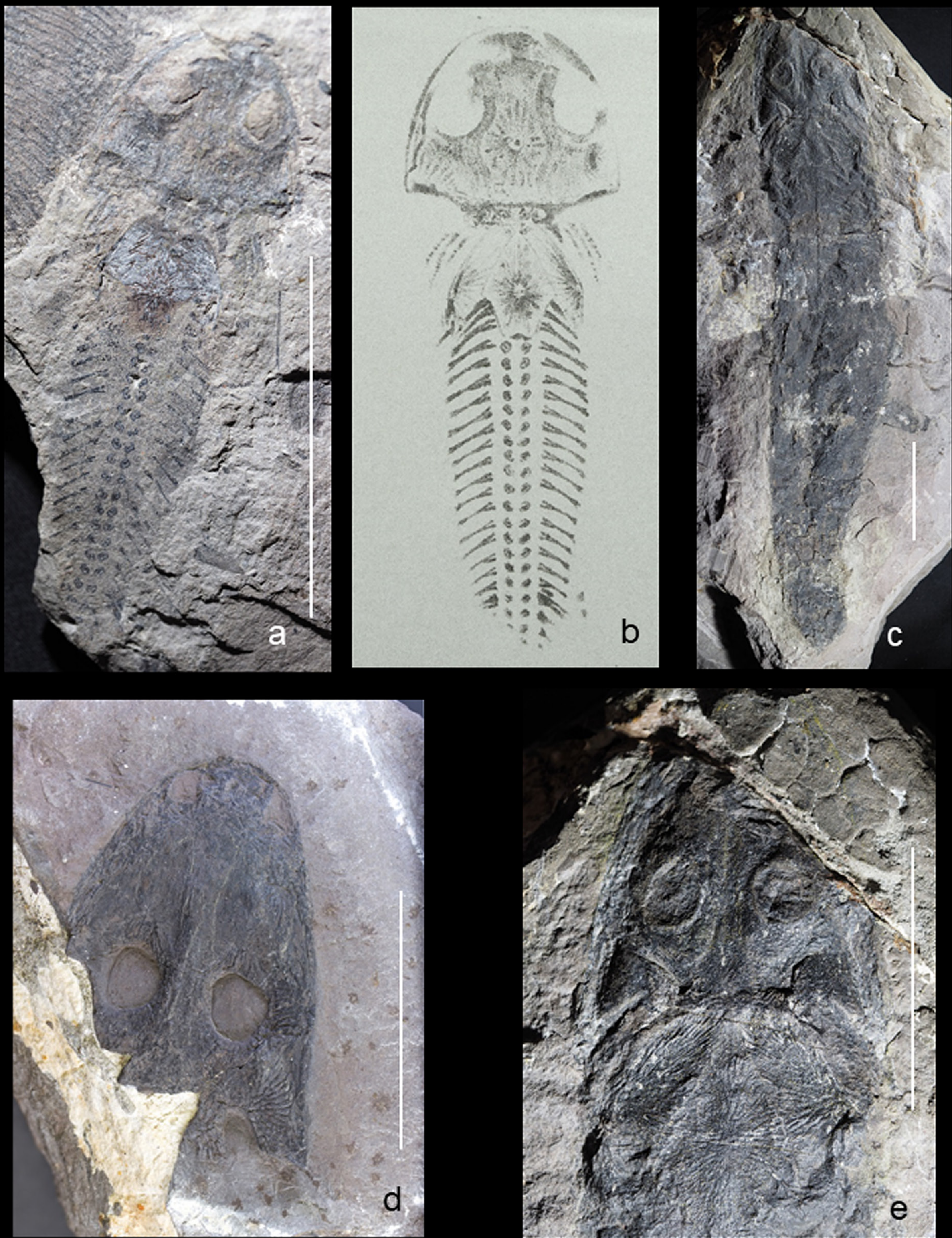

Figure 4. Gosford Ballast Quarry. Temnospondyli. (*a*) MMF 12572 *Platycepsion wilkinsoni.* (*b*) *Platycepsion wilkinsoni,* from Stephens (1887c) with permission of Linnean Society of NSW. (*c*) MMF 12696 *Parotosuchus wadei*. (*d*) AM F.55341 *Parotosuchus wadei*. (*e*) MMF 12696 *Parotosuchus wadei*. Scale bars = 5 cm.

Class Chondrichthyes

Order Xenacanthiformes

Family Sphenacanthidae incertae sedis

This specimen was described and noted as “Genus non det.” by Woodward (1890, p.3), but was not figured, and the specimen has since been lost. This is unfortunate as it had features suggestive of a British Carboniferous selachian, *Sphenacanthus* (Woodward, 1890). Further study of this specimen would have cast light on the presence of sharks in this area during the Triassic.

Woodward (1890) classified the specimen in Cestraciontidae within the Order Selachii.

Class Sarcopterygii

Subclass Dipnoi

Order Ceratodontiformes

Family Ceratodontidae

Gosfordia truncata Woodward, 1890

Fig. 5a–d

Syntype: AM F.50975 (MF 166) (MMF 389) (Fig. 5b) (pl. 1 fig. 1)—head and anterior portion of trunk—held in the AMTC under “Woodward 1890”.
Syntype: MMF 14235 (Fig. 5a) (pl. 2 fig. 1)—greater portion of trunk to tip of tail—held in the GSNSW collection.
Figured: AM F.85958 (MF 191) (MMF 186) (Fig. 5c) (pl. 1 fig. 2)—terminal portion of trunk with median and pelvic fins—held in the AMTC under “Woodward 1890”. | MMF 13347 (MMF 154) (Fig. 5d) (pl. 2 fig. 2)—fragment with fin rays—held in the GSNSW collection.
Mentioned: ¿—portion of the axial skeleton of trunk—possibly held in the GSNSW collection.
Other specimens held in the GSNSW collection are: MMF 13348, MMF 13382–13387, MMF 26663.

Woodward (1890) noted that the head was remarkably small and behind it the trunk rapidly deepened. Although the specimens were only fragments, he estimated the total length of the fish to be not less than 60 cm.

Class Actinopterygii

Subclass Chondrostei

Order Palaeonisciformes

Family Palaeoniscidae

Myriolepis clarkei Egerton, 1864

Fig. 5e

Syntype: Egerton (1864) named a specimen from Campbelltown, NSW as the holotype—it was not figured and is probably lost.
Syntype: AM F.5729. Egerton (1864) figured this specimen from Cockatoo Docks, NSW—head and anterior section of trunk—held in the AMTC under “Egerton 1864”.
Figured in Woodward (1890): AM F.50976 (MMF 391) (Fig. 5e) (pl. 2 fig. 3)—large complete fish—held in the AMTC under “Woodward 1890”. | AM F.120541 (MF 194) (MMF 110) (pl. 3 fig. 1)—head and pectoral fin—held in the AMTC under “Woodward 1890”. | MMF 13345 (MMF 155) (pl. 2 fig. 4)—dorsal fin—held in the GSNSW collection.
Mentioned in Woodward (1890): MMF 106—caudal pedicle with portions of fins—held in the GSNSW collection. | ¿—imperfect head and trunk—possibly held in the GSNSW collection.

Woodward (1890) noted that the large complete fish could have been at least 43.5 cm long, and the caudal region gradually tapered to a caudal pedicle which terminated into a large upper lobe.

Myriolepis latus Woodward, 1890

Fig. 5f

Type: AM F.50974 (MMF 384) (Fig. 5f) (pl. 3 fig. 2)—complete fish—held in the AMTC under “Woodward 1890”.
Figured: MMF 13344 (MMF 169) (pl. 3 fig. 3)—left infraclavicle—held in the GSNSW collection.
Mentioned: AM F.135648 (MF 193) (MMF 158)—greater portion of head and trunk—held in the AMTC under “Woodward 1890”.

Woodward (1890) observed that, compared with *M. clarkei*, this species was much less elongated and the scales are twice as large in proportion.

Apateolepis australis Woodward, 1890

Fig. 6a

Type: AM F.120548 (MF 175) (MMF 157) (Fig. 6a) (pl. 4 fig. 1)—complete fish—held in the AMTC under “Woodward 1890”.
Figured: AM F.120547 (MF 186) (MMF 144) (pl. 4 fig. 2)—fish without head on slab with *Pristisomus gracilis*—held in the AMTC under “Woodward 1890”. | MMF 171 (pl. 4 fig. 3)—tail—held in the GSNSW collection. | MMF 165 (pl. 4 fig. 4)—fragment showing flank scales—held in the GSNSW collection.
Mentioned: MMF 108 (counterpart of MMF 111)—greater part of fish—held in the GSNSW collection.

The trunk is slender, the upper tail lobe is elongated and the dorsal fin is placed over the posterior portion of the pelvic fins (Woodward, 1890).

Order Redfieldiformes incertae sedis

Dictyopyge symmetrica Woodward, 1890

Fig. 6b

Dictyopyge symmetrica Woodward, 1890: 17, pl. 4 figs 5,6.
Type: AM F.120553 (MF 173) (MMF 145) (Fig. 6b) (pl. 4 fig. 5)—complete fish—held in the AMTC under “Woodward 1890”.
Figured: AM F.120554 (MF 167) (MMF 121) (pl. 4 fig. 6)—almost complete—held in the AMTC under “Woodward 1890”.
Mentioned: MMF 13394 (MMF 120)—complete trunk without paired fins—held in the GSNSW

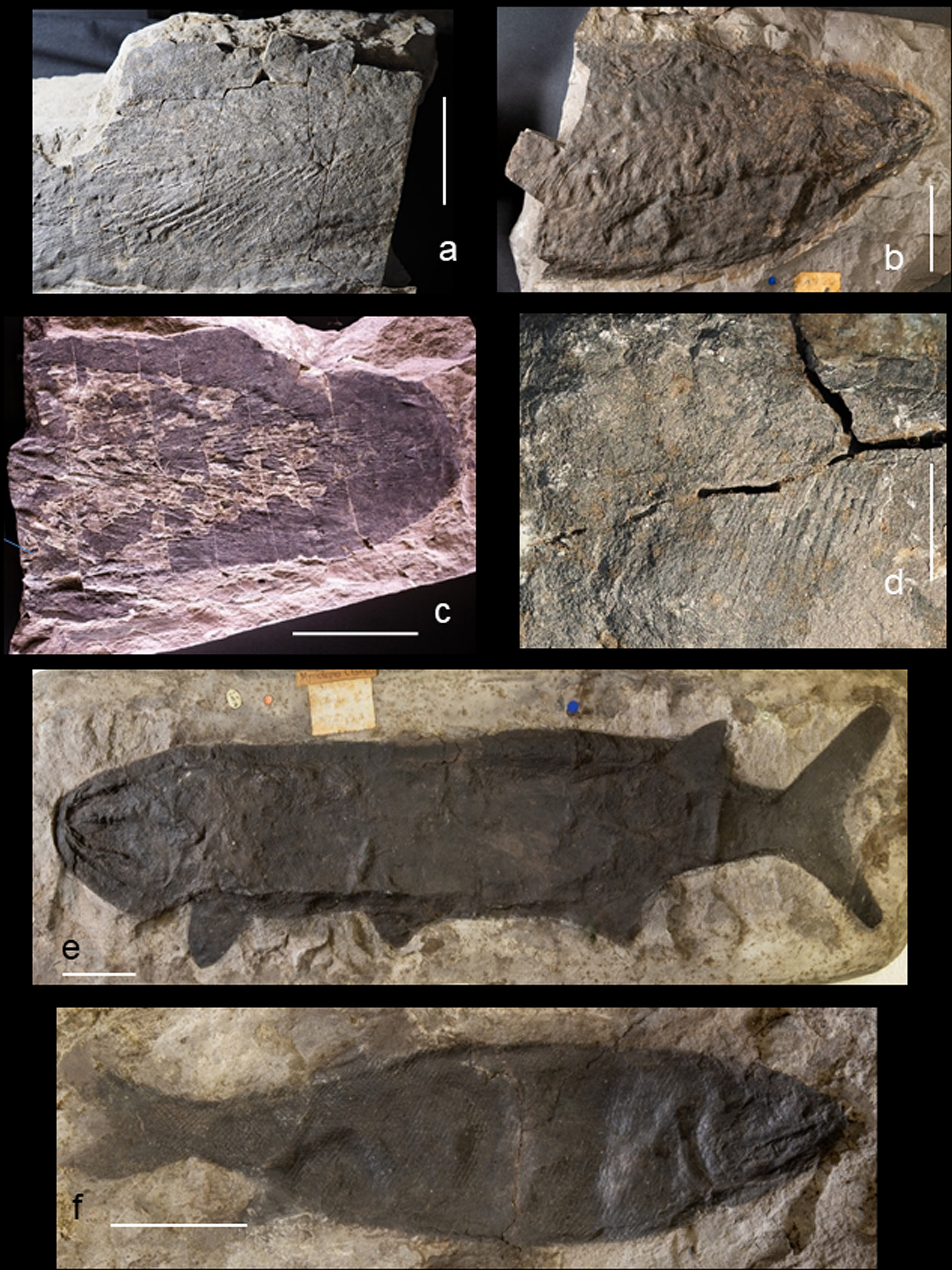

Figure 5. Gosford Ballast Quarry. Pisces. (*a*) MMF 14235 *Gosfordia truncata*. (*b*) AM F.50975 *Gosfordia truncata.* (*c*) AM F.85958 *Gosfordia truncata.* (*d*) MMF 13347 *Gosfordia truncata.* (*e*) AM F.50976 *Myriolepis clarkei*. (*f*) AM F.50974 *Myriolepis latus.* Scale bars: *a, b, c, e*, and *f* = 5 cm; *d* = 2 cm.

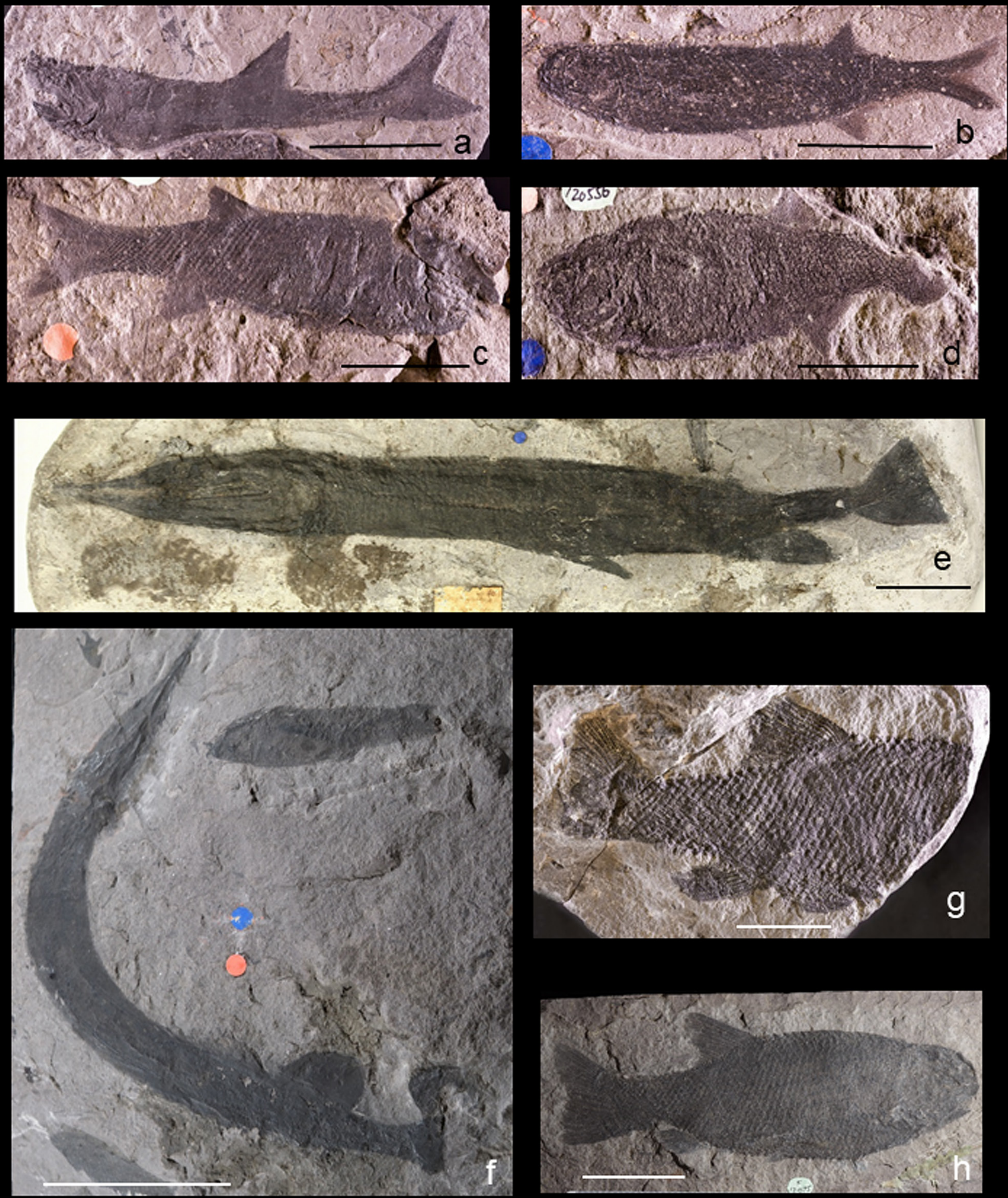

Figure 6. Gosford Ballast Quarry. Pisces. (*a*) AM F.120548 *Apateolepis australis*. (*b*) AM F.120553 as *Dictyopyge symmetrica* (ref. Woodward, 1890). (*c*) AM F.120555 as *Dictyopyge illustrans* (ref. Woodward, 1890). (*d*) AM F.120556 as *Dictyopyge robusta* (ref. Woodward, 1890). (*e*) AM F.50973 *Saurichthys gigas*. (*f*) MMF 13336 *Saurichthys gracilis*. (*g*) AM F.121078 *Zeuchthiscus australis*. (*h*) AM F.121075 *Zeuchthiscus australis*. Scale bars: *b, c*, and *g* = 2 cm; *a, d, e, f*, and *h* = 5 cm.

collection. | AM F.135654 (MF 168) (MMF 118)—a smaller fish showing parts of fins—held in the AMTC under "Woodward 1890".

Woodward (1890) identified these specimens as the smallest of the Australian species of *Dictyopyge* in the Catopteridae within Ganoidei.

However, Wade (1940) thought that the reference to the genus *Dictyopyge* could not be upheld for these specimens, as they were poorly preserved and it was impossible to determine the osteology of the head. *Dictyopyge* is now known to have a peculiar skull roof (Brough, 1931). These specimens possibly represent another genus (Wade, 1940).

Hutchinson (1973) provisionally ascribed this species to the Redfieldiformes. He saw some characters of these specimens in *Brookvalia*, such as body shape, scales and unpaired fins.

Dictyopyge illustrans Woodward, 1890

Fig. 6c

Dictyopyge illustrans Woodward, 1890: 18, pl. 4 figs 7–9.

Type: MMF 123 (Woodward, 1890: pl. 4 fig. 7)—complete fish—held in the GSNSW collection.

Figured: MMF 13342 (MMF 103) (pl. 4 fig. 8)—imperfect, distorted fish—held in the GSNSW collection. | AM F.120555 (MF 171) (MMF 122) (Fig. 6c) (pl. 4 fig. 7)—fish with well-preserved tail—held in the AMTC under "Woodward 1890".

Mentioned: AM F.135655 (MF 172) (MMF 105)—a similar fish to above—held in the AMTC under "Woodward 1890". | MMF 13343 (MMF 115)—an imperfect small specimen—held in the GSNSW collection.

Woodward (1890) identified these specimens as a separate species to *D. symmetrica* as they were larger. Woodward thus placed them in the Catopteridae within Ganoidei. He commented that *D. illustrans* differed from all known species of *Dictyopyge* in the comparatively forward position of the dorsal fin.

However, Wade (1940) thought that the reference to the genus *Dictyopyge* could not be upheld for these specimens, as they were poorly preserved and it was impossible to determine the osteology of the head. *Dictyopyge* is now known to have a peculiar skull roof (Brough 1931). These specimens were possibly *Brookvalia* (Wade 1940).

Hutchinson (1973) provisionally ascribed this species to the Redfieldiformes. He saw some characters of these specimens in *Brookvalia*, such as body shape, scales and unpaired fins.

Dictyopyge robusta Woodward, 1890

Fig. 6d

Dictyopyge robusta Woodward, 1890: 20, pl. 3 figs 4,5.

Type: AM F.120556 (MF 170) (MMF 119) (Fig. 6d) (pl. 3 fig. 4)—complete fish except for tail—held in the AMTC under "Woodward 1890".

Figured: AM F.120557 (MF 169) (MMF 104) (pl. 3 fig. 5)—a more imperfect trunk—held in the AMTC under "Woodward 1890".

Mentioned: ¿—a nearly complete trunk—possibly held in the GSNSW collection. | ¿—head and trunk without tail—possibly held in the GSNSW collection. | ¿—nearly complete fish without pectoral, dorsal and anal fins—possibly held in the GSNSW collection.

Woodward (1890) commented that this species can only be compared to *D. illustrans* but has a more robust trunk and a greater extent of dorsal and anal fins. He thus placed it in the Catopteridae within the Ganoidei.

Wade (1940) thought that the reference to the genus *Dictyopyge* could not be upheld for these specimens, as they were poorly preserved, and it was impossible to determine the osteology of the head. *Dictyopyge* is now known to have a peculiar skull roof (Brough, 1931). These specimens were possibly *Brookvalia* (Wade, 1940).

Hutchinson (1973) provisionally ascribed this species to the Redfieldiformes. He saw some characters of this genus in *Brookvalia*, such as body shape, scales and unpaired fins.

Order Saurichthyiformes

Family Saurichthyidae

Saurichthys gigas (Woodward, 1890)

Fig. 6e

Belonorhynchus gigas Woodward, 1890: 23, pl. 8 fig. 6, pl. 9 figs 1,2, pl. 10 figs 1,2.
Saurichthys gigas.—Stensiö, 1925.

Type: AM F.50973 (MMF 377) (Fig. 6e) (pl. 9 fig. 1)—nearly complete with imperfect fins—held in the AMTC under "Woodward 1890".

Figured: MMF 13381 (MMF 138) (pl. 10 fig. 1)—imperfect skull—held in the GSNSW collection. | AM F.50972 (MMF 387) (pl. 9 fig. 2)—trunk with imperfect caudal fin—held in the AMTC under "Woodward 1890". | AM F.120542 (MF 190) (MMF 148) (pl. 10 fig. 2)—large trunk and tail—held in the AMTC under "Woodward 1890". | AM F.120535 (MF 195) (MMF 142) (pl. 8 fig. 6)—imperfect caudal fin—held in the AMTC under "Woodward 1890".

Mentioned: ¿—a smaller fragment of skull and mandible—possibly held in the GSNSW collection. | ¿—fragment of middle portion—possibly held in the GSNSW collection.

Woodward (1890) noted that the *Belonorhynchus gigas* specimens had all the most characteristic features of a large species of *Belonorhynchus* but was distinguished from all known species of the genus by the breadth of the dorsal and ventral scutes. He thus placed this specimen in the Belonorhynchidae within the Ganoidei. He noted that "the Triassic and Rhaetic *Saurichthys* is closely related to *Belonorhynchus"* (Woodward 1890, 23).

Later, Stensiö (1925) re-assigned this species to *Saurichthys* in the Saurichthyidae.

Saurichthys gracilis (Woodward, 1890)

Fig. 6f

Belonorhynchus gracilis Woodward, 1890: 27, pl. 8 fig. 5, pl. 9 figs 3,4, pl. 10 figs 3,4.
Saurichthys gracilis.—Stensiö, 1925.

Type: MMF 13336 (MMF 102) (Fig. 6f) (pl. 8 fig. 5)—nearly complete head and trunk—held in the GSNSW collection.

Figured: MMF 147 (pl. 10 fig. 3)—detached head side view—held in the GSNSW collection. | MMF

13377 (MMF 140) (pl. 9 fig. 4)—hind portion of trunk and fins—held in the GSNSW collection. | MMF 13378 (MMF 141) (pl. 9 fig. 3)—portion of trunk and caudal area—held in the GSNSW collection. | # (pl. 10 fig. 4)—fragment of trunk with pelvic fin—possibly held in the GSNSW collection.

Mentioned: AM F.135628 (MF 192) (MMF 150)—greater portion of trunk—held in the AMTC under "Woodward 1890". | ¿—portion of trunk with both pelvic fins—possibly held in the GSNSW collection. | ¿—portion of trunk with fragments of fins—possibly held in the GSNSW collection.

Woodward (1890) observed that there were specimens of *Belonorhynchus* slenderer and more delicate than *B. gigas*, and he named them *B. gracilis*. He noted that "the Triassic and Rhaetic *Saurichthys* is closely related to *Belonorhynchus*" (Woodward 1890, 23).

Later, Stensiö (1925) re-assigned this species to *Saurichthys* in the Saurichthyidae.

Order Perleidiformes

Family Perleididae

Zeuchthiscus australis (Woodward, 1890)

Fig. 6g,h

Semionotus australis Woodward, 1890: 31, pl. 6 fig. 2.
Semionotus tenuis Woodward, 1890: 31, pl. 6 fig. 3.—Wade, 1940.
Zeuchthiscus australis.—Wade, 1940: 215, pl. 11 fig. 4, text figs 5,6.

Type: AM F.121078 (MF 188) (MMF 382) (Fig. 6g) (Woodward, 1890: pl. 6 fig.2 as *Semionotus australis*)—abdominal and caudal regions—held in the AMTC under "Woodward 1890".

Figured in Woodward (1890): MMF 109 (pl. 6 fig. 3 as *Semionotus tenuis*)—almost complete fish—held in the GSNSW collection.

Mentioned in Wade (1940): AM F.121075 (MF 861) (MMF 146) (Fig. 6h)—complete fish—held in the AMTC under "Wade 1940". AM F.121081 (MF 862) (MMF 132)—head and anterior trunk—held in the AMTC under "Wade 1940". | AM F.142656 (MF 183) (MMF 98)—complete fish (plus *Cleithrolepis*) on slab—held in the AMTC under "Wade 1940". | MMF 386—two specimens on one slab—held in the GSNSW collection.

Woodward (1890) assigned an imperfect specimen from Gosford to *Semionotus,* naming it *S. australis*, thus placing it in the Semionotidae in the order Ganoidei. However, Wade (1940) re-assigned this to another family, Perleididae, after examining other specimens in the available collections which had all the known characters of typical Perleididae. Wade (1940) then erected the genus *Zeuchthiscus* for the re-assigned species. The smaller individuals described as *Semionotus tenuis* by Woodward (1890: 31, pl. 6 fig. 3) were considered juveniles by Wade (1940) and placed in *Zeuchthiscus australis* also.

Pristisomus gracilis Woodward, 1890

Fig. 7a,b,c

Pristisomus gracilis Woodward, 1890: 33, pl. 5 fig. 1, pl. 6 fig. 1, pl. 8 fig. 1.
Pristisomus latus Woodward, 1890: 35, pl. 5 figs 2,3,4.—Wade, 1940: 212.
Pristisomus crassus Woodward, 1890: 36, pl. 5 figs 5,6,7.—Wade, 1940: 212.

Type: AM F.121080 (MF 177) (MMF 133) (Fig. 7a) (pl. 5 fig. 1)—complete fish except head details missing—held in the AMTC under "Woodward 1890".

Figured in Woodward (1890): AM F.120549 (MF 182) (MMF 137) (pl. 6 fig. 1)—head and anterior portion of trunk—held in the AMTC under "Woodward 1890". | AM F.120546 (MF 178) (MMF 136) (pl. 8 fig. 1)—caudal region—held in the AMTC under "Woodward 1890". | MMF 13339 (MMF 149a) (pl. 5 fig. 2 as *Pristisomus latus*)—fish missing tail—held in the GSNSW collection. | AM F.120540 (MF 181) (MMF 107) (Fig. 7b) (pl. 5 fig. 3 as *Pristisomus latus*)—fish missing head—held in the AMTC under "Woodward 1890". | AM F.142657 (MF 186) (MMF 144) (pl. 5 fig. 4 as *Pristisomus latus*)—portion showing pectoral fin—on slab with *Apateolepis*—held in the AMTC under "Woodward 1890". | AM F.120544 (MF 867) (MMF 151) (Fig. 7c) (pl. 5 fig. 5 as *Pristisomus crassus*)—imperfect fish—held in the AMTC under "Woodward 1890". | MMF 13339 (MMF 149b) (pl. 5 fig. 6 as *Pristisomus crassus*)—head and anterior trunk—held in the GSNSW collection. | AM F.120538 (MF 179) (MMF 113) (pl. 5 fig. 7 as *Pristisomus crassus*)—caudal region—held in the AMTC under "Woodward 1890".

Figured in Wade (1940): AM F.120536 (MF 864) (MMF 5549) (pl. 11 fig. 3)—head and anterior trunk—held in the AMTC under "Wade 1940".

Mentioned in Woodward (1890): ¿—mentioned as *Pristisomus crassus*—imperfect fish showing squamation—possibly held in the GSNSW collection.

Mentioned in Wade (1940): AM F.120539 (MF 189A) (MMF 96)—fish minus caudal fin (on slab with MF 189B *Tripelta dubia*)—held in the AMTC under "Woodward 1890". | AM F.120545 (MF 863) (MMF 117)—complete fish on slab with *Cleithrolepis*—held in the AMTC under "Wade 1940". | AM F.120543 (MF 865) (MMF 100)—complete fish on slab with *Cleithrolepis*—held in the AMTC under "Wade 1940". | AM F.121079 (MF 866) (MMF 134)—complete fish minus caudal fin—held in the AMTC under "Wade 1940". | AM F.6463—complete fish—held in the AMTC under "Wade 1940". | AM F.11033—two complete fish on slab with *Cleithrolepis*—held in the AMTC under "Wade 1940". | AM F.38906—fish minus fins—held in the AMTC under "Wade 1940". | AM F.38907—head and trunk—held in the AMTC under "Wade 1940". | MMF 157—held in the GSNSW collection. | MMF 378—held in the GSNSW collection. | MMF 386—held in the GSNSW collection.

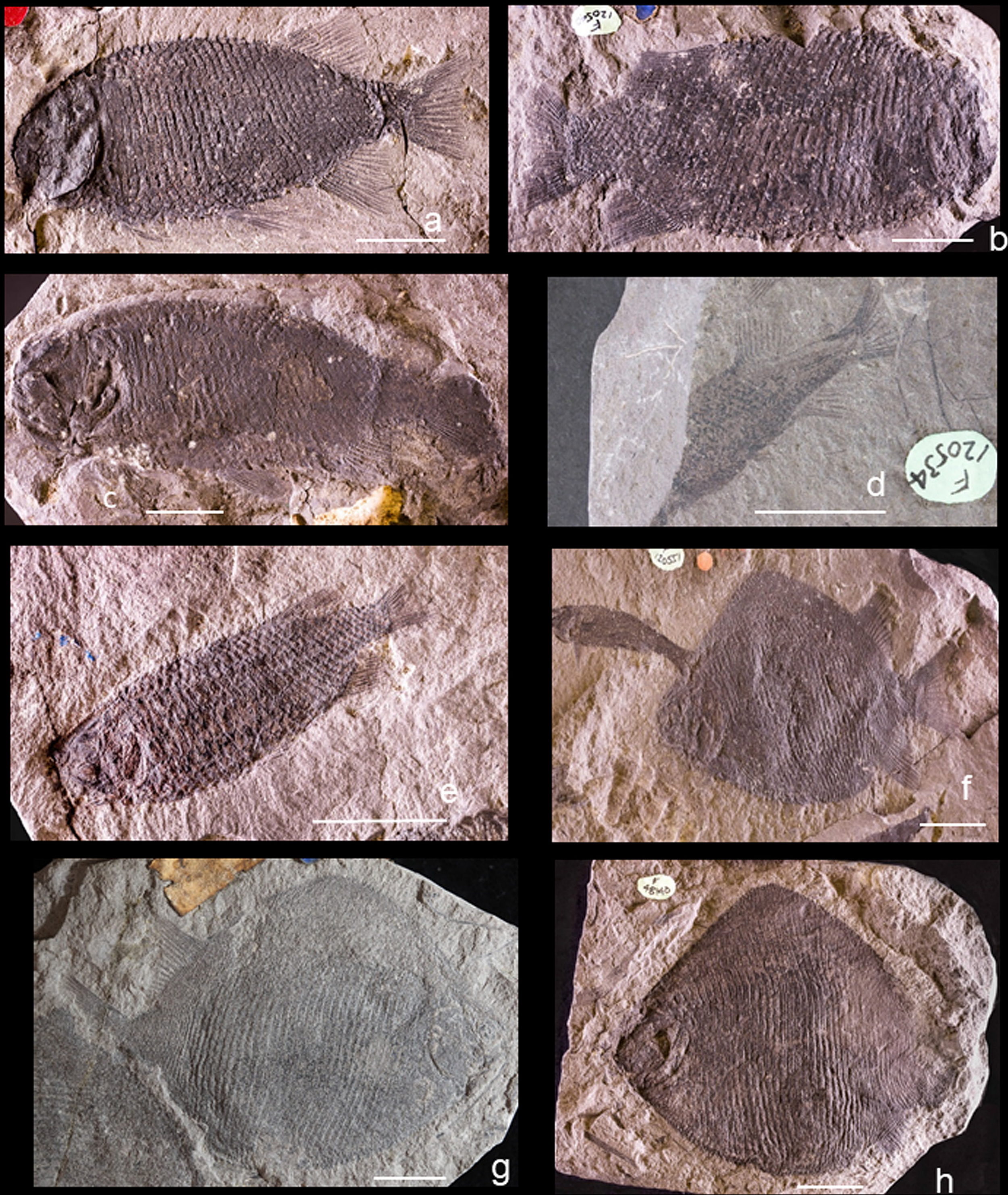

Figure 7. Gosford Ballast Quarry. Pisces. (*a*) AM F.121080 *Pristisomus gracilis*. (*b*) AM F.120540 as *Pristisomus latus* (ref. Woodward, 1890). (*c*) AM F.120544 as *Pristisomus crassus* (ref. Woodward, 1890). (*d*) AM F.120534 *Chroticthtys gregarius*. (*e*) AM F.120539 *Tripelta dubia*. (*f*) AM F.120551 *Cleithrolepis granulatus*. (*g*) AM F.50971 *Cleithrolepis granulatus*. (*h*) AM F.48140 *Cleithrolepis ?altus*. Scale bars = 2 cm.

Woodward (1890) erected a new genus *Pristisomus* for a number of specimens with a comparatively deep, but fusiform, body. He divided them into three new species based on variations in body proportions, the size of the head and the length of the dorsal fin. Wade (1940) re-assigned all these specimens to another family, Perleididae, based on the small head, the depth of the trunk and the small upper caudal fin lobe, among other characteristics. He assessed the differences between the three species erected by Woodward (1890) as being only individual differences within one species, so he re-assigned *P. latus* and *P. crassus* to *P. gracilis*.

Chrotichthys gregarious (Woodward, 1890)

Fig. 7d

Pholidophorus gregarious Woodward, 1890: 44, pl. 6 figs 6–10.
Chrotichthys gregarious.—Wade, 1940: 210, pl. 11 fig. 2, text fig. 2.

Type: MMF 152 (pl. 6 fig. 6)—complete fish—assumed lost.
Lectotype: AM F.120534 (MF 858) (MMF 153) (Fig. 7d)—counterpart (without head) to missing type—held in the AMTC under "Wade 1940".
Figured: MMF 161 (pl. 6 fig. 7)—smaller incomplete fish—held in the GSNSW collection. | # (pl. 6 fig. 8)—smaller elongated fish—possibly held in the GSNSW collection. | AM F.120557 (MF 859) (MMF 164) (pl. 6 fig. 10)—imperfect head with portion of trunk—held in the AMTC under "Woodward 1890". | # (pl. 6 fig. 9)—small, elongated fish—possibly held in the GSNSW collection.
Mentioned: MMF 112—imperfect head with portion of trunk—held in the GSNSW collection.

Woodward (1890) commented that this species is common amongst the Triassic of Sydney, and seemed to have lived in shoals. They are distinguished by the remote placement of the dorsal fin. He assigned this new species to *Pholidophorus* in the Pholidophoridae in the order Ganoidei. Wade (1940) re-assigned these specimens to another family, Perleididae, and a new genus, *Chrotichthys*, based on the structure of the jaw, and the spacing of the fin rays. As the type had been lost by 1939, Wade (1940) selected the counterpart of the type as lectotype.

Tripelta dubia (Woodward, 1890)

Fig. 7e

Peltopleurus(?) dubius Woodward, 1890: 47, pl. 6 figs 4,5.
Tripelta dubia.—Wade, 1940: 209, pl. 11 fig. 1, text fig. 1.

Type: AM F.120539 (MF 189B) (MMF 96) (Fig. 7e) (pl. 6 fig. 4)—complete fish on slab with *Pristisomus gracilis* (MF 189A)—held in the AMTC under "Woodward 1890".
Figured in Woodward (1890): AM F.142654 (MF 187) (MMF 114) (pl. 6 fig. 5)—trunk without fins—held in the AMTC under "Woodward 1890".
Figured in Wade (1940): AM F.142655 (MF 860) (MMF 5550B)—held in the AMTC under "Wade 1940".
Mentioned in Woodward (1890): MMF 116—smaller fish, slender—held in the GSNSW collection.
Mentioned in Wade (1940): AM F.6464—complete fish—held in the AMTC under "Wade 1940".

Due to differences in some scale structures Woodward (1890) only assigned this new species a provisional generic position as *Peltopleurus* in the Pholidophoridae in the order Ganoidei. Wade (1940) re-assigned these specimens to another family, Perleididae, and a new genus, *Tripelta,* based on newer criteria of a wide gape in association with a nearly vertical suspensorium, a delicate mandible, and the squamation.

Family Cleithrolepidae

Cleithrolepis granulatus Egerton, 1864

Fig. 7f,g

Syntype: anterior half of fish—from Cockatoo Island, NSW—possibly lost.
Syntype: AM F.1471—complete fish—from Cockatoo Island, NSW—held in the AMTC under "Egerton 1864".
Figured in Woodward (1890): AM F.120551 (MF 176) (MMF 126) (Fig. 7f) (pl. 7 fig. 1)—complete fish—held in the AMTC under "Woodward 1890". | AM F.50971 (MMF 381) (first of 2 on slab) (pl. 7 fig. 2)—complete except for caudal and anal fins—held in the AMTC under "Woodward 1890". | AM F.50971 (MMF 381) (Fig. 7g) (second of 2 on slab) (pl. 7 fig. 3)—head—held in the AMTC under "Woodward 1890". | MMF 99 (pl. 7 fig. 4)—complete trunk—held in the GSNSW collection. | AM F.120552 (MF 184) (MMF 98) (pl. 7 fig. 5)—caudal region—held in the AMTC under "Woodward 1890". | MMF 124 (pl. 8 fig. 3)—posterior half of trunk—held in the GSNSW collection. | MMF 129 (pl. 8 fig. 2)—ventral half of trunk—held in the GSNSW collection. | AM F.120550 (MF 185) (MMF 127) (pl. 7 fig. 7)—dorsal ridge—held in the AMTC under "Woodward 1890". | MMF 125 (pl. 7 fig. 6)—imperfect fish showing squamation—held in the GSNSW collection.
Mentioned in Woodward (1890): MMF 159—large imperfectly preserved fish—held in the GSNSW collection.

Egerton (1864) described and named this species from a specimen and a photo of another specimen, both from Cockatoo Docks, NSW. These specimens were found in Hawkesbury Sandstone. Woodward (1890) commented that, despite the large number of individual specimens collected from the Gosford Ballast Quarry, it was difficult to recognize more than a single species, although one imperfect specimen may indicate a second form (see *C. ?altus* below). Wade (1935) argued that *Cleithrolepis* was derived from the platysomids, and should therefore be placed in a new family, Cleithrolepidae.

Cleithrolepis ?altus Woodward, 1890

Fig. 7h

Type: MMF 128 (pl. 8 fig. 4)—fish with most of caudal region missing—held in the GSNSW collection. (AM F.48140 (MF 199) (MMF 130) (Fig. 7h) held in the AMTC under "Woodward 1890" is the counterpart of the type.)

Woodward (1890) noted that this lone specimen from Gosford Ballast Quarry may perhaps be a separate species, due to a deeper trunk than that of other *C. granulatus* specimens, so he tentatively erected a new species *C. ?altus*. Wade (1935) also recorded the presence of three specimens in the NHMUK (P 16826, P 17032 and P 17033) having a greater depth of trunk, which he identified as *C. alta*. However, he raised the possibility of this greater depth being due to distortion during preservation. Wade (1935) argued that *Cleithrolepis* was derived from the platysomids, and should therefore be placed in a new family, Cleithrolepidae.

Plan**tae**

Order Pentoxylales

Family Pentoxylaceae

Taeniopteris lentriculiforme (Etheridge, 1894)

Fig. 8a

Oleandridium lentriculiforme Etheridge, 1894: 49, pl. 8 fig. 1.
Taeniopteris lentriculiforme.—Walkom, 1917: 35, text fig. 11.

Type: AM F.35647 (Fig. 8a)—complete leaf—held in the AMTC under "Etheridge 1894f".

Etheridge (1894b) described and named a specimen of a leaf, collected from the Gosford Ballast Quarry by C. Cullen of the GSNSW, as a new species of *Oleandridium*. He described it as boat-shaped with a long petiole and compared it with similar leaves found on Freshwater Headland. Walkom (1917) stated that numerous similar specimens in Queensland went under a variety of generic names, including *Oleandridium* and *Taeniopteris*. He proposed all these be grouped under the one genus, *Taeniopteris*.

Other Plantae specimens

A number of other plant specimens were recovered from the Gosford Ballast Quarry but were not described. They are held in the collection of the GSNSW and are: MMF 3095—*Phyllotheca* sp. (Fig. 8b), MMF 3096a,b—*Phyllotheca* sp. (Fig. 8c,d), MMF 27083—plant fragments, MMF 27084—plant fragments, MMF 27085—fern (Fig. 8e), MMF 27086—*Phyllotheca* sp. (Fig. 8h), MMF 27087—*Dicroidium*, MMF 27088—plant fragments (Fig. 8f), MMF 27089—?Equisetalian stem (Fig. 8g), MMF 27090—?fertile organ (Fig. 8i), MMF 27091—?fertile organ (Fig. 8j).

Northern Beaches headlands

From Long Reef northwards along the Sydney Basin coast the Narrabeen Group of rocks are exposed on the series of headlands that alternate with the well-known surfing beaches.

As the fossils found in these locations are mainly plants and often of similar species, this section groups all the headlands together as one fossil site, while describing particular exceptions where necessary. The individual headlands are (from south to north) Long Reef, Narrabeen, Turimetta, Warriewood, Mona Vale, Newport, Bilgola, Avalon, Whale Beach, Palm Beach, Killcare, Little Beach, Avoca and Terrigal. The spread of headlands has allowed a number of workers, such as G. Retallack, to consider the broad implications of plant ecology and evolution during the Early Triassic period, using specimens obtained all along the coast and the geological structures exposed there.

Class Amphibia

Order Temnospondyli

Superfamily Mastodonsauroidea

Family Mastodonsauridae

Bulgosuchus gargantua Damiani, 1999

Fig. 9a

Holotype: AM F.80190 (Fig. 9a) (figs 2–5)—held in the AMTC under "Damiani 1999".
Referred material: AM F.54961—held in the AMTC under "Damiani 1999".

Part of a mandible and femur of a temnospondyl were found exposed in the rock platform of the Bulgo Sandstone at Long Reef Headland. (The Bulgo Sandstone of the Narrabeen Group was laid down as a freshwater fluvial deposit). Damiani (1999) placed this specimen in the Capitosauridae. The holotype is the posterior part of a left mandible, and the referred material is an incomplete right femur. The referred material is not in itself diagnostic but is referred to the holotype species as it was recovered nearby and is similar to the femora of known capitosaurids (Damiani, 1999).

Although Damiani (1999) placed this specimen in Capitosauridae, as a result of a new phylogenetic analysis Damiani (2001) emended this classification to Mastodonsauridae.

Mastodonsauroidea

Fig. 9b

Figured: AM F.57957 (Fig. 9b) (Damiani, 1999: fig. 10)—anterior section (440 mm long) of right mandible—held in the AMTC under "Damiani 1999".

A natural impression of the anterior portion of a right mandible was collected by A. Ritchie from the Terrigal Formation at Little Beach, north of Killcare, in the Bouddi National Park (Damiani, 1999). The specimen is part of an immense jaw of an animal at least equal in size to that of the above *Bulgosuchus gargantua*. It is possible that this is an adult of the immature *Parotosuchus wadei* (Damiani & Warren, 1997) which also comes from the Terrigal Formation (Damiani, 1999).

Although Damiani (1999) placed this specimen in Capitosauroidea, as a result of a new phylogenetic analysis Damiani (2001) emended this classification to Mastodonsauroidea.

Class Reptilia

Order Archosauriformes

Family Erythrosuchidae

Figured: SAM P41754 (Kear, 2009: fig. 2)—disarticulated vertebrae—held in the South Australian Museum.

Kear (2009) described two disarticulated vertebrae found embedded in the Bulgo Sandstone Formation at Long Reef Headland. He identified them as anterior dorsal vertebrae belonging to a proterosuchid archosaur. Triassic archosaur fossils are rare in Australia. One has been found in Tasmania and another in Queensland. Trace fossils have been found in Queensland also (Kear, 2009).

Although Kear (2009) placed these specimens in Proterosuchidae, Ezcurra (2016) has subsequently identified these specimens as indeterminate Erythrosuchidae.

Figure 8. Gosford Ballast Quarry. Plantae. (*a*) AM F.35647 *Taeniopteris lentriculiforme*. (*b*) MMF 3095 *Phyllotheca*. (*c*) MMF 3096a *Phyllotheca*. (*d*) MMF 3096b *Phyllotheca*. (*e*) MMF 27085, fern. (*f*) MMF 27088, plant fragments. (*g*) MMF 27089, ?Equisetalian stems. (*h*) MMF 27086 *Phyllotheca*. (*i*) MMF 27090 ?fertile organ. (*j*) MMF 27091 ?fertile organ. Scale bars = 1 cm.

Figure 9. Northern Beaches. Temnospondyli, Pisces, trace fossils. (*a*) AM F.80190. *Bulgosuchus gargantua.* (*b*) AM F.57957. Mastodonsauroidea. (*c*) AM F.43330. *Myriolepis latus*. Whale Beach. (*d*) AM F.151314. Internal cast of arthropod burrow. Scale bars = 5 cm.

Pisces

Class Actinopterygii

Subclass Chondrostei

Order Palaeonisciformes

Family Palaeoniscidae

Myriolepis latus Woodward, 1890

[See Gosford Ballast Quarry above for type specimens]

Fig. 9c

AM F.43330 (Fig. 9c)—*Myriolepis latus*—from Whale Beach Headland—held in the AMGC under "Pisces/Triassic/Whale Beach".

Class Chondrichthyes

AM F.135829—unidentified shark fin spine—from Long Reef Headland—held in the AMGC under "Pisces/Triassic/Long Reef".

Trace Fossils

Coprolites

Niedzwiedzki *et al*. (2016) describe a range of coprolites recovered from the Bulgo Sandstone Formation at Long Reef. They identified cylindrical coprolites as being produced by either small bodied tetrapods, or perhaps a large invertebrate. Ovoid and spherical specimens were most likely produced by temnospondyls. Polygonal or irregular coprolites were considered as of uncertain origin, but possibly from temnospondyls. Spiral coprolites were attributed to an early chondrichthyan, an actinopterygian or a dipnoan. Specimens all held in the South Australian Museum.

Arthropod tracks

Fig. 9d

AM F.151314 (Fig. 9d)—internal cast of the end of a burrow—held in the AMGC under "Trace Fossils".

A number of internal casts of burrows made by large arthropods have been found at Long Reef Headland and other Northern Beaches sites. They are characterized by parallel grooves in the floor of the burrow apparently caused by the leg drag of the burrowing animal, possibly a crustacean. They have not yet been attributed to any known species.

Plantae

Walkom (1925) was the first worker to attempt a detailed classification and description of Northern Beaches plant specimens. He sourced specimens from the Geological Survey of New South Wales and the Australian Museum that had been collected by B. Dunstan while Dunstan was lecturing in geology at the Technical College in Sydney. Walkom (1925) named four new species and opened up the detailed study of this group of fossils.

During 1933 the Students' Geological Society from the University of Sydney collected and examined fossil flora from the Narrabeen Group around Sydney. Burges (1935) published the results of this systematic examination.

Later, workers correlated their own studies with the developing body of knowledge of Gondwana plants from South Africa, India and South America, and this led to many emendations of taxonomy and new concepts of the construction of the entire plant. J. Townrow and G. Retallack were in the forefront of this work on the Northern Beaches headlands.

Although W. B. K. Holmes occasionally addressed some aspects of Northern Beaches headlands specimens in his publications, his extensive series of papers with his co-author H. Anderson in the early 21st Century on the palaeoflora of the Middle Triassic Nymboida Coal Measures, NSW, also provide some guidance in specific instances on the modern taxonomy of Northern Beaches specimens.

Six main plant groups were found at the Northern Beaches sites. These were lycopsids, ferns, equesitaleans, conifers, pteridosperms and ginkgoes.

The overwhelming number of plant fossils are parts of plants. Over the years of study of plants many names have been applied to plant components. This has caused name confusion when components (such as leaf, fertile organs, stems, roots and trunks) have been matched to form the complete plant. This led to the concept that whole plants should be named after their reproductive structures (Retallack, 1997). Applying this rule has caused much emendation, and many junior synonyms. This is particularly noticeable with the Lycopsida. Holmes and Anderson demonstrated that there was a spectrum of morphological structure within species of ancient plants and classified many of his Nymboida specimens within a "morpho-species complex".

Division Lycopodiophyta (club mosses)

The taxonomic history of this Division demonstrates the confusion caused by early separate taxonomic names applied to plant components (such as leaf, fertile organs, stems, roots and trunks) before the correlation of these components became evident.

Retallack (1997) finally regrouped all Northern Beaches headlands lycopsid specimens into four species, naming the complete plants after their reproductive structures.

Class Isoetopsida

Order Isoetales

Family Isoetaceae

Cylostrobus sydneyensis (Walkom, 1925)

Fig. 10a–k

?*Araucarites sydneyensis* Walkom, 1925: 221, pl. 31 fig. 2 (sporophore).

Lycostrobus longicaulis Burges, 1935: 259, text fig. 1 (stem with "cone").—Retallack, 1975.

Caulopteris sp.? Burges, 1935: 260, text figs 3,4 (stem).—Helby & Martin, 1965.

Cylostrobus sydneyensis.—Helby & Martin, 1965: 395, pl. 1 figs 3,5,7, pl. 2 figs 10,11,18, pl. 3 figs 22–27 (sporophore).

Cylostrobus major Helby & Martin, 1965: 396, pl. 1 figs 2,4,8,9, pl. 2 figs 12,13,19 (sporophore).—Retallack, 1975.

Cylostrobus grandis Helby & Martin, 1965: 396, pl. 1 fig. 1, pl. 2 figs 14,15,17,20,21 (sporophore).—Retallack. 1975.

Pleuromeia longicaulis Retallack, 1975: 17, figs 1,8–10 (complete plant).

Cylomeia longicaulis.—White, 1981: 730, figs 6,8 (leaf crown); synonymized with *Cylostrobus sydneyensis* by Retallack (1997).

Cylostrobus sydneyensis.—Retallack, 1997: 508, fig. 5 (complete plant).

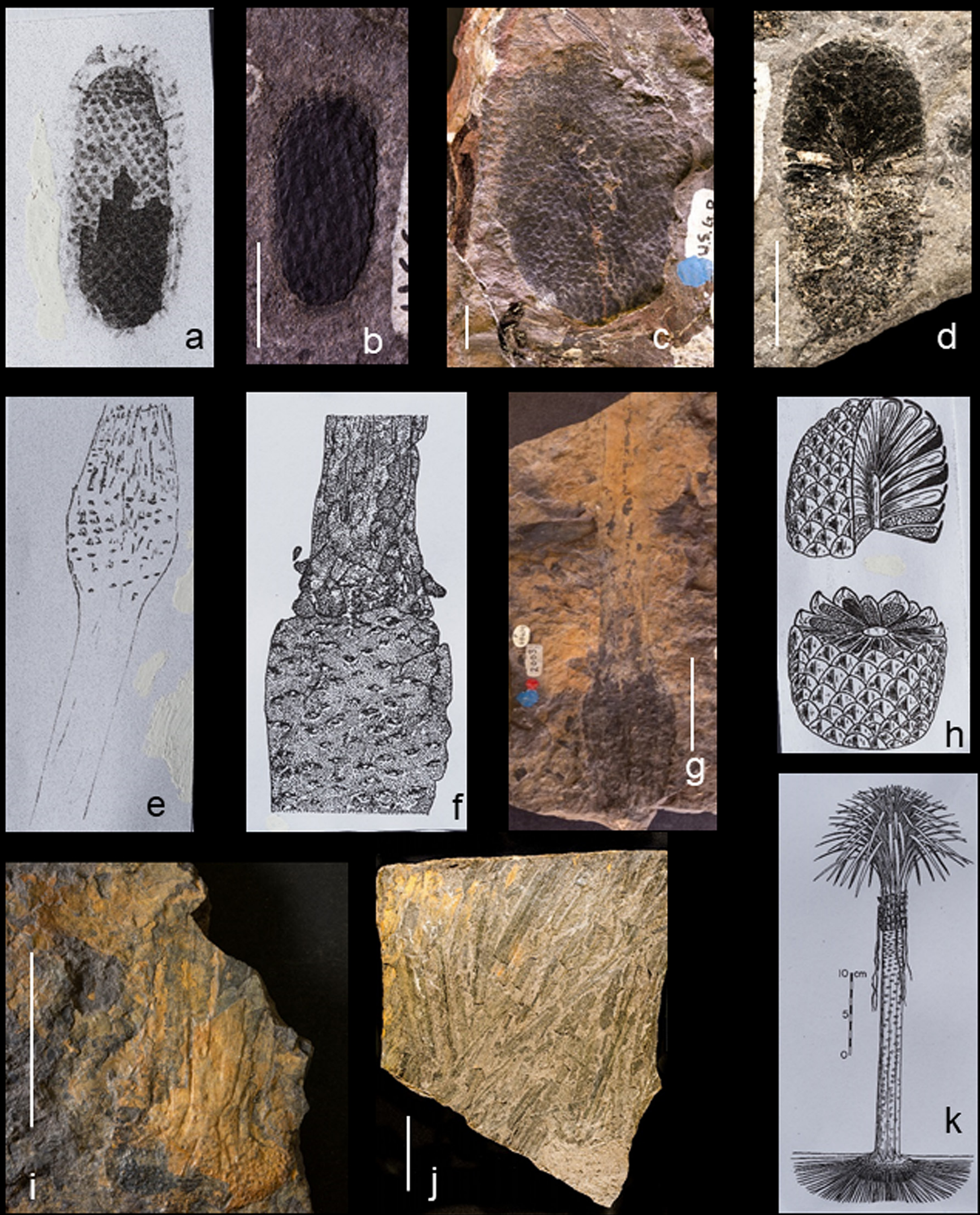

Figure 10. Northern Beaches. Plantae—Lycopodiophyta. (*a*) *Cylostrobus sydneyensis*. (*b*) AM F.68478 *Cylostrobus sydneyensis*. (*c*) AM F.68479 *Cylostrobus sydneyensis.* (*d*) AM F.68591 *Cylostrobus sydneyensis.* (*e*) AM F.68409 "Lycopod cone on stalk" (from Burges, 1935). (*f*) AM F.68409 *Cylostrobus sydneyensis* (from Retallack, 1975). (*g*) AM F.68409 *Cylostrobus sydneyensis.* (*h*) *Cylostrobus* "cone" (from Helby & Martin, 1965). (*i*) AM F.75261 *Cylostrobus sydneyensis*, rhizophore with scars. (*j*) AM F.59975 *Cylostrobus sydneyensis,* leaves and "cones". (*k*) Reconstruction of *Cylostrobus sydneyensis* (from Retallack, 1975). Scale bars: *b, c*, and *d* = 1 cm; *g, i*, and *j* = 5 cm; *a* and *e* with permission of Linnean Society of NSW; *f* and *k* with permission of Taylor & Francis Group, © Association of Australasian Palaeontologists; *h* with the permission of CSIRO Publishing.

Type: # (Fig. 10a) (Walkom, 1925: pl. 31 fig. 2)—"coniferous cone"—missing.

Neotype: AM F.68478 (SUGD 16016) (Fig. 10b) (pl. 1 fig. 3)—sporophore "cone"—from Turimetta Headland—held in the AMTC under "Helby & Martin 1965".

Figured in Burges (1935): SUGD 2010 (261, text figs 10,11)—*Araucarites*—sporophore "cone"—missing. | AM F.68411 (SUGD 2011) (261, text fig. 11)—*Araucarites*—"cone" scales—held in the AMTC under "Burges 1935". | AM F.68409 (SUGD 2003) (Fig. 10e,f,g) (260, text fig. 1)—lycopod cone on stalk—stem apex with leaves—held in the AMTC under "Burges 1935". | # (260, text fig. 3)—*Caulopteris* sp.—stem—missing. | AM F.68410 (SUGD 2006) (260, text fig. 5)—*Caulopteris* sp—stem—held in the AMTC under "Burges 1935".

Figured in Helby & Martin (1965): AM F.68479 (SUGD 16015) (Fig. 10c) (pl. 1 fig. 1)—*Cylostrobus grandis*—sporophore—held in the AMTC under "Helby and Martin 1965". | AM F.68593 (SUGD 16014) (pl. 1 fig. 2)—*Cylostrobus grandis*—sporophore—held in the AMTC under "Helby & Martin 1965". | AM F.68591 (SUGD 16018) (Fig. 10d) (pl. 1 fig. 4)—*Cylostrobus major*—sporophore—held in the AMTC under "Helby & Martin 1965".

Figured in Retallack (1975): AM F.68409 (SUGD 2003) (Fig. 10e,f,g) (figs 8A,9A)—*Pleuromeia longicaulis*—stem apex with leaves—held in the AMTC under "Burges 1935". | AM F.75261 (UNEF 13806) (Fig. 10i) (figs 8B,8F,9D,10G)—*Pleuromeia longicaulis*—rhizophore with scars—held in the AMTC under "Retallack 1975". | UNEF 13809 (figs 8C,8E,9B,10B,10D,10F)—*Pleuromeia longicaulis*—elongate leaf—missing. | AM F.75266 (UNEF 13812) (figs 8D,10A)—*Pleuromeia longicaulis*—leaf base—held in the AMTC under "Retallack 1975". | UNEF 13811 (figs 8G,10H)—*Pleuromeia longicaulis*—appendage scar—missing. | AM F.75263 (UNEF 13813) (fig. 9C)—*Pleuromeia longicaulis*—leaf bases—held in the AMTC under "Retallack 1975". | AM F.75268 (UNEF 13805) (fig. 9E)—*Pleuromeia longicaulis*—rhizophore—held in the AMTC under Rettalack 1975. | AM F.75264 (UNEF 14601) (fig. 10C)—*Pleuromeia longicaulis*—elongate leaf—held in the AMTC under "Retallack 1975". | UNEF 14601 (thin section) (fig. 10E)—*Pleuromeia longicaulis*—elongate leaf—missing.

Figured in White (1981): AM F.59975 (Fig. 10j) (fig. 8)—*Cylomeia longicaulis*—leaves and *C. sydneyensis* "cones"—held in the AMTC under "White 1981b".

Figured in Retallack (1997): AM F.68409 (SUGD 2003) (Fig. 10e,f,g) (fig. 5 no. 1)—*Pleuromeia longicaulis*—stem apex with leaves—held in the AMTC under "Burges 1935". | AM F.75269 (UNEF 13803) (fig. 5 no. 2)—sporophore "cones"—from Turimetta Headland—held in the AMTC under "Retallack 1975". | AM F.75268 (UNEF 13805) (fig. 3 no. 3)—rhizomorph—from North Avalon Headland—held in the AMTC under "Retallack 1975". | UNEF 13809 (fig. 5 no. 4)—leaf scars on stem—from Bilgola Headland—missing. | UNEF 13811 (fig. 5 no. 5)—root scar—from North Avalon Headland—missing.

Mentioned: many specimens from Northern Beaches headlands—held in the AMGC and GSNSW collections.

Walkom (1925) figured and described a "coniferous cone" from Turimetta Headland with scales arranged spirally, which suggested present day *Araucaria* cones. He named it *?Araucarites sydneyensis*.

Burges (1935) obtained many specimens of these "cones", still classing them as conifers, from Mona Vale Headland. The "cones" appeared to fracture easily and were preserved in cross section showing the scales in situ, while large numbers of detached scales were found. He commented that Walkom's specimens were megaspore "cones". Specimens illustrated by Walkom (1925, pl. 31 figs 7,8) as "incertae sedis" were probably cross-sections of *A. sydneyensis* "cones" (Burges, 1935).

Burges (1935) also described a lycopsid "cone" from Avalon Headland which was about 8 cm long by 4 cm wide, had an attached stem, and resembled the male cone of *Macrozamia spirales*. He named it *Lycostrobus longicaulis*. Chemical treatment of the "cone" indicated the presence of spores (Burges, 1935).

Burges (1935) described a "fern stem" with leaf scars found at North Avalon Headland, classifying it as *Caulopteris* sp.? He stated that large numbers of casts of these stems were found, bearing elliptical scars irregularly placed but tending to form oblique rows with ridges of raised tissue between them.

Helby & Martin (1965) collected a large number of lycopsid "cones" from most Northern Beaches headlands and from existing collections and erected the lycopsid genus *Cylostrobus* to classify them. They recognized that the "cones" had been previously described by Walkom (1925) as the "coniferous" *?Araucarites sydneyensis* and "incertae sedis", and by Burges (1935) as *?Araucarites* also. With many specimens available, they assessed the spread of dimensions and concluded that three *Cylostrobus* species were present, which they named *C. sydneyensis*, *C. major* and *C. grandis*. As they could not locate the specimen described by Walkom (1925, pl. 31 fig. 2) they erected a provisional neotype (AM F.68478 (SUGD 16016)) for *C. sydneyensis*.

Helby & Martin (1965) identified the "fern stem" specimen, described by Burges (1935) as *Caulopteris* sp?, as part of a lycopsid stem.

Retallack (1975) disagreed with Helby & Martin (1965) about the need for three distinct species of *Cylostrobus* "cones", placing all three species under *C. sydneyensis*. He considered the species were differentiated by size frequency distribution and this could be attributed to a simple growth of one species.

Retallack (1975) carried out a detailed taxonomic and environmental study of lycopsid specimens obtained from North Avalon Headland. He included the *Lycostrobus longicaulis* Burges, 1935 specimen from the same locality in his assessment, identifying *L. longicaulis* as a stem with leaves, not a cone as stated by Burges (1935). He concluded that they were from the Pleuromaceae and emended the name to *Pleuromeia longicaulis*. Helby and Martin (1965) had foreshadowed this emendation. Retallack (1975: 4, fig. 1) reconstructed the sporophyte showing radial rootlets, a sub-aerial bulbous rhizophore, a trunk approximately 40 cm high and a radial crown of ribbon-like leaves (Fig. 10k).

Retallack (1975: 8, fig. 5) also reconstructed the "cone" *Cylostrobus sydneyensis* based on Helby & Martin (1965) and specimens obtained from South Bilgola Headland and Turimetta Headland (Fig. 10h). Due to the association of *P. longicaulis* and *C. sydneyensis* specimens in the same horizon at the above sites, Retallack (1975) considered *C. sydneyensis* to be the "cone" of *P. longicaulis*. He postulated that *Pleuromeia* was a tidal flat plant, a Triassic "mangrove", which had carried out a shoreline migration from Eurasia.

White (1981) studied a well-preserved specimen of a whorled lycopsid leaf crown from the roof shales of Bellambi Colliery (and others). She noted the ribbon-like leaves bore a close resemblance to the leaf *Taeniopteris undulata* Burges, 1935 and *Pleuromeia longicaulis* Retallack, 1975. She erected a new genus *Cylomeia* to accommodate these specimens because they revealed that the distal edges of the crown leaf undulated (like *Taeniopteris undulata*), while its proximal edges were parallel (like *Pleuromeia longicaulis*).

White (1981) also argued that the use of the genus *Pleuromeia* by Retallack (1975) could not be justified due to different generic separation in the "cones". She assigned the unattached, long, narrow leaves with undulating margins of *Taeniopteris undulata* Burges, 1935 to *Cylomeia undulata*. The leaves with parallel margins of *Pleuromeia longicaulis* (Burges, 1935) she assigned to *Cylomeia longicaulis*. Rhizophores were referred to *Cylomeia*, but not to any species as they were likely to be a general type for all species. All the "cones" of *Cylostrobus* Helby & Martin, 1965 she assigned to *Cylomeia longicaulis*. She also observed a close similarity between the "cones" of *Skilliostrobus* Ash, 1979 and *Cylostrobus*, and argued conditionally that *Skilliostrobus* could be described as a species of *Cylostrobus*. In an addendum addressing a new specimen with a circlet of linear, hair-like "leaves" from Long Reef Headland, White (1981) erected a third species, *Cylomeia capillamentum* (see *Tomiostrobus australis* below).

Retallack (1997) saw sporophylls as the most diagnostic plant remains for recognizing species. Subjecting sporophylls to cladistics analysis he reviewed the Early Triassic evolutionary radiation of *Isoetes* and *Pleuromeia*-like subarborescent lycopsids and concluded that *Isoetes* pre-dates *Pleuromeia*, and in fact *Isoetes* was the common ancestor of the Early and Middle Triassic lycopsids. This placed the Triassic lycopsids in the Isoetales family Isoetaceae. Based on the principle that a complete plant should be named after the reproductive structures, Retallack (1997) emended the name *Cylomeia longicaulis* to *Cylostrobus sydneyensis*, as the "cone" *Cylostrobus sydneyensis* had been shown to be closely associated with *Cylomeia longicaulis* and was considered part of the same plant.

Pleuromeia dubia (Seward, 1908)

Fig. 11a–c

Stigmatodendron dubium Seward, 1908: 100, pl. 3, fig. 3.—Anderson & Anderson, 1985.
?Taeniopteris undulata Burges, 1935: 261, pl. 10 fig. 1 (leaf).—Retallack, 1995.
Cylomeia undulata.—White pro parte, 1981: 731, fig. 4.—Retallack, 1995.
Gregicaulis dubius—Anderson & Anderson, 1985: 152, pls 171–175.—Retallack, 1995.
Pleuromeia dubia.—Retallack, 1995: 59, fig. 2E.

Syntype: AM F.68406 (SUG 2005) (Fig. 11a) (Burges, 1935: pl. 10 fig. 1)—*Taeniopteris undulata* leaf—held in the AMTC under "Burgess 1935".

Figured in White (1981): AM F.59987 (Fig. 11b) (fig. 4)—*Cylomeia undulata* leaf—held in the AMTC under "White 1981b".

Figured in Retallack (1997): AM F.78281 (UNEF 13820) (Fig. 11c) (fig. 6 no. 1)—stem with leaves—from Whale Beach Headland—held in the AMTC under "Retallack 1980". | UNEF 13823 (fig. 6 no. 2)—stem with cortex—from Whale Beach Headland—missing. | UNEF 13819 (fig. 6 no. 3)—decorticated stem—from Mona Vale Headland—missing. | UNEF 13818 (fig. 6 nos.4, 5)—decorticated stem—from Mona Vale Headland—missing. | SUGD 10045 (fig. 6 no. 6)—decorticated stem—from Warriewood Headland—missing.

Mentioned: many specimens from Northern Beaches headlands held in the AMGC.

Burges (1935) described a linear leaf 50 cm long and 1.4 cm wide with a prominent midrib and undulating lamina. He placed this in the taeniopteroids (pteridosperms) due to the venation, naming it *Taeniopteris undulata*. White (1981) studied a whorled leaf crown from Bellambi Colliery and noted a similarity between *Taeniopteris undulata* and the leaves on the crown. She placed the whorled leaf crown and *T. undulata* in a new lycopsid genus *Cylomeia* and named the species *Cylomeia undulata*. Retallack (1995a), examining a single leaf from Western Australia with undulating margins, noted that this specimen was similar to *Taeniopteris undulata* and *Cylomeia undulata* leaves, but that this name was unsuitable because these leaves had been found attached to lycopsid stems of *Gregicaulis dubius* in Sydney and South Africa (Anderson & Anderson, 1985). Sporophyll specimens left little doubt that *Gregicaulis* was a junior synonym for *Pleuromeia*. Retallack (1995) therefore emended the undulate leaves of *Taeniopteris undulata* and *Cylomeia undulata* to *Pleuromeia dubia*. Retallack (1997) saw sporophylls as the most diagnostic plant remains for recognizing species. Subjecting sporophylls to cladistics analysis he reviewed the Early Triassic evolutionary radiation of *Isoetes* and *Pleuromeia*-like subarborescent lycopsids and concluded that *Isoetes* pre-dates *Pleuromeia*, and in fact *Isoetes* was the common ancestor of the Early and Middle Triassic lycopsids. This placed the Triassic lycopsids in the Isoetales family Isoetaceae.

Tomiostrobus australis (Ash, 1979)

Fig. 11d–g

Skilliostrobus australis Ash, 1979: 79, figs 4–11 (compressed sporophore).
Cylomeia capillamentum White, 1981: 731, fig. 9 (corm and rootlets).—Retallack, 1997.
Tomiostrobus australis.—Retallack, 1997: 503, fig. 4 (compressed sporophore).

Holotype: AM F.58856 (Fig. 11d) (fig. 5F)—compressed fertile specimen of sporophore—from Terrigal Headland—held in the AMTC under "Ash 1979".

Paratype: AM F.58846 (fig. 6A)—compressed sporophore—from Terrigal Headland—held in the AMTC under "Ash 1979". | AM F.58849 (fig. 7F)—microphyll—from Terrigal Headland—held in the AMTC under "Ash 1979". | AM F.58858 (Fig. 11e) (fig. 7A)—megasporophyll—from Terrigal Headland—held in the AMTC under "Ash 1979".

Figured in Ash (1979): AM F.58850 (fig. 5D)—compressed "cone"—from Terrigal Headland—held in the AMTC under "Ash 1979". | AM F.58852 (fig. 5E)—compressed "cone"—from Terrigal Headland—held in the AMTC under "Ash 1979". | AM F.58854 (fig. 5A)—compressed "cone"—from Terrigal Headland—held in the AMTC under "Ash 1979". | AM F.58845 (fig. 7H)—megasporophyll—from Terrigal Headland—held in the AMTC under Ash "1979". | AM F.58853 (fig. 7D)—megasporophyll—from Terrigal Headland—held in the AMTC under "Ash 1979".

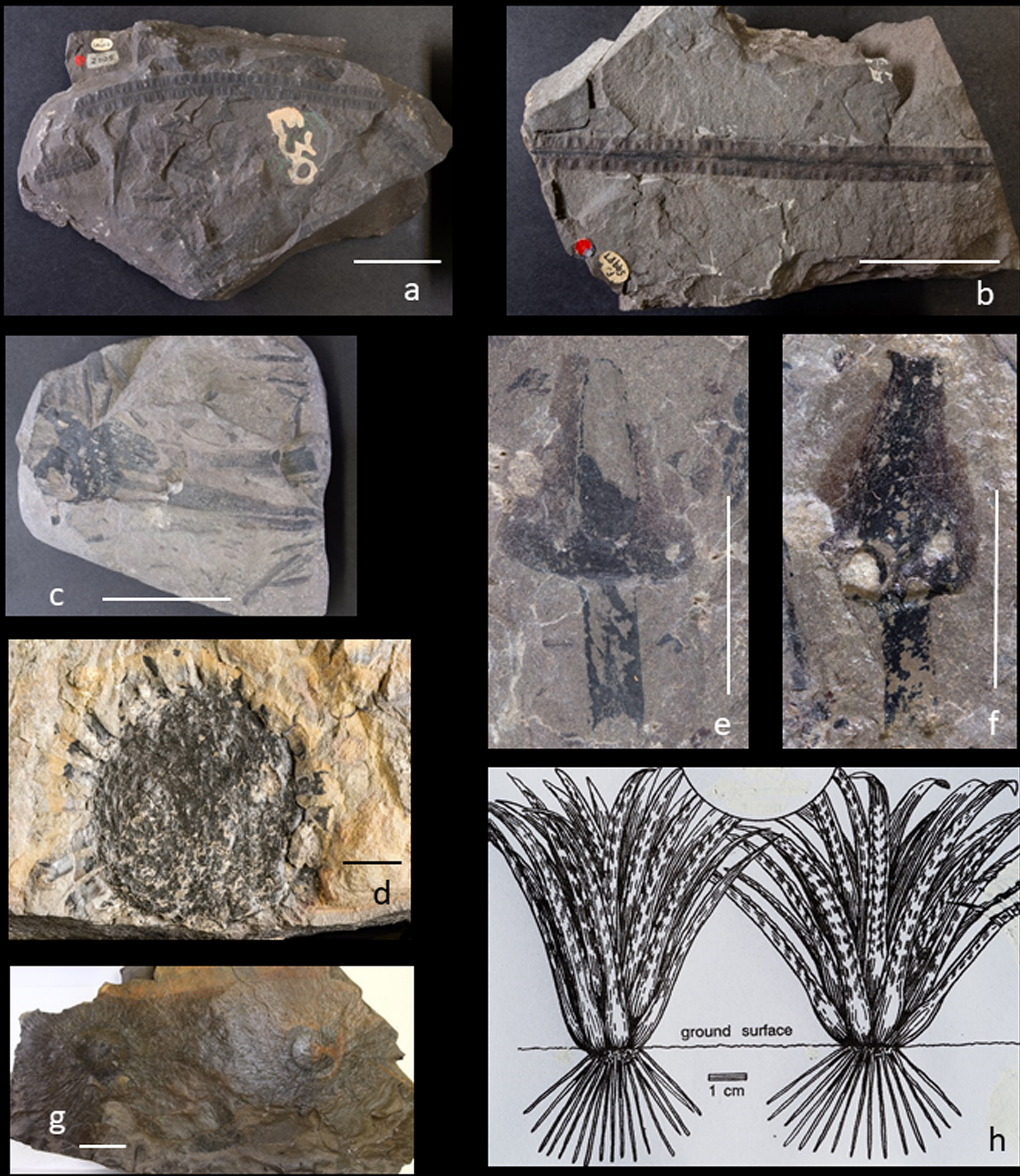

Figure 11. Northern Beaches. Plantae—Lycopodiophyta. (*a*) AM F.68406 *Pleuromeia dubia*, leaf. (*b*) AM F.59987 *Pleuromeia dubia,* leaf. (*c*) AM F.78281 *Pleuromeia dubia,* stem and leaves. (*d*) AM F.58856 *Tomiostrobus australis*, fertile sporophore. (*e*) AM F.58858 *Tomiostrobus australis*, compressed sporophores. (*f*) AM F.58857 *Tomiostrobus australi*s, compressed sporophores. (*g*) AM F.60890 *Tomiostrobus australis*. (*h*) *Isoetes beestonii* (from Retallack, 1997). Scale bars: *a, b, c*, and *g* = 5 cm; *d, e*, and *f* = 1 cm; *h* with permission of Cambridge University Press, © The Paleontological Society.

| AM F.58847 (fig. 7I)—microsporophyll—from Terrigal Headland—held in the AMTC under "Ash 1979". | AM F.58851 (fig. 7K)—dispersed microphylls—from Terrigal Headland—held in the AMTC under "Ash 1979". | AM F.58855 (fig. 7G)—microsporophyll—from Terrigal Headland—held in the AMTC under "Ash 1979". | AM F.58857 (Fig. 11f) (fig. 7C)—microsporophyll—from Terrigal Headland—held in the AMTC under "Ash 1979". | AM F.58848 (fig. 7E)—megasporangium—from Terrigal Headland—held in the AMTC under "Ash 1979".

Figured in White (1981): AM F.60890 (Fig. 11g) (fig. 9)—*Cylomeia capillamentum*—two "cones" with radiating rootlets—from Long Reef Headland—held in the AMTC under "White 1981b". | AM F.60891 (fig. 10)—*Cylomeia capillamentum*—one "cone" with radiating rootlets—from Long Reef Headland—held in the AMTC under "White 1981b".

Figured in Retallack (1997): AM F.91455 (fig. 4 no. 3)—corm with leaf bases above—from Terrigal Headland—held in the AMTC under "Retallack 1997". | AM F.91456a,b (fig. 4 no. 5)—cross section of fertile specimen—from Terrigal Headland—held in the AMTC under "Retallack 1997". | UNEF 13831 (fig. 4 no. 6)—corms and stems—from North Narrabeen Headland—missing. | SUGD 2058 (fig. 4 no. 7)—corms and stems—from Newport Headland—missing. | UNEF 13829 (fig. 4 no. 8)—corms and stems—from Turimetta Headland—missing. | AM F.78283 (UNEF 13824) (fig. 4 no. 9)—leaf circlet from North Narrabeen Headland—held in the AMTC under "Retallack 1980". | UNEF 13826 (fig. 4 no. 10)—short stem—from North Narrabeen Headland—missing. | AM F.78285 (UNEF 13827) (fig. 4 no. 11)—cross section of stem—from North Narrabeen Headland—held in the AMTC under "Retallack 1980".

Mentioned in Retallack (1997): SUGD 4013—from Turimetta Headland—missing. | MMF 17471—from Helensburgh Mine—possibly held in the GSNSW collection.

Ash (1979) described lepidodendralean megafossil sporophores found in the Terrigal Headland (The Skillion). They were large and heterosporous with numerous spirally arranged sporophylls. He noted that the microspores were similar to *Cylostrobus sydneyensis* and were ovoid in shape with a long, smooth peduncle. He erected a new genus, *Skilliostrobus*, and named the sporophores *Skilliostrobus australis*. Ash (1979) also noted that *Skilliostrobus* and two other large "cone" type specimens, *Cylostrobus* (Helby & Martin, 1965) and *Lycostrobus* (Nathorst,1908), probably represented three subarborescent lycopsids. White (1981) studied some well-preserved specimens of whorled lycopsid leaf crowns, erecting a new genus, *Cylomeia,* and three species, *C. undulata, C. longicaulis* and *C. capillamentum. C. capillamentum* was from Long Reef Headland and exhibited a circlet of linear, hair-like "leaves". Retallack (1997) saw sporophylls as the most diagnostic plant remains for recognizing species. Subjecting sporophylls to cladistics analysis he reviewed the Early Triassic evolutionary radiation of *Isoetes* and *Pleuromeia*-like subarborescent lycopsids and concluded that *Isoetes* pre-dates *Pleuromeia*, and in fact *Isoetes* was the common ancestor of the Early and Middle Triassic lycopsids. This placed the Triassic lycopsids in the Isoetales family Isoetaceae. Based on the principle that a complete plant should be named after the reproductive structures, Retallack (1997) emended Ash's taxonomy, placing the above plant components in the genus *Tomiostrobus,* and maintaining the species name of *australis* nominated by Ash (1979). This plant was conceived to have a basal corm with short, conical stem and leaves helically arranged in a single terminal cluster. The sporophylls had frayed, distal limbs and lateral lobes which were distinct from the fertile leaves of *Isoetes* (Pigg, 1992). Fossils with a circlet of fine, radiating hair-like "leaves" referred by White (1981) to *Cylomeia capillamentum* were interpreted as fertile individuals of *T. australis* in growth position with abundant fine, radiating rootlets (Retallack, 1997) (Fig. 11g).

Isoetes beestonii Retallack, 1997

Fig. 11h

Taeniopteris undulata Burges, 1935: pl. 10 fig. 1.
Cylomeia undulata.—White, 1981: 731, figs 2–5.—Retallack, 1997.
Isoetes beestonii Retallack, 1997: 502, fig. 3.

Holotype: GSQ 12953—fertile plant compression—from Blackwater, Queensland—held in the GSQ collection.

Figured in White (1981): AM F.58791 (figs 1,2)—plate-like crown of ribbon leaves—from Bellambi Colliery—held in the AMTC under "White 1981b". | AM F.59987 (fig. 4)—part of long leaf—from Avalon Headland—held in the AMTC under "White 1981b".

Figured in Retallack (1997): AM F.91460 (fig. 3 no. 4)—leaf base—from Coxs Gap—held in the AMTC under "Retallack 2002". | AM F.58791 (fig. 3 no. 6)—leaf circlet of sterile plant—from Bellambi Colliery—held in the AMTC under "White 1981b".

Mentioned in Retallack (1997): AM F.60882—from Bellambi Colliery, NSW—held in the AMTC under "White 1981b". | MMF 16456—from Kemira Colliery—held in the GSNSW collection. | MMF 13643–13646—from Coxs Gap—held in the GSNSW collection. | MMF 13648–13652—from Coxs Gap—held in the GSNSW collection. | MMF 13666—from Coxs Gap—held in the GSNSW collection. | AM F.39862—from Rylestone, NSW—held in the AMTC under "White 1981b".

White (1981) studied a well preserved specimen of a whorled lycopsid leaf crown from the roof shales of Bellambi Colliery (and others). She noted the ribbon-like leaves bore a close resemblance to the leaf *Taeniopteris undulata* (Burges, 1935) and *Pleuromeia longicaulis* (Retallack, 1975). She erected a new genus *Cylomeia* to accommodate these specimens because they revealed that the distal edges of the crown leaf undulated (like *Taeniopteris undulata*), while its proximal edges were parallel (like *Pleuromeia longicaulis*). White (1981) also argued that the use of the genus *Pleuromeia* by Retallack (1975) could not be justified due to different generic separation in the "cones". She assigned the unattached, long, narrow leaves with undulating margins of *Taeniopteris undulata* (Burges, 1935) to *Cylomeia undulata*. The leaves with parallel margins of *Pleuromeia longicaulis* (Retallack, 1975) she assigned to *Cylomeia longicaulis*. Rhizophores were referred to *Cylomeia*, but not to any species as they were likely to be a general type for all species. All the "cones" of *Cylostrobus* (Helby & Martin, 1965) she assigned to *Cylomeia longicaulis*. She also observed a close similarity between the "cones" of *Skilliostrobus* (Ash, 1979) and

Cylostrobus, and argued conditionally that *Skilliostrobus* could be described as a species of *Cylostrobus*.

Retallack (1997) viewed sporophylls as the most diagnostic plant remains for recognizing species. Subjecting sporophylls to cladistics analysis he reviewed the Early Triassic evolutionary radiation of *Isoetes* and *Pleuromeia*-like subarborescent lycopsids and concluded that *Isoetes* pre-dates *Pleuromeia*, and in fact *Isoetes* was the common ancestor of the Early and Middle Triassic lycopsids. This placed the Triassic lycopsids in the Isoetales family Isoetaceae. Retallack (1997) emended the taxonomy of the specimens of White (1981), placing the whorled leaf crown *Cylomeia undulata* (White, 1981) in the genus *Isoetes* with a new species name*, beestonii*. This plant was conceived to have long, ribbon-like leaves 5 mm broad with flared bases on which sporangia was deposited (unlike other species that had specialized cone-like sporophores). The leaves radiated from a corm which contained fine rootlets, forming a bunched, ground level plant (Fig. 11h). Although Retallack (1997) placed the whorled leaf crown from Bellambi Colliery *Cylomeia undulata* within *I. beestonii*, he placed the leaf *Taeniopteris undulata* (Burges, 1935), incorporated by White (1981) into *Cylomeia undulata,* in *Pleuromeia dubia*.

Division Pteridospermatophyta (pteridosperms) (seed ferns)

Order Peltaspermales

Family Peltaspermaceae

Lepidopteris madagascariensis Carpentier, 1935

Fig. 12a,b,c

Lepidopteris madagascariensis Carpentier, 1935: 14.
Alethopteris sp. Dun, 1908: 155.—Townrow, 1966.

Type: Carpentier, 1935 (pl. 3 figs 3,4)—from Madagascar.

Figured in Townrow (1966): MMF 12694 (pl. 1 fig. 1)—almost complete leaf—from Sydney Harbour Colliery, Balmain. | AM F.51726 (Fig. 12a) (pl. 1 figs 2,3)—lower cuticle, rachis and pinnule—from Turimetta Headland—held in the AMTC under "Townrow 1966". | AM F.51727 (Fig. 12b) (text fig. 1G)—portion of leaf—from Turimetta Headland—held in the AMTC under "Townrow 1966". | AM F.51728 (Fig. 12c) (text fig. 1C)—portion of leaf—from Turimetta Headland—held in the AMTC under "Townrow 1966". | AM F.51729 (text fig. 1F)—leaf fragment—from Turimetta Headland—held in the AMTC under "Townrow 1966". | AM F.51730 (text fig. 1D)—portion of leaf—from Coalcliff Colliery—held in the AMTC under "Townrow 1966". | AM F.51731 (text fig. 2C)—stoma of the rachis—from Turimetta Headland—held in the AMTC under "Townrow 1966".

Dun (1908) described a specimen from the Balmain Colliery as a new species of *Alethopteris*. Townrow (1960) addressed the then current knowledge of the various plant components of the Peltaspermaceae family. The various structural components of this family had previously been described separately as *Lepidopteris* (the leaf), *Antevsia* (the pollen organ) and *Peltaspermum* (the seed organ). Townrow (1966) collected specimens of Peltaspermaceae from Turimetta Headland and examined other material from the Balmain Shaft (identified as *Alethopteris*) and Coalcliff held in GSNSW and AMGC collections, identifying the leaves as *Lepidopteris madagascariensis.* He observed that *L. madagascariensis* can be distinguished by thick leaf substance, obtuse pinnules, lumps on rachis often paired, cell outlines straight, monocyclic stomata and unmodified leaf margins. However, he stated that nothing was known of the reproductive structures of *L. madagascariensis.* He also noted there were some indicators that point to *L. madagascariensis* being a woody plant, and some that point to an herbaceous habit. Townrow (1966) stated that those suggesting an herbaceous habit are the more impressive. Townrow (1966) also stated that five species of *Lepidopteris* (*L. madagascariensis, L. stormbergensis*—southern hemisphere; *L. martinsii, L. stuttgardiensis, L. ottinis*—northern hemisphere) form a close-knit group. Retallack (2002) re-assessed the frond structure of *Dicroidium callipteroides* and re-assigned it to *Lepidopteris*, thus adding *L. callipteroides* to the southern hemisphere group of *Lepidopteris* species. Holmes and Anderson (2005) placed the Northern Beaches headlands specimens, amongst others, within a "*Lepidopteris madagascariensis* complex", a taxonomic structure called a "morpho-species complex", to account for a range of structural variations within a morpho-species.

Family Umkomasiaceae

Zuberia feistmanteli (Johnston, 1893)

Fig. 12d,e,f

Thinnfeldia feistmantelii Johnston, 1893: 175.
Dicroidium feistmanteli [sic].—Gothan, 1912.
Zuberia feistmanteli.—Pattemore, 2016: 150, fig. 13A.

Lectotype: Feistmantel, 1890: pl. 5 figs 1,2—subsequently lost (Fletcher, 1970: 14).

Neotype: QMF 42594—*Zuberia feistmanteli*—from Blackstone Hill, Ipswich (Pattemore, 2016: 150, fig. 13A).

Figured in Walkom (1925): AM F.50119 (Fig. 12d) (pl. 24 fig. 6)—fragment with pinnules—held in the AMTC under "Walkom 1925". | AM F.50122 (Fig. 12e) (pl. 24 fig. 8)—fragment with pinnules—held in the AMTC under "Walkom 1925". | AM F.50126 (pl. 24 fig. 7)—fragment with pinnules—held in the AMTC under "Walkom 1925". | MMF 13080 (pl. 24 fig. 9)—fertile pinna—held in the GSNSW collection. | AM F.50120 (pl. 25 fig. 2)—large fragment of frond—held in the AMTC under "Walkom 1925". | AM F.50124 (Fig. 12f) (pl. 25 fig. 1)—large fragment of frond—held in the AMTC under "Walkom 1925".

Figured specimens locality: mainly Turimetta Headland.

Johnston (1893) proposed the name *Thinnfeldia feistmantelii* for a bipinnate specimen from Mt Victoria found by Feistmantel in 1879.

Gothan (1912) erected the genus *Dicroidium*, as the group of plants with bifurcating rachides from Mt Victoria was distinct from *Thinnfeldia*.

Walkom (1925) was not aware of this emended genus. While studying specimens from the Northern Beaches headlands, he commented that, although some workers suggested referring this species to *Ctenopteris,* the dichotomous forking of the rachis of Australian *Thinnfeldia* species including *T. feistmanteli* made him unable to agree to this transfer for any of the Australian species.

Pattemore (2016) commented that new discoveries related to pinnules arising directly from the rachis was an important difference distinguishing *Zuberia* from *Dicroidium*, and that their wood stems differ genetically. Therefore, *Dicroidium feistmanteli* should be emended to *Zuberia feistmanteli*.

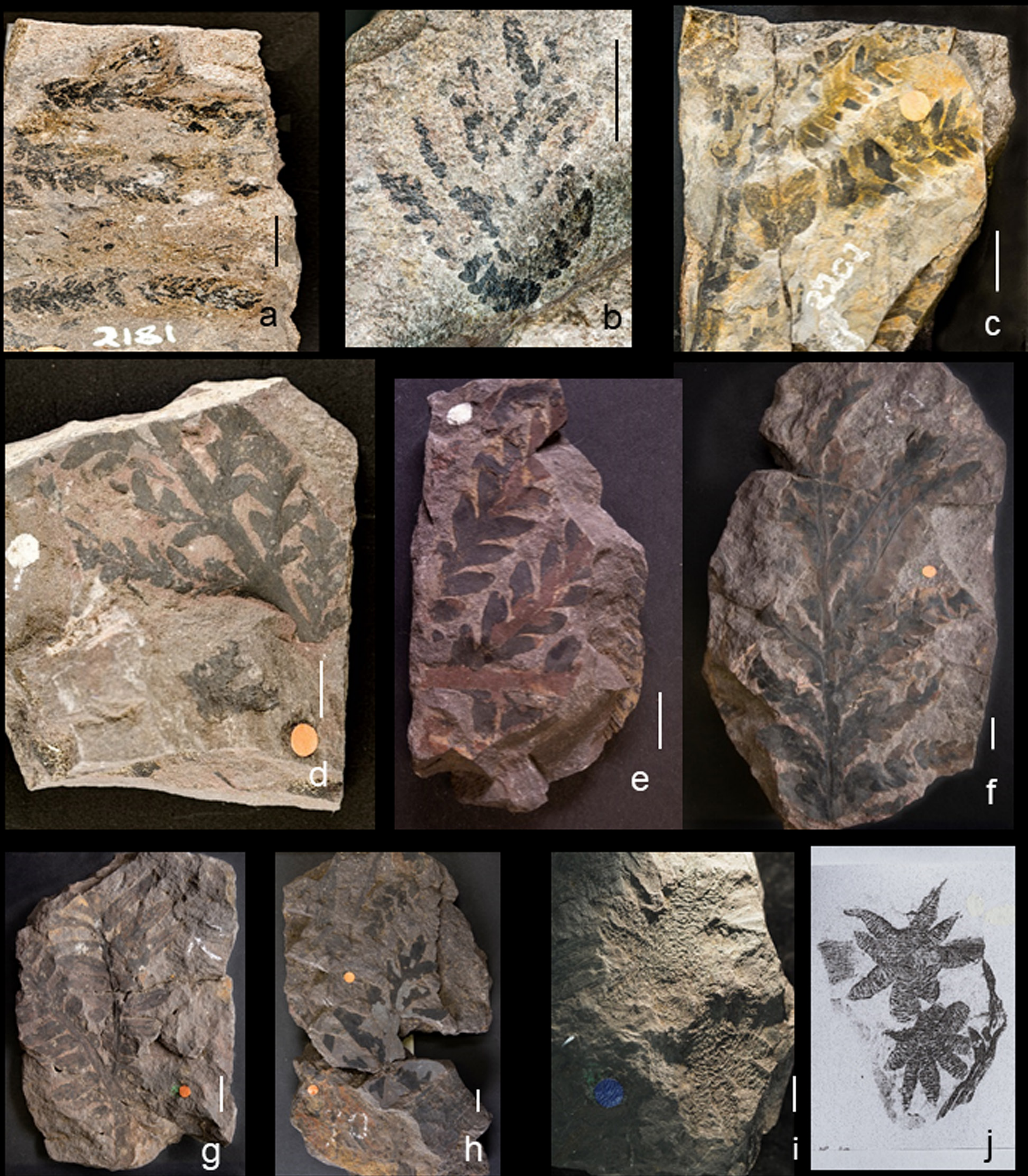

Figure 12. Northern Beaches. Plantae—Pteridospermatophyta. (*a*) AM F.51726 *Lepidopteris madagascariensis.* (*b*) AM F.51727 *Lepidopteris madagascariensis*. (*c*) AM F.51728 *Lepidopteris madagascariensis*. (*d*) AM F.50119 *Zuberia feistmanteli.* (*e*) AM F.50122 *Zuberia feistmanteli.* (*f*) AM F.50124 *Zuberia feistmanteli.* (*g*) AM F.50121 *Dicroidium odontopteroides.* (*h*) AM F.50125 *Dicroidium odontopteroides.* (*i*) MMF 13135 *Umkomasia* sp. (*j*) MMF 13135 *Umkomasia* sp. (from Walkom, 1925) with permission of the Linnean Society of New South Wales. Scale bars = 1 cm.

Dicroidium odontopteroides (Morris, 1845)

Fig. 12g,h

Pectopteris odontopteroides Morris (in Strzlecki), 1845: 249, pl. 6 figs 2–4.
Thinnfeldia odontopteroides.—Szajnocha, 1888: 231, 232, pl. 1 figs 4b,5–7.
Dicroidium odontopteroides.—Gothan, 1912: pl. 16 figs 2–4.
Thinnfeldia lancifolia Walkom, 1925: 217, pl. 25 fig. 3, pl. 26 figs 1–3, pl. 27 figs 1,2,4,5.—Pattemore, 2016.
Thinnfeldia narrabeenensis Walkom, 1925: 218, pl. 26 fig. 4, pl. 27 figs 3,6, pl. 28 figs 1–4.—Pattemore, 2016.
Dicroidium odontopteroides.—Pattemore, 2016: 134.

Syntype: AM F.50125 (Fig. 12h) (pl. 28 fig. 4)—*Thinnfeldia narrabeenensis*—frond fragment—held in the AMTC under "Walkom 1925".

Figured in Walkom (1925): *Thinnfeldia lancifolia* | MMF 13070 (pl. 25 fig. 3)—portion of frond with seeds—held in the GSNSW collection. | AM F.50121 (Fig. 12g) (pl. 26 fig. 1)—frond bifurcation—held in the AMTC under "Walkom 1925". | # (pl. 26 fig. 2)—frond bifurcation—possibly held in the GSNSW collection. | AM F.50123 (pl. 26 fig. 3)—frond fragment—held in the AMTC under "Walkom 1925". | MMF 13071 (pl. 27 fig. 1)—frond fragment—held in the GSNSW collection. | MMF 13068 (pl. 27 fig. 2)—frond fragment—held in the GSNSW collection. | # (pl. 27 fig. 4)—frond bifurcation fragment—possibly held in the GSNSW collection. | # (pl. 27 fig. 5)—frond fragment—possibly held in the GSNSW collection. | *Thinnfeldia narrabeenensis* | MMF 13038 (pl. 26 fig. 4)—frond fragment—held in the GSNSW collection. | # (pl. 27 fig. 3)—frond fragment—possibly held in the GSNSW collection. | MMF 13039 (pl. 27 fig. 6)—frond fragment—held in the GSNSW collection. | # (pl. 28 fig. 1)—apical frond fragment—possibly held in the GSNSW collection. | MMF 13040 (pl. 28 fig. 2)—basal frond fragment—held in the GSNSW collection. | # (pl. 28 fig. 3)—apical frond fragment—possibly held in the GSNSW collection.

Figured specimens locality: mainly Turimetta Headland.

Gothan (1912) erected the genus *Dicroidium*, as plants with bifurcating fronds were distinct from *Thinnfeldia*. Walkom (1925), not knowing about this reclassification, named some specimens from the Northern Beaches headlands *Thinnfeldia lancifolia* and described the frond structure of these specimens which divided dichotomously into two linear pinnae and were inclined to one another at an acute angle. The figured specimens illustrated this well. He stated that this species was common in the Lower Mesozoic rocks of Australia and South Africa. Walkom (1925) also described the species *Thinnfeldia narrabeenensis* from this area as being a larger and more robust type than other species of this genus, having large, pinnate, dichotomous fronds. Over a period of many years diverse taxonomies of similar specimens with bifurcating rachides were recombined, based on unipinnate structure and pinnule size, as *Dicroidium odontopteroides*. Pattemore (2016) included *Thinnfeldia lancifolia* and *Thinnfeldia narrabeenensis* in his list of synonyms for *D. odontopteroides.*

Umkomasia sp.

Fig. 12i,j

?*Williamsonia* sp. Walkom, 1925: 220, pl. 29 figs 7.
Umkomasia sp. Thomas, 1933: 203; Anderson *et al*., 2019: 45.

Figured in Walkom (1925): # (pl. 29 fig. 7)—"flowerlike" bract arrangement—possibly held in the GSNSW collection. | MMF 13134 (pl. 29 fig. 8)—"flowerlike" bract arrangement—held in the GSNSW collection. | MMF 13135 (Fig. 12i,j) (pl. 29 fig. 9)—"flowerlike" bract arrangement—held in the GSNSW collection.

Early workers were puzzled by star shaped plant specimens found amongst Triassic plant deposits in eastern Australia. Walkom (1925) described some "flowerlike" specimens from the Northern Beaches consisting of 5 to 8 bracts petaloid in shape and arranged radially. They were similar to specimens found in Mexico, Sweden and India. He associated these with stems that showed rhomboidal leaf bases spirally arranged. He placed them in the genus *Williamsonia* within Cycadophyta. Thomas (1933) erected a new genus, *Umkomasi*a, for similar South African specimens. Later, workers in Triassic plants worldwide recognized their persistent association with pteridosperms, particularly *Dicroidium*. Detailed study of these specimens in association with pteridosperms has been carried out in Queensland (e.g., Pattemore, 2016) and South Africa (e.g., Anderson *et al*., 2019). Species names have been allocated to many specimens in these regions. Although Northern Beaches headlands specimens have been compared to *Umkomasia feistmantelii* (Anderson *et al*., 2019: 52, Table1) they have not been described in detail. *Umkomasia* are megasporophylls now recognized as the female fertile organs of *Dicroidium*, matched to the male fertile organs *Pteruchus.*

Order Medullosales

Family Neurodonteridaceae

Odontopteris dubia Burges, 1935

Fig. 13a

Type: AM F.68408 (SUGD 2007) (Fig. 13a) (text figs 6,6a)—frond—held in the AMTC under "Burges 1935".

Figured locality: possibly Turimetta Headland.

The leaves were simple, linear and lanceolate, 10 to 12 cm long and 2 cm wide, and segments were rounded (Burges, 1935). The taxonomic placement of this particular specimen has not been reviewed since Burges (1935), but recent papers place *Odontopteris* sp. with other pteridosperms in the Neurodonteridaceae within the Medullosales.

Figure 13. Northern Beaches. Plantae—Pteridospermatophyta, Equisetophyta, Pteridophyta. (*a*) AM F.68408 *Odontopteris dubia*. (*b*) MMF 13171 ?*Sphenopteris* sp. (*c*) *Phyllotheca australis* (from Walkom, 1925). (*d*) AM F.60560 *Phyllothica*. (*e*) AM F.60570 *Paraschizoneura jonesii*. (*f*) AM F.60569 *Paraschizoneura jonesii*. (*g*) *Coniopteris* sp. cf. *lobata* (from Walkom, 1925). (*h*) *Taeniopteris tennison-woodsii* (from Walkom (1925). (*i*) MMF 13126 *Taeniopteris crassinervis*. Scale bars = 1 cm. *c*, *g*, and *h* with permission of Linnean Society of New South Wales.

Order Lyginopteridales

Family Lyginopteridaceae

?*Sphenopteris* sp.

Fig. 13b

Figured in Walkom (1925): MMF 13171 (Fig. 13b) (pl. 29 fig. 5)—frond fragment—held in the GSNSW collection.
Figured specimen locality: possibly Turimetta Headland.

Walkom (1925) referred the specimen provisionally to this genus. No venation was observed. At that time *Sphenopteris* was considered to be a fern. It is now classed as a pteridosperm after other specimens have been studied worldwide.

Division Equisetophyta (Sphenophyta) (horsetails)

Class Equisetopsida

Order Equisetales

Family Phyllothecaceae

Phyllotheca australis Brongniart, 1828

Fig. 13c,d

Figured in Walkom (1925): # (Fig13c) (pl. 24 fig. 1)—stem—from Turimetta Headland—possibly in the GSNSW collection. | # (pl. 24 fig. 2)—two nodes—from Turimetta Headland—possibly in the GSNSW collection. | # (pl. 24 fig. 3)—nodal diaphragm—from Turimetta Headland—possibly in the GSNSW collection.
Other specimens from Turimetta Headland held in AMGC: AM F.60560 (Fig. 13d)—*Phyllotheca* sp. | AM F.60818—*Phyllotheca* sp.

Brongniart (1828) described *Phyllotheca australis* from specimens obtained from "mines along the Hawkesbury River in New South Wales" (Townrow 1955). Walkom (1925) referred all equisetalean specimens in his study to *P. australis* based on the leaves preserved on the figured specimen (Walkom, 1925: pl. 24 fig. 2). Townrow (1955) compared a number of specimens attributed to *P. australis* by various authors (including Walkom, 1925) and concluded that *P. australis* is better considered as a Permian species and its existence into the Triassic had not been exclusively demonstrated. Holmes (2001a) noted that, due to the nodal structure of the Triassic Gondwanan equisetaleans, he also suspected that *Phyllotheca australis* did not survive the end Permian extinction. Although these two authors have suggested doubt that *P. australis* survived into the Triassic, no author presently has emended the classification of the Northern Beaches specimens made by Walkom (1925). Holmes (2000) suggested generally that all Gondwana sphenophyte foliage bearing stems previously placed in *Neocalamites* or *Phyllotheca* should be re-assessed for possible inclusion in his newly erected genera *Zonulamites* or *Townroviamites*.

Family incertae sedis

Paraschizoneura jonesii Holmes, 2001

Fig. 13e,f

Holotype: AM F.60570 (Fig. 13e) (fig. 6A,B)—node with leaf whorl—held in the AMTC under "Holmes 2001a".
Paratype: AM F.60569 (Fig. 13f) (fig. 6C)—stem and node with leaf whorl—held in the AMTC under "Holmes 2001a".
Type locality: Turimetta Headland.
Other specimens from Turimetta Headland held in the AMGC: AM F.128208—node with leaf whorl.

Holmes (2001a) studied specimens held in the AMGC and described the above specimens from Turimetta Headland as a new species. He stated that *P. jonesii* was closely comparable to Permian South African *Schizoneura* and Siberian *Paraschizoneura* species, but due to the wide temporal and geographical separation from these species these Triassic Australian specimens are best described as a new species of *Paraschizoneura*.

Division Pteridophyta (Filicophyta) (ferns)

Order Filicales

Family Cyatheaceae

?*Coniopteris* sp. cf. *lobata* Oldham & Morris, 1863

Fig. 13g

Figured in Walkom (1925)**:** # (Fig. 13g) (pl. 29 fig. 4)—frond—possibly in the GSNSW collection. | # (pl. 29 fig. 6)—frond—possibly in the GSNSW collection.
Figured specimens locality: possibly Turimetta Headland.

Walkom (1925) noted that these specimens were similar to *Coniopteris lobata* from the Jurassic rocks of Graham Land (Halle, 1913).

Family Marrattiaceae

Taeniopteris tennison-woodsii (Jack & Etheridge, 1892)

Fig. 13h

Angiopteridium tennison-woodsii Jack & Etheridge, 1892: 375.
Taeniopteris tennison-woodsii.—Shirley, 1898: 23, pl. 9 fig. 2.—Walkom, 1925: 218, pl. 19 fig. 1.

Figured in Walkom (1925): # (Fig. 13h) (pl. 29 fig. 1)—two leaves—possibly held in the GSNSW collection.
Figured specimen locality: possibly Turimetta Headland.

Jack & Etheridge (1892) described a Queensland specimen as *Angiopteridium tennison-woodsii,* which had originally been named as *Angiopteridium ensis* by Tennison Woods, but who did not figure the specimen. Shirley (1898) emended the classification to *Taeniopteris tennison-woodsii.* Walkom (1925) commented that the two leaves from the Northern Beaches resemble previous *Taeniopteris tennison-woodsii* specimens in size and venation except that secondary veins in the figured specimen are slightly curved and not straight like the specimens recorded in Queensland. Holmes *et al*. (2010) placed *T. tennison-woodsii* previously described from Queensland and New Zealand in *Linguifolium tennison-woodsii,* together with specimens from the Nymboida Coal Measures, NSW.

Taeniopteris crassinervis (Feistmantel, 1877)

Fig. 13i

Macrotaeniopteris crassinervis Feistmantel, 1877: 102, text fig. 38, figs 1–3.
Taeniopteris crassinervis.—Walkom, 1917: 39, pl. 1 fig. 2 (Qld specimen).—Walkom, 1925: 29, pl. 29 fig. 2, pl. 31 fig. 12 (Northern Beaches specimen).

Figured in Walkom (1925): MMF 13125 (pl. 29 fig. 2)—central rib of leaf—held in the GSNSW collection. | MMF 13126 (Fig. 13i) (pl. 31 fig. 12)—portion of leaf—held in the GSNSW collection.
Figured specimens locality: Turimetta Headland.

This species was originally named from Indian specimens (Feistmantel, 1977). Subsequently, Jack & Etheridge (1892) identified specimens from Queensland as the same species. Walkom (1917a) emended the genus to *Taeniopteris* for specimens from a number of Queensland localities and stated that this species was characterized by its size and coarse venation. Walkom (1924) also described a specimen from Bellevue, Queensland as *Taeniopteris crassinervis.* Walkom (1925) identified some specimens from the Northern Beaches as *T. crassinervis* and noted that the veins were closer on the figured specimens from the Northern Beaches compared to those obtained from Queensland and India. Holmes (2001b) described similar specimens from the Middle Triassic Nymboida Coal Measures as *Osmus adinus*, and suggested a growth form similar to the extant *Asplenium nidus.* Later, Holmes *et al*. (2010) placed *T. crassinervis* from Queensland, described by Walkom (1917a), in *Nilsonnia dissita*, and *Taeniopteris crassinervis* from Bellevue, Queensland, described by Walkom (1924), in *Taeniopteris adunca.*

Taeniopteris triassica Walkom, 1925

Fig. 14a

Type: AM F.17820 (Fig. 14a) (text-fig. 1)—single leaf—held in the AMTC under "Walkom 1925".
Type Locality: Narrabeen Headland.

This species described by Walkom (1925) differs from others of the genus in being quite long and narrow with a prominent midrib and a rounded apex, and secondary veins making an angle of 70° with the midrib.

Taeniopteris wianamattae (Feistmantel, 1878)

Fig. 14b

Macrotaeniopteris wianamattae Feistmantel, 1878: 107, text fig. 13, fig. 2.
Taeniopteris wianamattae.—Walkom, 1917: 38 (Qld specimen).—Walkom, 1925: 220, pl. 29 fig. 3 (Northern Beaches specimen).

Figured in Walkom (1925): MMF 13127 (Fig. 14b) (pl. 29 fig. 3)—apical portion of leaf—held in the GSNSW collection.
Figured specimen locality: possibly Turimetta Headland.

A Sydney fern specimen was originally named *Macrotaeniopteris wianamattae* by Feistmantel (1878). Subsequently, Jack & Etheridge (1892) identified specimens from Queensland as the same species. When describing a similar Queensland specimen, Walkom (1917a) stated that it was one of the large species of *Taeniopteris* and placed it in *Taeniopteris*. Walkom (1925), when commenting on a Northern Beaches specimen he identified as *Taeniopteris wianamattae*, noted that the secondary veins were numerous and made an angle of 60–70° with the midrib.

Order Osmundales

Family Osmundaceae

Cladophlebis sp.

Fig. 14c

Figured in Walkom (1925): # (pl. 24 fig. 4)—portion of fertile frond—possibly held in the GSNSW collection. | # (pl. 24 fig. 5)—isolated pinnae—possibly held in the GSNSW collection.
Figured specimens locality: Turimetta Headland.

Absence of preservation of many diagnostic details prevented Walkom (1925) from describing these specimens to species level, although he thought one specimen could possibly be *C. australis*. Holmes (2001b) placed *Cladophlebis australis* in the Asterothecaceae within the Marattiales as a junior synonym of *Asterotheca trullensis* found in the Nymboida Coal Measures. However, Pattemore (2016) noted that the Osmundaceae, including *Cladophlebis*, are now placed in the order Osmundales.
Other specimen: MMF 13165 (Fig. 14c)—2 fronds—held in GSNSW collection.

Todites narrabeenensis Burges, 1935

Fig. 14d

Type: AM F.68407 (SUGD 2004) (Fig. 14d) (text fig. 2)—fertile frond—held in the AMTC under "Burges 1935".
Figured specimen locality: either Turimetta, Mona Vale, or Avalon Headland.

This plant had pinnate fronds, probably 30 to 50 cm long, and sporangia was scattered over the under-surface (Burges, 1935). Holmes (2001b) placed *Todites* specimens found in the Middle Triassic Nymboida shales in Osmundaceae.

Division Ginkgophyta (ginkgoes)

Order Ginkgoales

Family Ginkgoaceae

Ginkgoites sp.

Figured in Walkom (1925): # (Fig. 14e) (pl. 31 fig. 1)—fragment of leaf—possibly held in the GSNSW collection.
Figured specimen locality: possibly Turimetta Headland.

The specimen was a fragment of a leaf provisionally referred to *Ginkgoites,* but there was not enough leaf preserved for correct determination (Walkom, 1925). Holmes and Anderson (2007) drew attention to the wide range of leaf

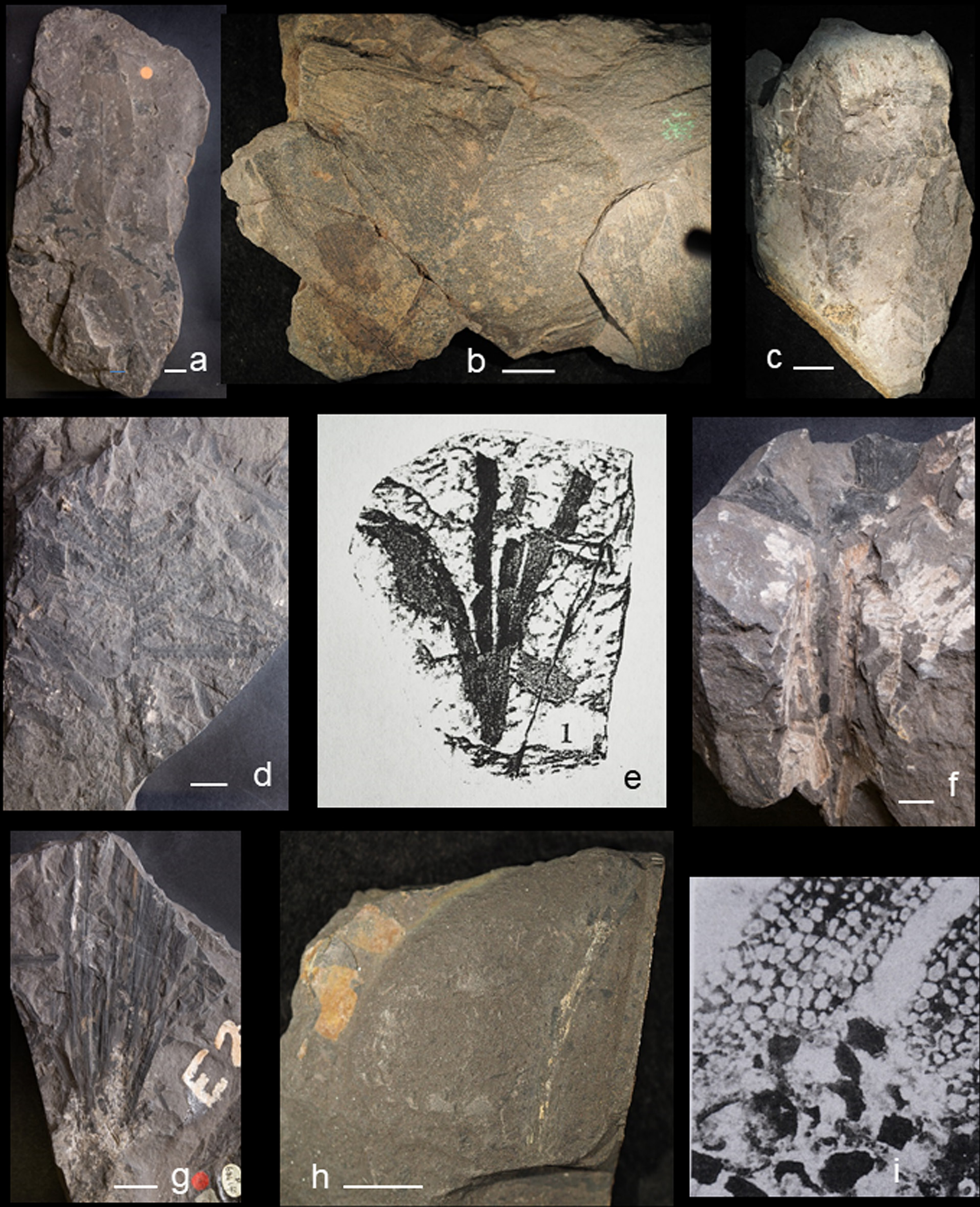

Figure 14. Northern Beaches. Plantae—Pteridophyta, Ginkgophyta, Coniferata. (*a*) AM F.17820 *Taeniopteris triassica.* (*b*) MMF 13127 *Taeniopteris wianamattae.* (*c*) MMF 13165 *Cladophlebis* sp. (*d*) AM F.68407 *Todites narrabeenensis*. (*e*) *Ginkgoites* sp. (from Walkom, 1925). (*f*) AM F.68412 *Rhipidopsis narrabeenensis*. (*g*) AM F.68414 *Baiera simmondsii.* (*h*) MMF 13022 *Voltziopsis angusta*. (*i*) *Cupressinoxylon novae-valesiae* (from Burges, 1935). Scale bars = 1 cm. Images *e* and *i* with permission of Linnean Society of New South Wales.

morphology variation in species among Triassic vegetation, and encompassed this genus within a "morpho-species" complex. They placed leaves with a fan shaped lamina and a distinct petiole in *Ginkgoites*.

Rhipidopsis narrabeenensis Walkom, 1925

Fig. 14f

Type: # (pl. 30 figs 3,4)—fragments of leaves—possibly held in the GSNSW collection.
Figured in Burges (1935): AM F.68412 (SUGD 2012) (Fig. 14f) (text fig. 9)—leaf showing petiole—held in the AMTC under "Burges 1935".
Figured locality: possibly Turimetta Headland

Walkom (1925) observed that leaves on his specimen (pl. 30 figs 3,4) were divided into seven segments which were borne on a petiole. The veins were fine and numerous. Walkom (1925) also noted that Dun (1910) described leaves from the roof shales of Sydney Harbour Colliery as *Rhipidopsis ginkgoides* var. *sussmilchi,* and that the habit of the leaf differentiated it from *Psygmophyllum*. Burges (1935) confirmed from further material that these specimens belonged to *Rhipidopsis* rather than *Psygmophyllum*.

Baiera simmondsi (Shirley, 1898)

Fig. 14g

Ginkgo simmondsi Shirley, 1898: 12, pl. 2.
Baiera simmondsi.—Walkom, 1917: 10, pl. 2 (Qld specimen); Burges, 1935: 261, text figs 7,8 (Northern Beaches specimen).
Figured in Burges (1935): AM F.68413 (SUGD 2008) (text fig. 7)—portion of leaf—held in the AMTC under "Burges 1935". | AM F.68414 (SUGD 2009) (Fig. 14g) (text fig. 8)—portion of leaf—held in the AMTC under "Burges 1935".
Figured locality: either Turimetta, Mona Vale, or Avalon Headland.

Shirley (1878) originally described Queensland specimens as *Ginkgo simmondsi.* Walkom (1917b) stated there was no doubt the Queensland species should be referred to *Baiera*. The leaves of Northern Beaches specimens were multi-lobed, and larger than the previously described *B. simmondsi* (Burges, 1935). Holmes & Anderson (2007) commented that Anderson & Anderson (1989) included *Baiera simmondsi* within *Ginkgo palmata* in their study of the palaeoflora of South Africa.

Division Coniferophyta (conifers)

Order Coniferales

Family Voltziaceae

Voltziopsis angusta (Walkom, 1925)

Fig. 14h

Brachyphyllum angustum Walkom, 1925: 221, pl. 30 figs 5,6.
Voltziopsis angusta.—Townrow 1967: 183, figs 1B,D, 2F, 6A–C, 7A–C.
Syntype: # (Walkom, 1925: pl. 30 fig. 5)—portion of sterile branch—missing (Townrow, 1967).
Syntype: # (Walkom, 1925, pl. 30 fig. 6)—portion of sterile branch—missing (Townrow, 1967).
Figured in Townrow (1967): MMF 13021 (figs 1C,6B)—fragments of branch—held in the GSNSW collection. | MMF 13022 (Fig. 14h) (figs 1B,1D,2F,6A,6C,7A–C)—fragments of branch—held in GSNSW collection.
Figured localities: Narrabeen Headland (MMF 13021), Turimetta Headland (MMF 13022).

The sterile branches had short, narrow, obtusely pointed leaves arranged in spirals (Walkom, 1925). The specimens were provisionally referred to *Brachyphyllum*, but may also be compared with *Voltzia* (Walkom, 1925). Townrow (1967) could not locate the syntypes, so he studied two similar specimens from the same locations. He reasoned that the leaf shape and cuticle were extremely close to the two species of known *Voltziopsis*. (This was foreshadowed by Walkom (1925)). Townrow (1967) therefore emended the *Brachyphyllum angustum* classification to *Voltziopsis angusta*. Holmes & Anderson (2013) noted that a specimen from the Middle Triassic Nymboida Coal Measures that they named *Voltziopsis* sp.A was similar in gross morphology to *V. angusta.*

Seeds

Carpolithus sp.

Figured in Walkom (1925): MMF 13172 (pl. 31 figs 3–5)—oval seeds—held in the GSNSW collection.
Figured locality: possibly Turimetta Headland.

There were some oval seeds up to 1.5 cm long by 1.0 cm wide, but they showed no diagnostic detail (Walkom, 1925).

Wood

Cupressinoxylon novae-valesiae Burges, 1935

Fig. 14i

Syntype: # (Fig. 14i) (pl. 10 figs 2–5)—thin sections of stems—Possibly held in the GSNSW collection. Syntype # (pl. 10 fig. 6)—primary wood and early secondary wood—possibly held in the GSNSW collection.
Locality: Terrigal Headland (The Skillion).

The specimens were compressed portions of petrified stems and branches, oval in shape, and cellular structure was well retained (Burges, 1935).

?*Cedroxylon triassicum* Burges, 1935

Type: # (pl. 10 figs 7–9)—longitudinal thin sections of stems—possibly held in the GSNSW collection.
Locality: Terrigal Headland (The Skillion).

The specimens were compressed, petrified stems, oval in shape, and pith and xylem were fairly well preserved (Burges, 1935).

Sydney Basin Collieries

The various collieries within the Sydney Basin are located around the periphery of the Triassic rocks, as they mine coal from the Permian coal measures immediately under the Narrabeen Group. Many are in the Wollongong area as they have access through the escarpment. The Bulli or Upper Coal Measures are the youngest deposits and the closest to the Triassic sediments. Other collieries penetrate the Permian strata directly in the Lithgow and Newcastle regions. The one exception was the Sydney Harbour Colliery which was constructed in the late 1890s to a considerable depth to reach the Permian coal below Sydney.

The roof shales of the collieries mining Permian coal in the Sydney Basin are considered to be the Permian/Triassic boundary (Retallack, 2002), although this is still subject to periodic discussion. This means that roof shale specimens were most likely obtained from the bottom stratum of the Narrabeen Group.

Sydney Harbour Colliery, Balmain

Sydney Harbour Colliery was located on the northern side of the Balmain peninsular (now in Birchgrove) within the inner Sydney area. Sydney Harbour Collieries Ltd obtained permission to mine in 1895 and were bought by Harbour Collieries Co. in 1896.

Two shafts named Birthday and Jubilee were sunk between 1897 and 1902. The mine produced coal until 1931 and natural gas until 1945. It reached a depth of 880 m.

Class Insecta

Order Orthoptera

Family Elcanidae

Elcanopsis sydneiensis Tillyard, 1918

Fig. 15a,b

Type: MMF 15455 (Fig. 15a)—portion of a forewing—held in the GSNSW collection.

Tillyard (1918b) described a fossil insect wing recovered from the roof shale of a Permian coal seam below Sydney harbour. This specimen was impressed on a specimen of *Taeniopteris* separately described by Dun (1911) (See *Taeniopteris* cf. *mcclellandi* below). Tillyard (1918b) compared the venation of the specimen (Fig. 15b) with the Elcanidae previously found in England and Germany, and found a close association, although some characteristics were missing due to its fragmentary nature. Tillyard erected a new genus and species for this specimen.

Class Crustacea

Although no specific description of the *Estheria* found during the sinking of the Birthday Shaft at Balmain has been made, the levels at which *Estheria* were noted correlates generally with the *Estheria* Shales described by Etheridge (1888) from bores in the Sydney region. They were noted at levels 1770 ft and 2937 ft in the Birthday Shaft (Dun, 1908), and at the Dent's Creek bore at 1,362 ft and 1,625 ft, then at 1,932 ft and 2,000 ft (with a maximum bore depth of 2,000 ft) (Etheridge, 1888).

Plantae

In the annual report of the Department of Mines 1907, Dun (1908) listed in detail the strata of the Birthday Shaft and noted the fossils therein. These included fossils of *Thinnfeldia* and *Equisetum* at 1,000 ft, *Thinnfeldia odontopteroides, T. narrabeenensis, Alethopteris, Taeniopteris* and *Equisetum* at 1,010 ft, *Equisetum*, *Thinnfeldia* between 1187 ft and 1409 ft and *Schizoneura* at 2874 ft. At 2880 ft *Glossopteris* with *Schizoneura* was seen and *Glossopteris* and *Vertebraria* were recorded in the sump of the Birthday Shaft at 2937 ft. Some of these fossils were described by Etheridge (1903) and Dun (1910).

Division Pteridophyta (Filicophyta) (ferns)

Order Filicales

Family Marrattiaceae

Taeniopteris cf. *mcclellandi* (Oldham & Morris, 1863)

Fig. 15c

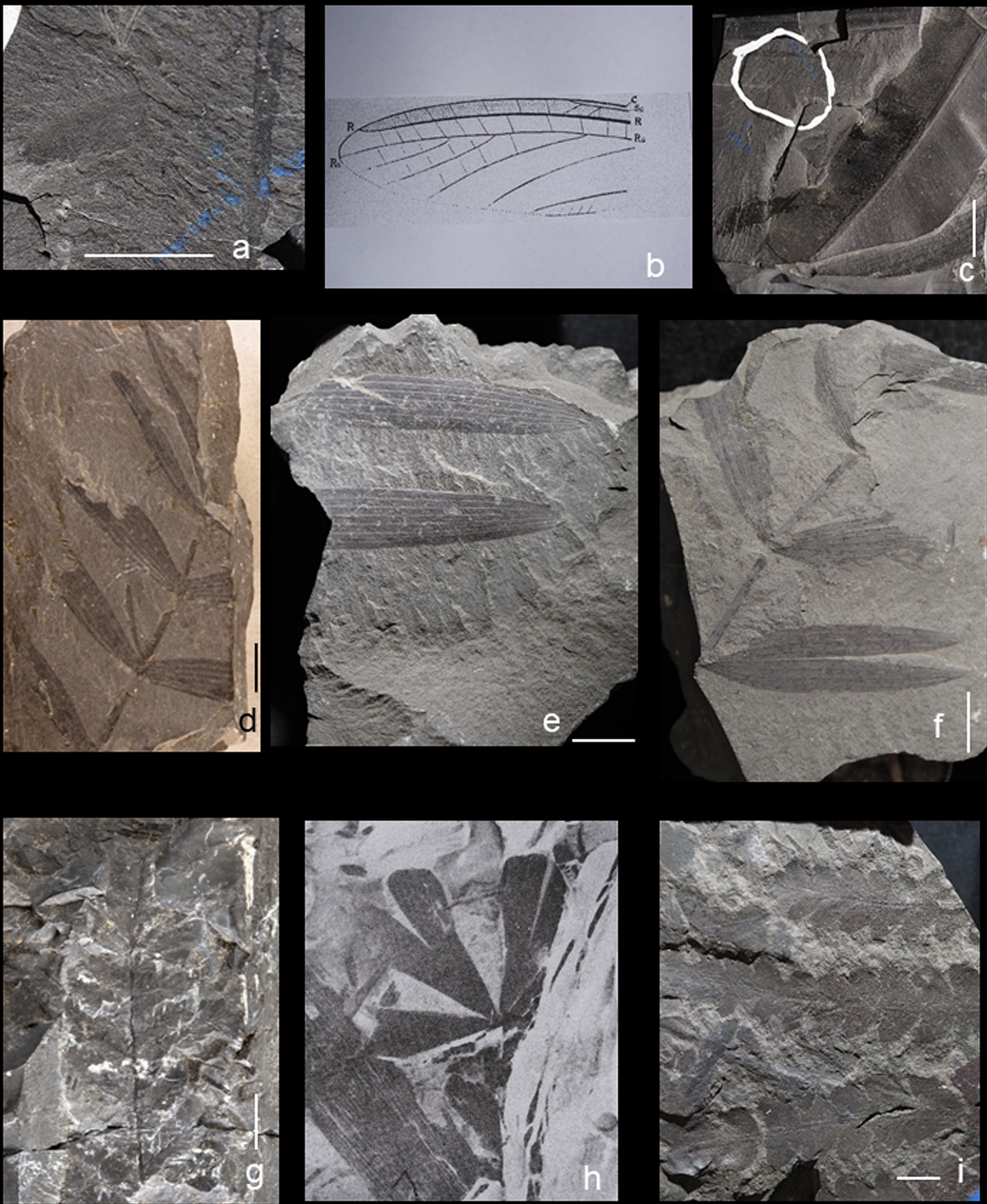

Figure 15. Sydney Harbour Colliery, Balmain. Insecta, Plantae. (*a*) MMF 15455 *Elcanopsis sydneiensis*. (*b*) MMF 15455 *Elcanopsis sydneiensis* (from Tillyard, 1918b) with permission of the Linnean Society of NSW. (*c*) MMF 15455 *Taeniopteris* cf. *mcclellandi*. (*d*) AM F.21231 *Schizoneura australis*. (*e*) MMF 12096 *Schizoneura* sp. (*f*) AM F.21243 *Schizoneura* sp. (*g*) AM F.11036 *Cladophlebis* cf. *roylei*. (*h*) *Rhipidopsis ginkgoides* (from Dun, 1910) with permission of the Royal Society of NSW. (*i*) MMF 12694 *Lepidopteris madagascariensis*. Scale bars: *a* = 0.5 cm; *b–i* = 1 cm.

Stangerites mcclellandi Oldham & Morris, 1863: 32, pl. 23, figs 1–3.
Taeniopteris mcclellandi.—Sahni & Rao, 1933: 197.
Taeniopteris cf. *mcclellandi.*—Dun, 1911: 554, pl. 41 fig. 1.
Figured in Dun (1911): MMF 15455 (Fig. 15c) (pl. 41 fig. 1)—leaf fragment (with superimposed insect wing)—held in the GSNSW collection.

Oldam & Morris (1863) erected the species *Stangerites mcclellandi* to identify an Indian specimen. Subsequently, Sahni & Rao (1933) emended this classification of Indian specimens to *Taeniopteris mcclellandi*. Dun (1911) described a leaf fragment from the Sydney Harbour Colliery as 24 mm in width with a prominent midrib and slightly inclined venation and identified it as *T.* cf. *mcclellandi*. Dun commented that no exactly similar form had been noticed from Australia hitherto, although it occurred abundantly in India. This specimen also contained the impression of an insect wing (see *Elcanopsis sydneiensis* above).

Order Osmundales

Family Osmundaceae

Cladophlebis cf. *roylei* Arber, 1905

Fig. 15g

Cladophlebis roylei Arber, 1905: 142.
Cladophlebis cf. *roylei.*—Dun, 1909: 312, pl. 49 fig. 3; Dun, 1910: 616, pl. 49 figs 1,2.
Type: AM F.35635 (pl. 49, fig. 3)—from Benelong (Jurassic)—held in the AMTC under "Dun 1909".
Figured in Dun (1910): # (pl. 49 figs 1,2)—portion of frond—possibly held in the GSNSW collection.
Mentioned in Retallack (2002): AM F.11036 (Fig. 15g)—*Cladophlebis*—held in the AMTC under "Retallack 2002".

Arber (1905) listed this species in the catalogue of plants of the British Museum (Natural History) London as known from India and Queensland. Dun (1909) identified specimens from Benelong, NSW (Jurassic) as *Cladophlebi*s close to *C. roylei*. Dun (1910) commented that, at higher levels in the Birthday Shaft above the *Glossopteris* and *Schizoneura,* plants with Mesozoic affinities became common. A fern closely related to *Cladophlebis roylei* was abundant. The frond was bipinnate and the pinnular attachment was similar to the Indian species. The venation was very close to that of *C. roylei*. It was also similar to *Alethopteris lindleyana* described from Mt Esk, Queensland by Etheridge (Jack & Etheridge, 1892). In describing early Triassic plant radiation, Retallack (2002) mentioned one specimen of this genus from the Birthday Shaft. Pattemore (2016) placed *Cladophlebis* in the Osmundaceae in the Osmundales.

Division Equisetophyta (Sphenophyta) (horsetails)

Order Equisetales

Family incertae sedis

Schizoneura australis Etheridge, 1893

Fig. 15d–f

Type: AM F.35729 (pl. 13)—portion of stem with leaves—from Bulli Colliery—held in the AMTC under "Etheridge 1893".
Figured in Etheridge (1903): MMF 10380 (pl. 48 fig. 1)—leaves on twigs—held in the GSNSW collection.
Figured in Dun (1910): # (pl. 50 fig. 1)—stem with leaves—possibly held in the GSNSW collection. | # (pl. 52 fig. 1)—large stem with 2 nodes—possibly held in the GSNSW collection.
Mentioned in Retallack (2002): AM F.21243 (Fig. 15f)—*Schizoneura*—held in the AMTC under "Retallack 2002". | AM F.21231 (Fig. 15d)—*Schizoneura*—held in the AMTC under "Retallack 2002".
Other specimens from this site: MMF 12096 (Fig. 15e)—*Schizoneura* sp.—held in GSNSW collection. | AM F.35761—*Schizoneura* sp.—held in the AMGC under "Plantae/Triassic/Balmain". | AM F.8259—*Schizoneura* sp.—held in the AMGC under "Plantae/Triassic/Balmain".

Etheridge (1893) named a plant specimen from the shale roof of Bulli Colliery as a new species *Schizoneura australis,* following this up by identifying further specimens from the 2nd Cremorne Borehole similarly (Etheridge, 1894b). Later, Etheridge (1903) figured specimens from the Birthday shaft of the Sydney Harbour Colliery obtained from a depth of 2,870 ft (875 m). They showed characteristic features of pseudo-leaves, nodes and veins of *Schizoneura.* One of the specimens clearly exhibited a fertile shoot, comprising two cone-like strobili, previously unknown for this genus. This fertile shoot was quite different to the strobilus of *Phyllotheca,* but bore a closer relationship to the *Equisetum* group (Etheridge, 1903). Dun (1910) noted that this species was particularly abundant in the Sydney Harbour Colliery roof shales, from about 5 feet (1.6 m) above the coal seam. He surmized that, from the stems, the Australian *Schizoneura* attained a great size. In describing early Triassic plant radiation, Retallack (2002) mentioned two specimens of this species from the Birthday Shaft.

Division Ginkgophyta (ginkgoes)

Order Ginkgoales

Family Ginkgoaceae

Rhipidopsis ginkgoides Schalhausen, 1879

Fig. 15h

Figured in Dun (1910): # (Fig. 15h) (pl. 51 fig. 1)—two imperfect leaf sprays—possibly held in the GSNSW collection.

Dun (1910) noted that one specimen shows the leaf divided into 3 main segments, 2 of which show accentuated lobation. The venation was fine. Although some comparisons could be made with Ginkgo *digitata* and *Baiera phillipsi*, Dun suggested this form could be regarded as *Rhipidopsis ginkgoides*.

Other plant specimens from this site:
Mentioned in Townrow (1966): MMF 12694 (Fig. 15i) (pl. 1 fig. 1)—*Lepidopteris madagascariensis*—held in the GSNSW collection.
Mentioned in Retallack (2002): MMF 18161—*Lepidopteris*—held in the GSNSW collection. | MMF 18155—*Isoetes*—held in the GSNSW collection. | AM F.7695—petrified wood (found at 2,225 ft)—held in the AMGC under "Plantae/Triassic/Balmain".

Bellambi Colliery

The Bellambi Coal Company re-opened the decommissioned Woonona Mine north of Wollongong in 1888. In 1902 the South Bulli Mine was bought by the BCC and its underground workings were linked to the Bellambi Colliery. These mines worked the Permian Upper Coal Measures in the south coast escarpment. After losing long term contracts to Germany at the outbreak of WWI the Bellambi Colliery was closed in 1917.

Trace Fossil

Dicynodontipus bellambiensis Retallack, 1996

Fig. 16a

Holotype: MMF 13639 (figs 2A,B, 3)—natural mould—held in the GSNSW collection. | AM F.141465 (Fig. 16a)—fabricated cast of MMF 13639—held in the AMTC under "Retallack 1996".

In 1913 a tetrapod trackway was revealed during a rockfall from the roof of the Bellambi Colliery. The tracks had been preserved in shale 25–50 cm above the Bulli coal seam. Although it was initially thought to have been formed in the Permian sediments, Retallack (1996) placed it just above the Permo-Triassic boundary in the Narrabeen Group, and argued that it was made by a dicynodont, possibly *Lystrosaurus*. Warren (1997) accepted that the trackway was made in sediment that lies close to the Permo-Triassic boundary, but considered evidence for it being latest Permian or earliest Triassic was equivocal. Another similar trackway (AM F.51043) (Fig. 16g) from the nearby Kemira Colliery was donated to the Australian Museum in 1964. Although this trackway has not yet been described, it seems possible that it was made by an animal similar to the one that made the Bellambi Colliery trackway as it has similar characteristics and both collieries were positioned close by and mined the same coal seams.

Plantae

Division Lycopodiophyta (club mosses)

Order Isoetales

Family Isoetaceae

Isoetes beestonii Retallack, 1997

Fig. 16c

[Synonymies given above, see under *Northern Beaches*]
[Specimen data given above, see under *Northern Beaches*]

White (1981) described a whorled lycopod leaf crown obtained from the roof shales above the Bulli Seam in the Bellambi Colliery (AM F.58791) (Fig. 16c). The leaves were identical to that previously described by Burges (1935) as *Taeniopteris undulata*. White (1981) erected a new genus for this plant, *Cylomeia,* and maintaining the species name *undulata*. A second specimen (AM F.60882) from the same site was also assigned to this species. Later, Retallack (1997) saw sporophylls as the most diagnostic of plant remains. He subjected lycopod sporophylls to cladistics analysis and concluded that *Isoetes* pre-dates *Pleuromeia*-like sub-arborescent lycopods. He placed *Cylomeia* in the Isoetaceae within the Isoetales, and emended the classification of the Bellambi specimens to *Isoetes beestonii*.

Other mentioned plant specimens: a paper by Retallack (2002) dealt with early Triassic plant radiation and listed identified specimens over a range of sites. The listed specimens from Bellambi Colliery, other than those above, were:

Mentioned in Retallack (2002): AM F.27431—*Lepidopteris callipteroides*—held in the AMTC under "Retallack 2002" (see Bulli Colliery below for a taxonomic history). | AM F.27432—*Cladophlebis carnei*—held in the AMTC under "Retallack 2002".

Other plant specimens from Bellambi Colliery roof shales held in the AMGC: *Lepidopteris callipteroides, Lepidopteris stormbergensis, Rissikia apiculata*, petrified wood.

Figure 16. Bellambi, Bulli, and Kemira Collieries. Trackways, Plantae. (*a*) AM F.141465 *Dicynodontipus bellambiensis,* Bellambi Colliery (cast). (*b*) AM F.63735 *Isoetes beestonii,* Bulli Colliery. (*c*) AM F.58791 *Isoetes beestonii,* Bellambi Colliery. (*d*) AM F.35729 *Schizoneura australis*, Bulli Colliery. (*e*) AM F.22426 *Voltziopsis africana*, Bulli Colliery. (*f*) AM F.58519 *Lepidopteris callipteroides,* Bulli Colliery. (*g*) AM F.51043 ?Therapsid trackway, Kemira Colliery. Scale bars = 5 cm.

Bulli Colliery

Bulli Colliery was opened in 1862 and worked the Permian Upper Coal Measures north of Wollongong. The Permian coal seams were worked upwards until shale occurred. These roof shales are considered to be the Permo-Triassic boundary (although there is still controversy about this) and therefore fossils found in the roof shales are recognized as the earliest fossils of the Triassic.

Plantae

Division Equisetophyta (Sphenophyta) (horsetails)

Order Equisetales

Family incertae sedis

Schizoneura australis Etheridge, 1893

Fig. 16d

Type: AM F.35729 (Fig. 16d) (pl. 13)—stem with leaves attached—held in the AMTC under "Etheridge 1893".

Mentioned in Retallack (2002): AM F.35729 (Fig. 16d)—*Schizoneura*—stem with leaves—held in AMTC under "Etheridge 1893". | AM F.35761—*Schizoneura*—stem with leaves—missing.

Etheridge (1893) described a plant specimen from the shale roof of No.1 seam of the Bulli Colliery. The specimen was a thin stem with 6 leaves placed in pairs. He compared the specimen with that of *Schizoneura* from India and noted a similar mode of articulation, together with a similar leaf shape and venation. *Schizoneura* had not been previously identified in Australia, so he named this specimen *Schizoneura australis.*

Division Coniferophyta (conifers)

Order Coniferales

Family Voltziaceae

Voltziopsis africana Seward, 1934

Fig. 16e

Figured in Townrow (1967): AM F.22426 (Fig. 16e) (figs 1A, 2A,D)—long shoot with leaves—held in the AMTC under "Townrow 1967".

Figured in White (1986): AM F.22426 (Fig. 16e) (fig. 196)—long shoot with leaves—held in the AMTC under "Townrow 1967".

Mentioned in Retallack (2002): AM F.22426 (Fig. 16e)—*Voltziopsis*—held in the AMTC under "Townrow 1967".

This specimen was included in the Mitchell Collection held in the AMGC and alleged to have come from "Woonoona Park". Townrow (1967) disputed this provenance and surmised it came from the nearby Bulli Colliery roof shales. Townrow (1967) commented that, although no branching was seen, it seemed that branching was sparse, and the leaf surface was concave.

Division Pteridospermatophyta (pteridosperms) (seed ferns)

Order Peltaspermales

Family Peltaspermaceae

Lepidopteris callipteroides (Carpentier, 1935)

Fig. 16f

Thinnfeldia callipteroides Carpentier, 1935: 12, pl. 3 figs 1,2.
Dicroidium callipteroides.—White, 1986: 138.
Lepidopteris callipteroides.—Retallack, 2002: 489, fig. 2A–f, 3A–D, 4A.

Holotype: Leaf figured by Carpentier (1935 pl. 3 fig. 1) but lost (Retallack, 2002).

Figured in White (1986): AM F.58519 (Fig. 16f) (fig. 194)—held in the AMTC under "White 1986" (but incorrectly numbered as AM F.59519).

Figured in Retallack (2002): AM F.58519 (Fig. 16f) (fig. 2A—held in the AMTC under "White 1986" (but incorrectly numbered as AM F.59519 in White (1986) and Retallack (2002)).

Carpentier (1935) described specimens from Madagascar as *Thinnfeldia callipteroides*. White (1986) named *Dicroidium callipteroides* as the first of the forked-frond seed ferns that made its appearance at the Permo-Triassic boundary and commented that it may have been the ancestral plant that gave rise to later *Dicroidium* and *Lepidopteris* species. Retallack (2002) addressed early Triassic plant radiation and listed identified specimens of this species over a range of basal Triassic sites that included the collieries at Bellambi, Bulli, Nattai and Oakdale. He re-assigned all specimens previously described as *Thinnfeldia callipteroides* or *Dicroidium callipteroides* to the genus *Lepidopteris*, as the previous genera have very different cuticular structure. He stated that this plant was an early invader of the Sydney Basin after the Permian Mass Extinction, spreading south from northern Gondwana in Triassic greenhouse conditions.

Other figured and mentioned specimens from Bulli Colliery:

Figured in White (1986): AM F.63735 (Fig. 16b) (fig. 201)— as *Cylomeia undulata*—held in the AMTC under "White 1986".

Mentioned in Retallack (2002): MMF 3084—*Podozamites*—held in the GSNSW collection. | MMF 25687—*Isoetes*—held in the GSNSW collection.

Other specimens from Bulli Colliery held in the AMGC but not described or mentioned: *Lepidopteris callipteroides, Dicroidium narrabeenensis, Cylostrobus undulata, Willistocladus nigracristatus*, lycopod leaves.

Kemira Colliery

In 1883 a cliff of coal was discovered on Mt Kiera, above Wollongong, and soon after, Dana from the USA expedition measured the seam between 200 and 300 feet above sea level. The Albert Coal Mine was opened on the site in 1849, and mining activity developed in the late 1800s in what became known as the Mt Kiera Mine. New shafts were sunk in 1903. In 1937 AI&S Ltd purchased the mine to supply its expanding steelworks in Port Kembla. Mechanization commenced in 1938. In 1955 the colliery changed its name to Kemira Colliery (a combination of Kembla and Kiera). Longwall mining was introduced in 1965, and the Kemira Colliery was linked to Corrimal Colliery by a drift above the Bulli Seam. Peak production was reached in 1979. Retrenchments commenced in 1982 and the mine was closed in 1991.

Trace Fossil

?Therapsid Trackway

Fig. 16g

AM F.51043 (Fig. 16g)—natural mould—held in the Castle Hill facility by the Australian Museum.

This specimen is not yet described, but bears a strong resemblance to the tetrapod trackway from Bellambi Colliery described by Retallack (1996).

Plantae

No plant specimens have been described in detail from this site, but Retallack (2002), in a discussion of early Triassic plant radiation, listed the following specimen found in Kemira Colliery.

Mentioned in Retallack (2002): MMF 16456—*Isoetes beestonii*—held in the GSNSW collection.

Nattai River Colliery

In the early 1880s Permian strata was discovered exposed in the Nattai River Gorge. Steps to open a coal mine in this area were made by the Mittagong Coal-mining Co. from 1883. This required constructing a steep tramway incline into the Nattai Gorge.

The Nattai Colliery, 6 km NW of Mittagong, was initially known as the Box Vale Colliery by 1890, and a private railway transported coal from this mine. Difficulties with working and transporting coal from a mine in this rough country caused the mine to be closed down after 8 years, and the mine site was abandoned.

Plantae

No plant specimens have been described in detail from this site, but Retallack (2002), in a discussion of early Triassic plant radiation, listed the following specimen found in Nattai Colliery.

Mentioned in Retallack (2002): AM F.53796—*Lepidopteris callipteroides*—held in the AMTC under "Retallack 2002" (see Bulli Colliery above for a taxonomic history).

Other specimens held in the AMGC: AM F.60543 (Fig. 17a)—*Voltziopsis wolganensis*—held under "Triassic/Plantae/Nattai River". *Lepidopteris callipteroides*—held under "Triassic/Plantae/Nattai River".

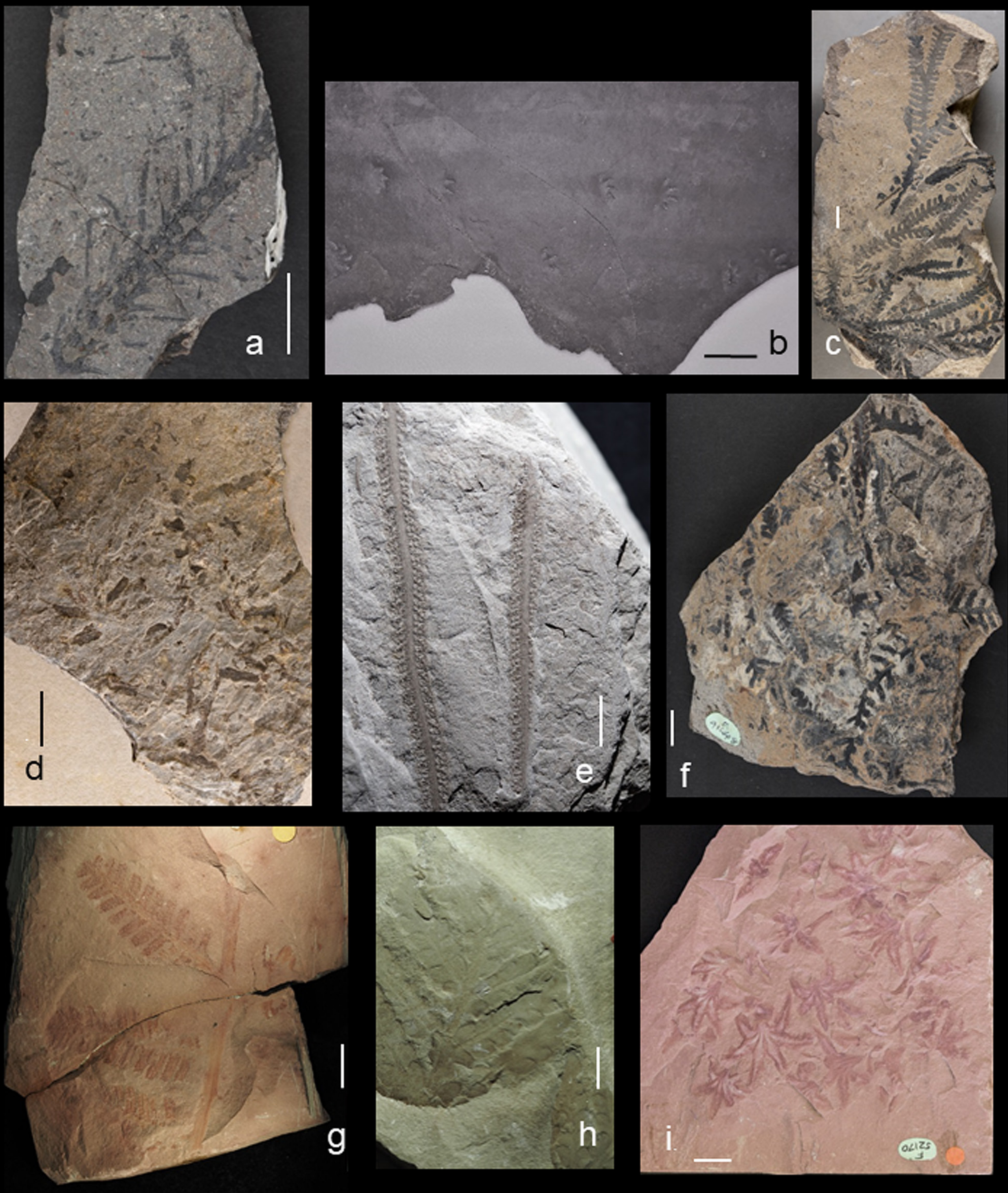

Figure 17. Nattai River Colliery, Oakdale Colliery, Burragorang Valley, Clarence Siding, Mt Piddington. Trackway, Plantae. (*a*) AM F.60543 *Voltziopsis* sp. Nattai River Colliery. (*b*) AM F.97129 ?Therapsid trackway, Oakdale Colliery. (*c*) AM F.118243 *Lepidopteris callipteroides*, Oakdale Colliery. (*d*) AM F.45264 *Lepidopteris callipteroides,* Burragorang Valley. (*e*) MMF 12487 *Reinitsia spathulata*. Clarence Siding. (*f*) AM F.91448 *Lepidopteris callipteroides*, Coxs Gap. (*g*) MMF 3022 *Cladophlebis australis*, Mt Piddington. (*h*) MMF 3105 *Zuberia feistmanteli*, Mt Piddington. (*i*) AM F.52170 *Umkomasia* sp. Mt Piddington. Scale bars: *a, c–i* = 1 cm; *b* = 5 cm.

Oakdale Colliery

Oakdale Colliery was opened in the late 1800s and was located on the edge of the Burragorang Valley nearby the Nattai Colliery. It became non-economic towards the end of the 20th Century and was closed down in 1999.

Trace Fossil

?Therapsid Trackway

Fig. 17b

Figured: AM F.97129 (Fig. 17b) (fig. 8)—natural mould—held in the AMTC under "Warren 1997".

In 1995 A. Wright donated a trackway to the Australian Museum from the roof shales of the Bulli Seam in the Oakdale Colliery, north of Wollongong. Warren (1997) attributed this trackway to a small dicynodont or a procolophonid. Retallack (1996) argued that trackways from the roof shales of the Bulli Seam were just above the Permo-Triassic boundary. However, Warren (1997) considered evidence for it being latest Permian or earliest Triassic was equivocal, but accepted that the trackways were near this boundary.

Plantae

No plant specimens have been described in detail from this site, but Retallack (2002), in a discussion of early Triassic plant radiation, listed the following specimens found in Oakdale Colliery.

Figured **i**n Retallack (2002): AM F.118243 (Fig. 17c) (fig. 2B)—*Lepidopteris callipteroides* | AM F.118244 (fig. 2C)—*Lepidopteris callipteroides* (see Bulli Colliery above for a taxonomic history).

Mentioned in Retallack (2002): AM F.118245, AM F.118246—*Lepidopteris callipteroides*. | AM F.118237, AM F.118238, AM F.118239, AM F.118241, AM F.118242—*Peltaspermum townrovii* | AM F.118240—*Lepidopteris* sp.

All the above specimens are held in the AMTC under "Retallack 2002".

Burragorang Valley

Burragorang Valley is situated to the west of the south coast escarpment and south of the Blue Mountains National Park. It is now inundated by the Sydney water storage held back by the Warragamba Dam.

Plantae

Retallack (2002), in a discussion of early Triassic plant radiation, listed the following specimens found in the Burragorang Valley.

Mentioned in Retallack (2002): AM F.45262, AM F.45263, AM F.45264 (Fig. 17d), AM F.45265, AM F.45266—*Lepidopteris callipteroides*—held in the AMTC under "Retallack 2002" (see Bulli Colliery above for a taxonomic history).

These specimens were originally identified as *Dicroidium dentatum*.

Other specimens held in the AMGC: AM F.45260, AM F.45261, AM F.45267—*Lepidopteris callipteroides*—held under "Plantae/Triassic/Burragorang Valley".

Clarence Siding

Clarence Siding is located on the western escarpment of the Blue Mountains above Lithgow. It was originally a railway outpost of the first railway line across the Blue Mountains. (The reconstituted Zig Zag Railway was part of this rail route). By 1908 it was being used as the headquarters for tunnel deviation works which opened in 1910. It is possible that the specimen described below was found during the tunnelling activity.

Plantae

Division Pteridophyta (Filicophyta) (ferns)

Order Marattiales

Family Marattiaceae

Reinitsia spathulata Walkom, 1932

Fig. 17e

Type: MMF 12487 (Fig. 17e) (pl. 5 figs 1,2)—3 narrow fertile pinnae—held in the GSNSW collection.

The Curator of the Mining Museum of Sydney, G. Card, brought to the attention of A. B. Walkom a plant fossil from Clarence Siding. Walkom (1932) noted that the specimen comprised portions of three narrow fertile pinnae, the longest being 14.5 cm. Walkom (1932) did not recognize this specimen as matching any genus known to him. The general shape could be compared to several described species of fern, including the Australian *Taeniopteris carruthersi,* but he found it justifiable to erect a new genus for this specimen. Retallack (1981: 175) described the specimen MMF 12487 as a "pinnifid, fertile marattiaceous fern".

Coxs Gap

Between 1946 and 1949 a train tunnel was cut through the mountain at Coxs Gap at the head of the Hunter Valley to link the coastal rail system through the Great Dividing Range to the western slopes of New South Wales. Excavation spoil provided some fossil specimens from the Narrabeen Group.

Plantae

Retallack (1997) listed the following specimens from Coxs Gap: MMF 13643–13646—*Isoetes beestonii*—possibly held in the GSNSW collection. | MMF 13648–13652—*Isoetes beestonii*—possibly held in the GSNSW collection. | MMF 13666—*Isoetes beestonii*—possibly held in the GSNSW collection. | AM F.91460—*Isoetes beestonii*—held in the AMTC under "Retallack 2002".

Retallack (2002), in a discussion of early Triassic plant radiation, listed the following specimens found at Coxs Gap. AM F.48168—*Voltziopsis*—held in the AMGC under "Mt Piddington, NSW". | AM F.91440—*Lepidopteris callipteroides*—held in the AMTC under "Retallack 2002". | AM F.91447—*Paracalamites*—missing. | AM F.91457—*Merionopsis*—held in the AMGC under "Terrigal, NSW". | AM F.91460—*Isoetes*—held in the AMTC under "Retallack, 2002". | AM F.91461—*Cladophlebis*—held in the AMTC under "Retallack 2002".

Other specimens held in the AMGC: AM F.91448 (Fig. 17f)—*Lepidopteris callipteroides*—held under "Plantae/Triassic/Coxs Gap". *Coniopteris, Paracalamites*—held under "Plantae/Triassic/Coxs Gap".

The collection of the GSNSW contains the following specimens collected from Coxs Gap: *Lepidopteris, Voltziopsis, Cladophlebis, Isoetes, Schizoneura*.

Mt Piddington

Mt Piddington is placed at the edge of the western escarpment of the Blue Mountains, close to Mt Victoria.

Plantae

A small selection of plant specimens from Mt Piddington were submitted to A. B. Walkom for description by D. S. Dun, palaeontologist to the Geological Survey of New South Wales.

Division Pteridophyta (Filicophyta) (ferns)

Order Osmundales

Family Osmundaceae

Cladophlebis australis Morris (in Strzelecki), 1845

Fig. 17g

Type: AM F.25256 (pl. 7 fig. 1)—from Bexhill (Jurassic)—held in the AMTC under "Walkom 1919".

Mentioned in Walkom (1932): MMF 3022 (Fig. 17g)—part of fertile frond—held in the GSNSW collection.

Walkom (1932) briefly described part of a fertile frond from Mt Piddington with broad rachis and portions of 3 pinnae as *Cladophlebis australis*. The pinnules had a strong midrib with groups of sporangia on either side. He compared it to a very similar specimen from Denmark Hill, Ipswich, Queensland, described in Walkom (1917a).

Division Pteridospermatophyta (pteridosperms) (seed ferns)

Order Peltaspermales

Family Umkomasiaceae

Zuberia feistmanteli (Johnston, 1893)

Fig. 17h

[Synonymies given above, see under *Northern Beaches*]

[Specimen data given above, see under *Northern Beaches*]

Mentioned in Walkom (1932): MMF 3105 (Fig. 17h)—from Mt Piddington—portion of frond—held in the GSNSW collection. | MMF 12485—from Mt Piddington—fragment—held in the GSNSW collection.

The specimens from Mt Piddington were typical examples of this species found in Australian Triassic rocks, very similar to specimens found at Denmark Hill, Ipswich, Queensland (Walkom, 1932). He identified them as *Thinnfeldia feistmanteli.* Gothan (1912) had already erected the genus *Dicroidium* to contain similar specimens from Mt Victoria, unbeknown to Walkom. Pattemore (2016) re-classified the genus to *Zuberia* based on the rachis structure.

Umkomasia sp.

Fig. 17i

[Synonymies given above, see under *Northern Beaches*]

[Specimen data given above, see under *Northern Beaches*]

Figured in Walkom (1932): MMF 12486a,b (pl. 5 figs 4,5)—"petaloid" bracts—held in the GSNSW collection. | AM F.52170 (MMF 3107) (Fig. 17i) (pl. 5 fig. 3)—a group of "petaloid" bracts—held in the AMTC under "Walkom 1932".

In 1932 palaeobotanists were still puzzled by "flower-like" specimens found in plant deposits, initially described as *Williamsonia*. They had been previously discovered in the Northern Beaches headlands (Walkom, 1925: 220) and in other Triassic deposits around the world. Walkom (1932) described MMF 12486a,b from Mt Piddington as *?Williamsonia*, and MMF 3107 as a possible modification of some of the floral parts of *Williamsonia*. Thomas (1933) erected a new genus, *Umkomasia*, for similar specimens from South Africa. Later workers in Triassic plants worldwide recognized their persistent association with *Dicroidium*. Pattemore (2016) and Anderson *et al*. (2019), amongst others, now describe them as the megasporophyll *Umkomasia*, the female fertile organs of the pteridosperm *Dicroidium*, matched to the male fertile organs *Pteruchus.*

Other specimens from Mt Piddington held in the AMGC: *Dicroidium odontopteroides, Thinnfeldia, Umkomasia* fructifications*, Pteruchus, Gleichenites, Cladophlebis*.

Sydney Boreholes

During the 1880s a number of boreholes were sunk around the Sydney region to determine the geological structure of the area. The boreholes were:

Dent's Creek Borehole—Holt-Sutherland Estate, Georges River
Moore Park Borehole—Baptist Gardens, Bourke Street, Surry Hills
Botany Borehole—Holt-Sutherland Estate, Port Hacking
Heathcote Borehole
Narrabeen Borehole
Liverpool Borehole
Cremorne Boreholes

These boreholes encountered a shale layer at the bottom of the Narrabeen Group and above the Permian coal measures that contained fossil remains of the conchostracan *Estheria,* and this stratum was called the *Estheria* Shales.

Subphylum Crustacea

Class Branchiopoda

Subclass Phyllopida

Order Conchostraca

Family Limnadidae

Palaeolimnadia coghlani (Cox, 1881)

Fig. 18a,b,c

Estheria coghlani Cox, 1881: 276.—Etheridge, 1888: 6, pl. 1 figs 1–5.
Palaeolimnadia coghlani.—Raymond, 1946: 264.

Type: Obtained from Moore Park Borehole by Cox (1881) but subsequently lost—sketch by Cox described by Etheridge (1888: 6, pl. 1 fig. 1).
Figured in Etheridge (1888): Four specimens from Moore Creek Borehole (pl. 1 figs 2–5)—from sketches by Cox (1881). | AM F.35720 (MMF 3110) (pl. 1 fig. 6)—from Dents Creek Borehole—held in the AMTC under "Etheridge 1888a". | AM F.35721 (MMF 3110) (Fig. 18a) (pl. 1 fig. 7)—from Dents Creek Borehole—held in the AMTC under "Etheridge 1888a". | AM F.35723 (MMF 3110) (pl. 1 fig. 8)—from Dents Creek Borehole—held in the AMTC under "Etheridge 1888a". | AM F.35722 (MMF 3110) (pl. 1 fig. 9)—from Dents Creek Borehole—held in the AMTC under "Etheridge 1888a". | AM F.35719 (MMF 3112) (Fig. 18b) (pl. 1 fig. 10)—from Narrabeen Borehole—held in the AMTC under "Etheridge 1888a".
Figured in Mitchell 1927: MMF 3113 (Fig. 18c) (pl. 2 fig. 3)—from Cremorne Borehole—held in the GSNSW collection. | AM F.25474 (pl. 2 fig. 4)—from Dents Creek Borehole—held in the AMTC under "Mitchell 1927".
Other specimens: MMF 3111—from Cremorne Borehole—held in the GSNSW collection. | MMF 3114—from Cremorne Borehole—held in the GSNSW collection. | MMF 42194—from Dent's Creek Borehole—held in the GSNSW collection. | MMF 42195—from Dent's Creek Borehole—held in the GSNSW collection.

The first specimens obtained from the Moore Park and Port Hacking bores by J. C. Cox were named by him after John Coghlan who sunk the bores (Cox, 1881). These specimens were lost, but sketches of the specimens were shown by Cox to R. Etheridge who subsequently described them (Etheridge, 1888). Some specimens from the Dent's Creek bore, the Cremorne bore and the Narrabeen bore found their way into the official collection at the Mining and Geological Museum, Sydney. Some specimens from the Dents Creek bore, the Narrabeen bore and the Cremorne bore were later transferred to the Australian Museum (Etheridge, 1888). Mitchell (1927) reviewed the Etheridge description and figures and agreed with Etheridge's taxonomic conclusions. Both thought there may be evidence for two species within these specimens but the evidence was not conclusive. Raymond (1946) recognized these specimens as palaeolimnadiids after studying the umbo configuration and emended the genus to *Palaeolimnadia.*

Plantae

Division Equisetophyta (Sphenophyta)

Order Equisetales

Family incertae sedis

Schizoneura australis Etheridge, 1893

Type: AM F.35729—stem with leaves attached from the Bulli Colliery—held in the AMTC under "Etheridge 1893".
Figured in Etheridge (1894b): #—fragmentary stem cross section—possibly in the GSNSW collection.

Etheridge (1894b) compared a specimen recovered from the 2nd Cremorne Borehole with the *Schizoneura australis* holotype from Bulli Colliery and other *Phyllotheca* specimens. He concluded that the specimen was most closely similar to the *Schizoneura australis* type. He noted that it occurred in a much higher horizon in this borehole than in the Bulli Colliery as it was obtained from a depth of 1,274 ft.

Division Pteridospermatophyta (pteridosperms) (seed ferns)

Order Caytoniales

Family Caytoniaceae

Sagenopteris salisburoides Johnston, 1887

Figured in Etheridge (1894b): #—fragmentary fronds—possibly held in the GSNSW collection.

Venation of these flabellate fronds led Etheridge (1894b) to conclude they were similar to *Sagenopteris salisburoides* from Tasmania figured by Johnson (1887), although the pinnule attachment differs from that previously described for this genus. The specimen was collected at 1,410 ft depth in the 2nd Cremorne Borehole.

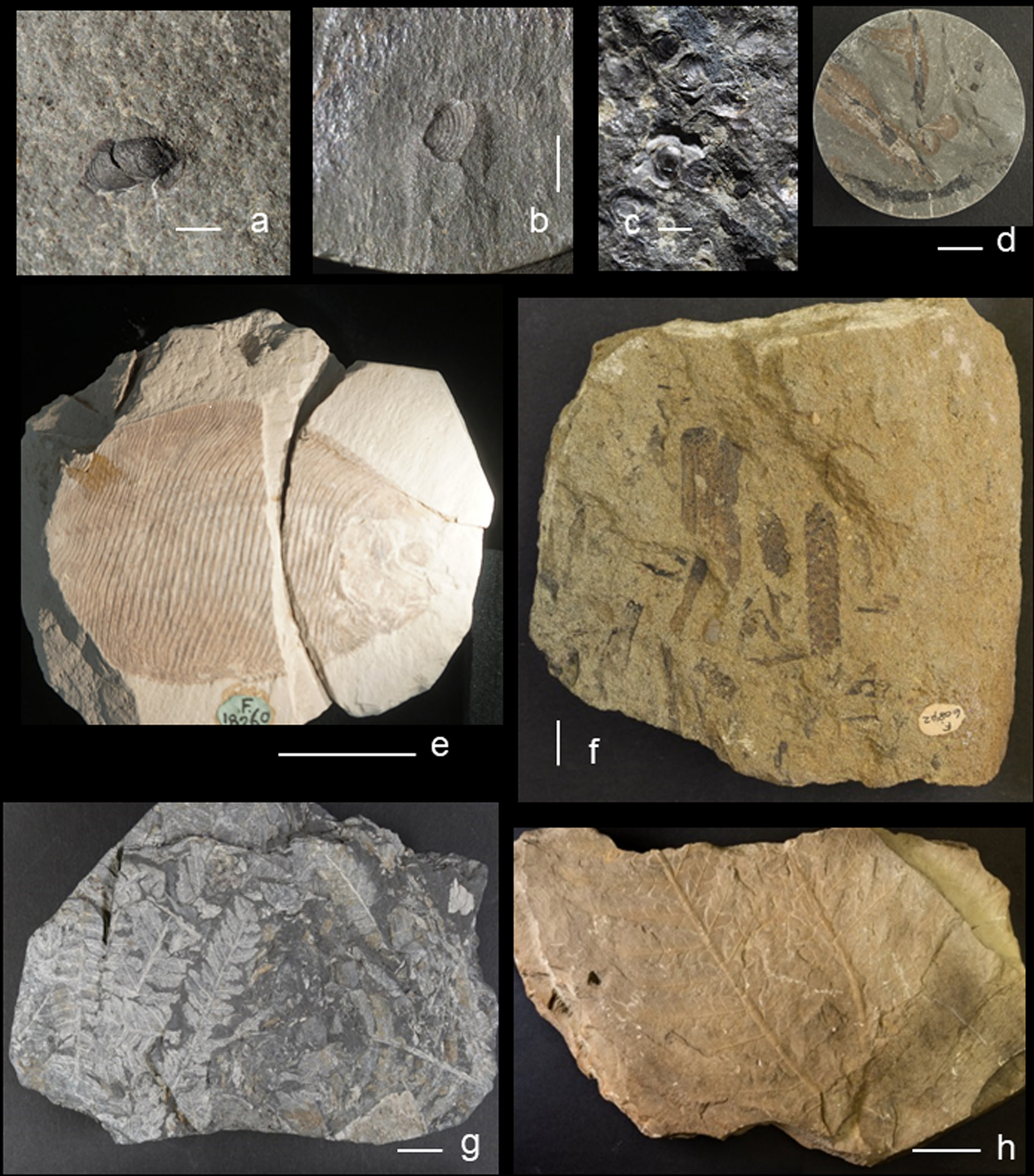

Figure 18. Boreholes and minor unpublished sites. (*a*) AM F.35721 *Palaeolimnadia coghlani,* Dent's Bore. (*b*) AM F.35719 *Palaeolimnadia* sp. Narrabeen Bore. (*c*) MMF 3113 *Palaeolimnadia* sp. 2nd Cremorne Borehole. (*d*) AM F.51456 *Walkomiella australis,* Wyong Bore. (*e*) AM F.18260 *Cleithrolepis granulatus*, Katoomba. (*f*) AM F.60842 *Voltziopsis* sp. Garie Beach. (*g*) AM F.50148 *Cladophlebis australis,* Hawkesbury River. (*h*) AM F.5505 *Dicroidium odontopteroides*, Mt Victoria. Scale bars: *a, b,* and *c* = 2 mm; *d, f,* and *g* = 1 cm; *e* and *h* = 5 cm.

Minor unpublished sites

There are some sites around the Sydney Basin where specimens were collected but were not the subject of a peer reviewed paper. Nevertheless, they provided valuable information of the overall ecosystem of the Sydney Basin.

These specimens reside in the general collections of a number of organizations, including the Australian Museum where the following specimens are held in the AMGC. (The names shown are those of the original identifications).

Cockle Creek

Plantae

Lepidopteris madagascariensis, Cladophlebis, Phyllotheca australis, Taeniopteris triassica, Neocalamites carrere.

Garie Beach

Plantae

AM F.68042 (Fig. 18f)—*Voltziopsis.*

Hawkesbury River area

Plantae

AM F.50148 (Fig. 18g)—*Cladophlebis australis*. *Taeniopteris crassinervis, Reinitsia spathulata, Dicroidium odontopteroides.*

Helensburgh Colliery

Plantae

Dicroidium odontopteroides.

Katoomba (Chandler's Building)

Dun (1911) recorded that specimens from Katoomba were sent to Smith Woodward in the BMNH London. The AMGC hold one specimen of *Cleithrolepis*, found in 1900 and presented to the AM in 1927.

Pisces

AM F.18260 (Fig. 18e)—*Cleithrolepis granulatus*.

Kincumber

Temnospondyli

AM F.125866—complete specimen in sandstone block—held in the AMGC at Castle Hill Discovery Centre. This specimen has recently been described (Hart *et al*., 2023).

Mount Victoria

Plantae

AM F.5505 (Fig. 18h)—*Dicroidium odontopteroides*. *Dicroidium feistmanteli, Coniopteris*.

Wyong Borehole

Plantae

AM F.51456 (Fig. 18d)—*Walkomiella australis, Cladophlebis*, *Sphenopteris polymorpha*.

ECOSYSTEMS

The Permo-Triassic Transition

The Permian Period that preceded the Triassic was initially cold but warmed during its latter half. There was no longer ice at the Poles. On land, plants proliferated in its swamps, insects and other arthropods diversified and vertebrates hunted in its lagoons and rivers while others browsed in the forests.

Gondwana and Laurasia were still joined to form Pangea, and this allowed migrations by both animals and plants across broad territories. Smith and Ward (2001) document the existence of the therapsid dicynodont *Lystrosaurus* in the Late Permian in the Karoo Basin in South Africa. Amphibian temnospondyls and archosaurs were also present. During the Late Permian in Laurasia the insect clade Archaeorthoptera contained Orthoptera (grasshoppers and crickets), Caloneurodea (insects with two pairs of identical wings), and Titanoptera. The clade Odonatoptera contained the "giant dragonfly" first noted in the Carboniferous, as well as damselflies. Coleoptera (beetles) were a minor presence, but Diptera (flies) do not have a fossil presence (although later diverse presence indicates earlier divergence) (Béthoux *et al*., 2005). *Glossopteris* forests dominated the swamps of Gondwana, with an understory of ferns, seed ferns and cycads. These forests laid down thick layers of organic material that were later to become the Coal Measures of eastern Australia.

Then came the End Permian Mass Extinction. Up to 95% of marine species became extinct. The rate of extinctions on land is less clear, but they were severe. The *Glossopteris* forests disappeared. Insect groups, such as the Caloneuroidea, disappeared. Vertebrate diversity was severely reduced.

Some animals and plants survived this boundary with lower species diversity, but with many unpopulated niches in which to radiate and again diversify. Early Triassic fossil remains of *Lystrosaurus* have been found in present day South Africa, Antarctica, India, China and Russia (Colbert, 1982). Amphibian temnospondyls and reptilian archosaur fossils are present in Early Triassic deposits. Immediately after the Permo-Triassic boundary there is evidence of a much reduced insect diversity worldwide (Shcherbakov, 2008), but by the end of the Early Triassic many orders of insects were established, including rapidly diversifying Coleoptera, Diptera, Odonata, Orthoptera and Hemiptera (Béthoux *et al*., 2005). The *Glossopteris* forests of Gondwana were replaced by seedferns, particularly *Lepidopteris callipteroides* in the initial Olenekian Stage. New species of horsetails evolved, and ginkgoes and conifers survived. Surviving freshwater fishes began evolving more modern characteristics.

The Sydney Basin

There are a number of hypotheses concerning the cause of the End Permian Mass Extinction. These include oceanic anoxia, catastrophic release of methane from oceanic and permafrost clathrates, and the massive eruption of the flood basalts of the Siberian Traps (Retallack, 1999). Evidence indicates that in the initial period after the Permian mass extinction there were bursts of warming, acid rain, wildfire and erosion world-wide (Benton & Newell, 2014). Carbon isotopes and palaeosols from the Sydney Basin indicate a shift to a greenhouse climate, with increased atmospheric carbon dioxide or methane. CO2 rose from 0.03% in the Permian to 0.15% in the Early Triassic (5 times our present level). There was a 6–11°C rise across the Permo-Triassic boundary (Retallack, 1999). Fungal and fern spikes occurred at the boundary, indicating large scale rotting of plants which would have caused de-forestation and subsequent erosion (Retallack, 1999).

After this initial instability the climate stabilized. During the time of the deposition of the Narrabeen Group in the Early Triassic the Sydney Basin was within the Antarctic Circle (Hallam, 1994). No ice was present at the Poles, so the temperature gradient between the Equator and the South Pole was comparatively even and the climate remained mild, moist and temperate (Tucker & Benton, 1982), stimulating plant growth. But life within the Basin would have had to cope with periods of extended darkness.

The Narrabeen Group was laid down immediately after the most severe mass extinction of all time. The transition from Permian to Triassic floras was abrupt. Only four genera and one species of megafossil plants are known to have survived in the Sydney Basin (Retallack, 1995b). So life was recovering, radiating and diversifying in the Sydney Basin during the Narrabeen Group sedimentation.

Fossil evidence provides a glimpse of the biota diversity of the Narrabeen Group at this time. Examination of the specimens in the collection of the Australian Museum reveals that plants dominate the fossil evidence in the eastern coastal area which is now the Northern Beaches. Club Mosses such as *Cylostrobus sydneyensis*, *Pleuromeia dubia*, *Tomiostrobus australis* and *Isoetes beestonii* formed monospecific meadows along the edges of lakes and bays (Retallack, 1975). The horsetails *Phyllotheca australis* and *Paraschizoneura jonesii* grew within the swamps. Ferns such as *Cladophlebis, Taeniopteris* spp. and *Todites narrabeenensis* grew in low scrub in the understory. The multilobed ginkgoes *Ginkgoites, Rhipidopsis narrabeen-ensis* and *Baiera simmondsii* grew in the heathland while the conifer *Voltziopsis angusta* dominated the ridges (Retallack, 1977a). One group of plants, the pteridosperms *Dicroidium*, began to diversify. The seedfern *Lepidopteris callipteroides* initially filled the space left by the demise of the *Glossopteris*. As this group diversified they dominated the forest canopy, re-establishing peat forming vegetation (Fielding *et al*., 2019). These plants had fern-like foliage, propagated by pollen and seeds. Some fossil trunks up to 10 m long and 0.5 m diameter with distinct growth rings (found in Leigh Creek, South Australia) indicated a forest growth habit with seasonal variation, probably driven by Antarctic winters. They were most likely deciduous (Mays & McLoughlin, 2019).

Although insect fossils were not abundant during this time in the Sydney Basin (one orthopteran was described by Tillyard (1918b)), insect damage to foliage indicated the development of a complex food web. Leaf fossils showed galling, hole feeding, margin feeding, leaf mining and surface feeding similar to that exhibited today (Mays & McLoughlin, 2019). Not until the time of the Hawkesbury Sandstone deposition is there evidence of large insects in the Sydney Basin fossil record. However, there must have been a diversification and evolution of insects during the 5 million years of the period of Narrabeen Group deposition to lead to the diversity of insect orders and species evident in the Hawkesbury Sandstone fossils.

Boreholes drilled in the eastern Sydney basin revealed a layer of shale at the bottom of the Narrabeen Group containing *Estheria coghlani*, a crustacean associated with a brackish or freshwater environment. Ichnofossils found at Long Reef Headland indicated arthropod activity in tidal areas. Naing (1993) lists crustacean dwelling and feeding burrows found in brackish water sediments of the Newport Formation.

A single fish fossil (*Myriolepis latus*) was recovered from Whale Beach Headland and a shark spine was found at Long Reef Headland. A temnospondyl *Bulgosuchus gargantua* was found at Long Reef Headland, and temnospondyls have been collected from Little Beach Headland and Kincumber. Vertebrae of an archosaur were found at Long Reef Headland (Kear, 2009), while coprolites from the same site indicated fish and tetrapod presence (Niedzwiedzki *et al*., 2016). Vertebrate trackways found in the roof shales of the Illawarra coalmines have been attributed to the therapsid *Lystrosaurus* (Retallack, 1996; Warren, 1997).

Although animal fossil finds at the headlands are rare, an assemblage of fish and temnospondyls were found in the Terrigal Formation at the Gosford Ballast Quarry. These included the temnospondyls *Platycepsion wilkinsoni* and *Parotosuchus wadei*, 14 species of ray-finned fish, a lung fish *Gosfordia truncata* and a shark, indicating a diverse population within the Narrabeen Group freshwater rivers and lagoons.

So within cool, temperate climatic conditions with long summer days and Antarctic Circle winter nights lived plant communities of conifer forests on ridges, with seed ferns forming forests on the slopes and plains with ferns as understory and scrub. Low monospecific clubmoss swamps and horsetails grew beside lakes and estuaries and along sinuous rivers and creeks. Amphibian temnospondyls were top ambush predators in freshwater waterways teeming with fish. Fish fed on algae, small bivalves and crustaceans and were in turn hunted by larger fish such as the torpedo-like *Saurichthys.* Crustaceans, worms and bivalves burrowed in the estuarine mud. On land rare early dinosaur-like archosaurs roamed the river banks.

By the time the deposition of the Narrabeen Group had ended, plants and animals, invertebrate and vertebrate, were diversifying to fill every niche opened by the Permo-Triassic extinction event.

ACKNOWLEDGEMENTS. My thanks go to the successive collection managers and curators of the Australian Museum, Yong Yi Zhen, Ross Pogson and Matthew McCurry, who gave me regular access to the Palaeontology Collection during the extended period required to research this paper. Patrick Smith of the Australian Museum provided advice on biostratigraphy and contributed to the production of the figures. Yong Yi Zhen, in his current capacity as Principal Research Scientist at the Geological Survey of New South Wales, offered access to the GSNSW palaeontology collection and records. The Australian Museum DigiVol teams, under the capable co-ordination of Leonie Prater, imaged more than 80 specimens displayed in the figures. Robert Jones, Senior Research Fellow at the Australian Museum, provided knowledge of the many fossil sites described and the specimens found there.

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