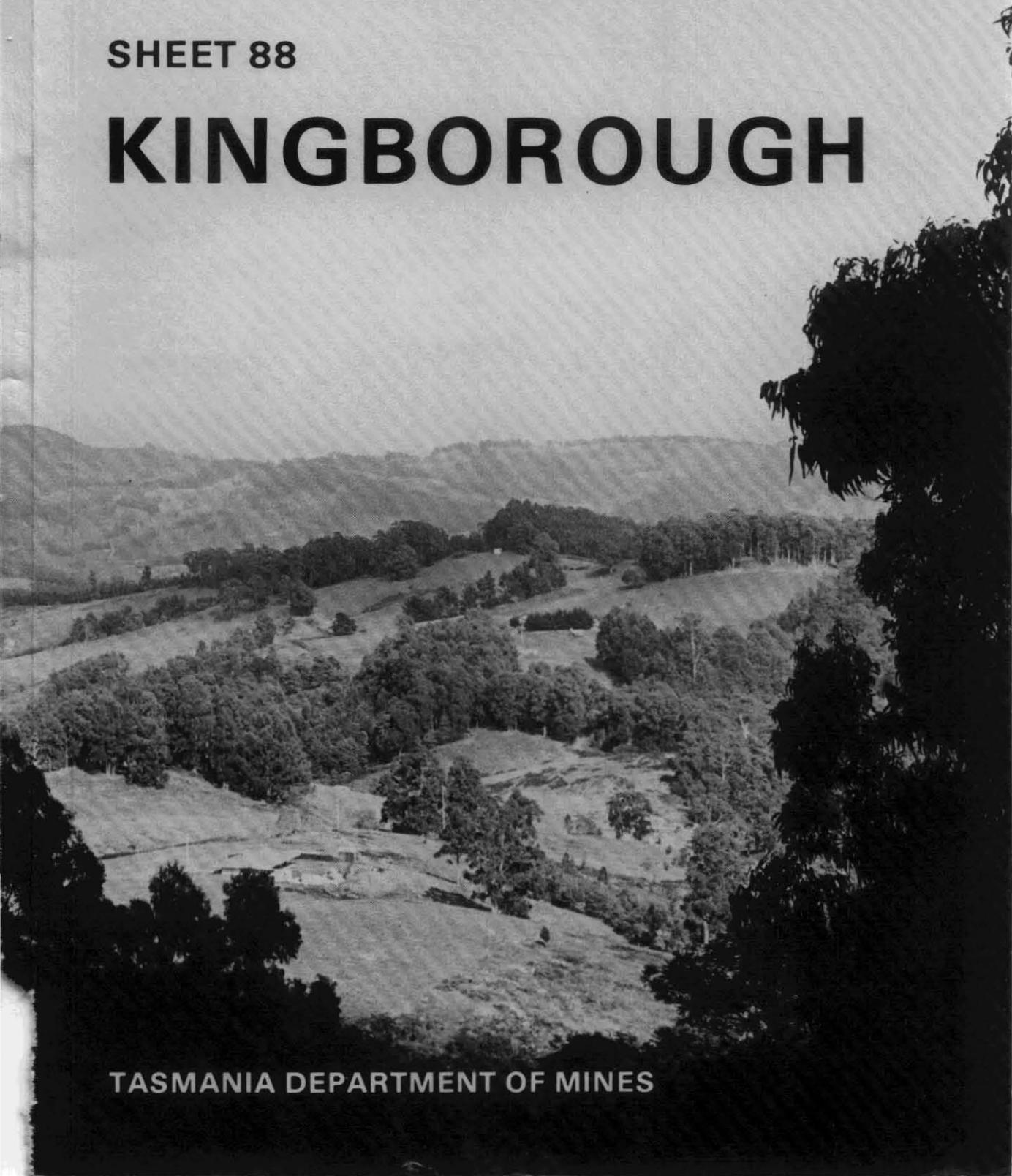# GEOLOGICAL SURVEY EXPLANATORY REPORT

SHEET 88

KINGBOROUGH

TASMANIA DEPARTMENT OF MINES

TASMANIA DEPARTMENT OF MINES

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GEOLOGICAL SURVEY EXPLANATORY REPORT

GEOLOGICAL ATLAS 1:50 000 SERIES

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KINGBOROUGH

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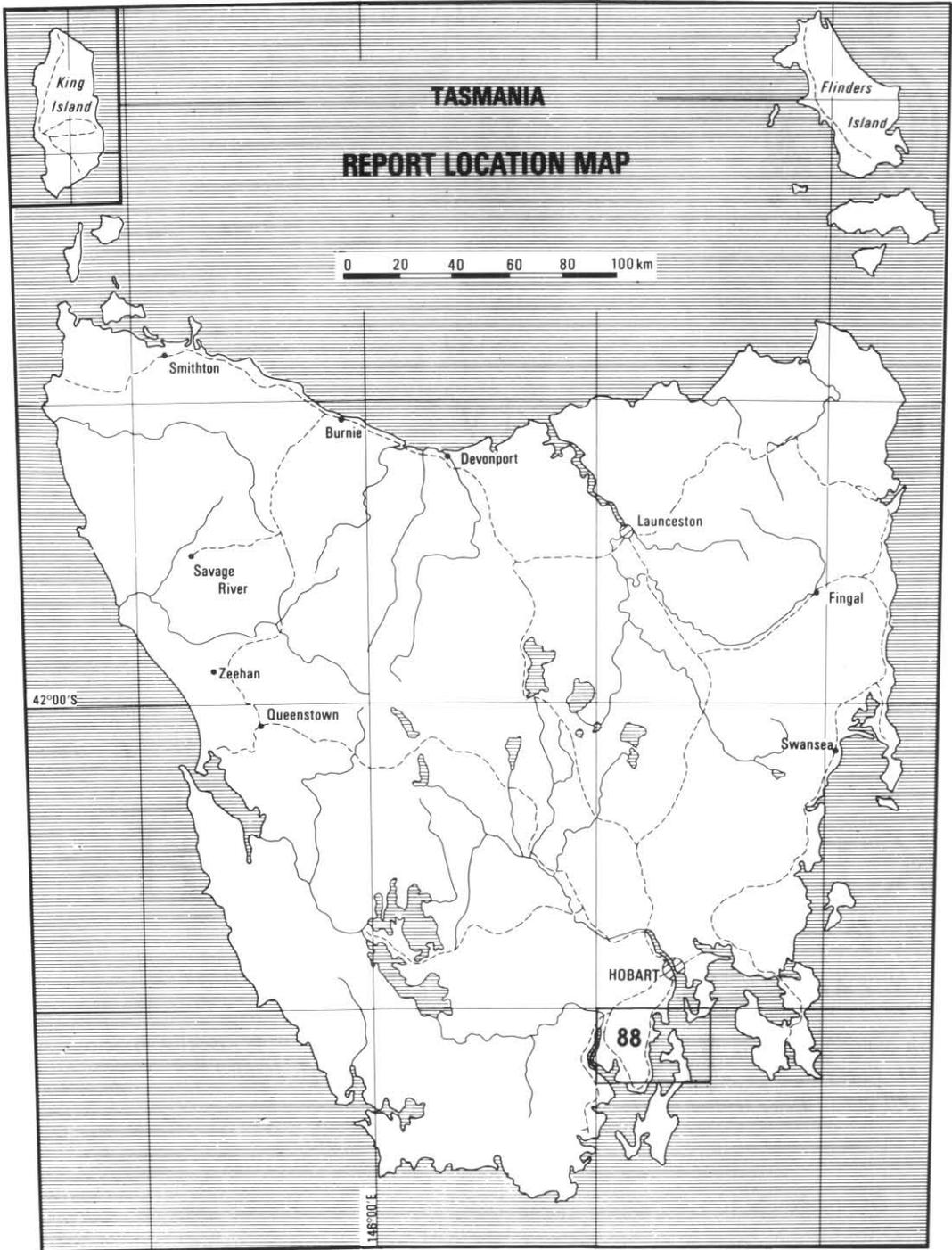
Figure 1. *Location map*

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PREFACE

The Cygnet District of the Kingborough Quad-rangle has long been noted for the occurrence of a suite of alkaline igneous rocks sufficiently rare to have attracted the attention of geologists, more especially petrologists. Gold is associated with these alkaline rocks and coal seams within the Parmeener Super-Group have been worked at Mt Cygnet and Kaoota. Sections of the Parmeener Super-Group are among the best exposed and most important anywhere in the State, and serve as a detailed time frame for the coal measures sequences which occur here and elsewhere. Soil types and groundwater resources are intimately related to the geology and are important in agriculture and forestry which are now the principal components of the economy of the area.

The late Dr Farmer mapped the adjoining King-borough and Dover Quadrangles concurrently. Mapping and compilation of the Kingborough map sheet was essentially completed in 1978, with publication of the 1:50 000 map in 1981. Mapping of the Dover map sheet continued, however, but remains uncompleted. These factors combined to reduce Dr Farmer's opportunities to complete this explanatory report. He did, however, write up a substantial part of the Lower Parmeener Super-Group. These sections are included virtually un-changed except for very minor amendment where more recent borehole information has become available. The remainder has been compiled by M. J. Clarke, P. W. Baillie, S. M. Forsyth and E. Williams from Dr Farmer's field note books, maps, sections, unpublished reports, and rock and fossil collections. As far as possible the original format established by Dr Farmer has been followed. Dr F. L. Sutherland, Australian Museum, Sydney, has kindly supplied the detailed petrological account of the Tertiary basalts. Compilers initials are indicated at the end of each particular section.

INTRODUCTION

The Kingborough Quadrangle (fig. 1) lies to the south of the Hobart Quadrangle and embraces the so-called Channel District of south-eastern Tas-mania and North Bruny Island. It lies between latitudes 43° S to 43° 15'S and longitudes 147° E to 147° 30'E, and has a land area of about 740 km². It is traversed by both the Channel and Huon High-ways and a network of other roads and tracks give excellent access to all parts of the map sheet. Outcrop is generally good, the more so along the extensive stretches of coastal shore platforms and cliffs about the Derwent Estuary and North Bruny Island, and about Port Cygnet in the Huon estuary.

The district has a mild but humid climate with an annual rainfall of about 750 mm in the lower lying areas and up to 1 250 mm in the higher forested areas. The relative variability of rainfall ranges from 12% in the south to 16% in the north. The annual mean temperature range is 5·5–16·6° C.

Much of the area has been cleared for horticultural purposes. However, in the more rugged uncleared dolerite uplands there is a dense sclerophyll forest with an understorey of low scrub and bracken. Extensive thickets of wattle regrowth and black-berry blanket previously burnt areas. The soils are predominantly podzolic, being yellow podzols on rocks of the Parmeener Super-Group and Creta-ceous alkaline syenites, but grey-brown to brown podzols on Jurassic dolerite.

The main centres of population are Blackmans Bay, Margate, Snug, Kettering, Woodbridge, Cygnet and Huonville, with numerous other smaller communities at Cradoc, Woodstock, Ranelagh, Glaziers Bay, Wattle Grove, Petcheys Bay, Lyming-ton, Gardners Bay, Nicholls Rivulet, Oyster Cove, Electrona, Middleton, Garden Island Creek, Franklin, Kaoota, Sandfly, Pelverata, South Arm and Dennes Point on North Bruny Island.

The economy of the area is based on orcharding, berry fruits, grazing, dairying, logging, sawmilling and seafood harvesting. Coal mining at Mt Cygnet ended in 1940, and at Kaoota in 1971.

The primary geological survey was carried out between 1970–1977 at a scale of 1:15 840 and the colour-printed map sheet was published in 1981 at a scale of 1:50 000. A complementary stratigraphic drilling programme accompanied the later stages of mapping and was completed in April 1984.

PREVIOUS WORK

Possibly the earliest observation of the geology of the area is due to Peron (1807) when a rock was thrown at him by a native during a sojourn at Port Cygnet by the French explorer Nicolas Baudin's expedition in 1801. Specimens were collected and later described by von Buch. His descriptions (1814) refer to augite in basaltic greenstone, and augite with booklets of mica and white, needle-like crystals of feldspar in a rock comparable with basaltic greenstone. These descriptions ostensibly refer to dolerite, but if the recognition of the mica booklets is accurate, that specimen may have been collected from the Regatta Point area. During the early months of 1804 the mineralogist A. W. Humphrey visited the area with the eminent botan-ist Robert Brown and collected samples of garnet trachyte from near Langdons Point.

The next significant observation was made by Milligan (1852) who reported reddish golden mica from Port Cygnet. Milligan (1855) also recorded the presence of a feldspathic rock with tourmaline and a granitic texture south of Oyster Cove. Both sanidine bearing rocks and syenite porphyry occur here.

Thureau (1881) reported on the gold deposits near Lymington and the coal deposits near Gardners Bay (Mt Cygnet). The geological map of Tasmania (Johnston, 1888a) showed a series of NW-trending intrusions of granite and porphyry from Cygnet to Oyster Cove, but no text comment was made.

The alkaline rocks of the Cygnet–Oyster Cove areas were first described and classified in detail by Twelvetrees and Petterd (1899), Twelvetrees (1901, 1903a, 1903b) and Paul (1906). Macleod and White (1900) described a species of garnet considered to be peculiar to the Cygnet area. Smith (1899) reported gold at Mt Mary, and Twelvetrees (1902, 1907) made a critical evaluation of the gold and coal resources. The alkaline rocks were thought to be Permian in age until Skeats (1917) showed that they also intrude Jurassic dolerite at Kettering. Additional examples of this relationship were subsequently discovered at Port Cygnet (Hills et al., 1922). The map produced by these authors, although generalised and very approximate was the first geological map which covered a substantial part of the Kingborough map sheet.

Edwards (1947) considered the alkaline rocks at Regatta Point to have been formed by reaction of a potash-rich alkaline magma, of syenitic composition, with pre-existing dolerite. Edwards considered the main intrusion to be a stock of syenite porphyry (banatite) with later stage dyke intrusions of varying composition. Whereas the present survey indicates a significantly different geometry for the intrusions, Edwards' petrological studies remain as the best published account of the various rock types and mineralogical variations.

Carey (1958) suggested that the alkaline rocks and dolerite were essentially contemptoraneous with the former being produced by the assimilation of limestone by differentiated dolerite. This view conflicts with more recent radiometric age determinations.

Irving (1956) and Robertson and Hastie (1962) recorded palaeomagnetic data for the Cretaceous alkaline rocks and Jurassic dolerite. Evernden and Richards (1962) measured K-Ar ages ranging from 99 Ma (sanidine and biotite) to 109 Ma (hornblende) for the Cretaceous syenites. McDougall and Leggo (1965) remeasured the hornblende sample of Evernden and Richards at 95 Ma and also found an age of 98 Ma for their own sample.

McDougall (1961, 1962) gave detailed petrological information and measured K-Ar ages of 143 Ma to 167 Ma for the granophyric dolerite at Red Hill. More recent work (Schmidt and McDougall, 1977) gives a preferred age of 170·5±8 Ma (late Early–early Middle Jurassic) for the Red Hill dyke and various other Tasmanian occurrences.

Detailed stratigraphic studies are of a more recent date. Hills and Carey (1949) following Hogg (1902) recorded and described Late Palaeozoic tillite at Little Peppermint Bay, Woodbridge as the 'Woodbridge Glacial Formation'. The 'Woodbridge Glacial Formation' was incorrectly placed stratigraphically between so-called rocks of the Cascades Group and the Ferntree Mudstone, and used to support a period of Late Permian glaciation. Mather (1955) and Rodger (1957) mapped limited parts of the map sheet around Huonville and Oyster Cove–Sandfly respectively. Rocks mapped by them as 'Woodbridge Glacial Formation' are lithologically dissimilar and occupy a very different stratigraphic position to the beds at Little Peppermint Bay. Leaman and Naqvi (1968) and Leaman (1967) studied the stratigraphy, structure and groundwater geology of the Cygnet area using geophysical methods. Their work, too, has serious defects in the understanding of the stratigraphy of the Lower Parmeener Super-Group. They failed to recognise the substantial diastem in the sequence at Cygnet, erroneously considered the Deep Bay Formation to be a lateral time equivalent of the Berriedale Limestone of the Granton area, and frequently confused the Bundella and Deep Bay Formations.

Ford (1967) demonstrated that the johnstonotite garnet of Macleod and White (1900) was essentially spessartite.

Banks and Naqvi (1967) defined a type section for the Cygnet Coal Measures at Sandrock Bay, but it is shown herein that drilling of the once mined area at Mt Cygnet indicates that the coal measures are developed within the Barnetts Member of the Springs Sandstone. The Cygnet Coal Measures (sensu Banks and Naqvi) are here included within the Abels Bay Formation.

Clarke and Banks (1975) and Clarke and Farmer (1976) summarise critical data from the Kingborough map sheet in their stratigraphic and biostratigraphic accounts of Tasmanian Late Palaeozoic rocks.

Moore (1979) documents the complexity of Tertiary erosion and sedimentation in his detailed investigation of dam sites at Whitewater Creek, but most of the area lies within the Hobart Quadrangle.

Bacon (1983a, 1983b) has summarised the coal geology at Mt Cygnet and Kaoota.

Plate 1. *General view of the Cygnet area from Woodbridge Hill. Mt Windsor and Mt Mary in the heart of the Cretaceous syenite complex are prominent in the middle distance.*

PHYSIOGRAPHY

The relief ranges from sea level to 831 m at Grey Mountain [EN094288] in the Snug Tiers. Rock type and geological structure are the predominant factors which control physiographic development. Thus most of the higher ground is occupied by densely forested dolerite terrain which forms the divide between the Derwent and Huon Rivers.

In the Cygnet area the physiography is strongly influenced by the broad, gently dipping and much faulted dome of Lower Parmeener Super-Group rocks. This has given rise to a central ridge along the Cygnet Peninsula with Coads Hill [EN025215] and Silver Hill [EN023222] as high points. Syenite porphyry crops out prominently here. In an area west of Cygnet syenite porphyry also crops out as substantial sheet-like bodies and a group of hills which include Mt Mary [EN048193] and Mt Windsor [EN027188] (plate 1) reflect the influence of this rock type. From these hills the land drops to sea level to the west, south and east, and to about 120 m in the north to the Balfes Hill saddle. From Balfes Hill the land rises northward to Cradoc Hill [EN050265] and falls slowly westward to the Huon River at Cradoc.

There are several drainage systems within the map sheet. The northern and western slopes of Grey Mountain and Cradoc Hill drain northward to Kellaways Creek and thence to the Huon River, but their southern and eastern slopes drain southward via Agnes Rivulet to Port Cygnet. The hills in the Tobys Hill [EN102228]-Gardners Bay [EN102185] region drain toward Nicholls Rivulet and Port Cygnet. Many of these streams flow into small floodplains and alluvial tracts in their lower reaches, and meanders are usually slightly entrenched. Many streams are intermittent and only the larger rivulets are perennial.

The landscape in general has been influenced by the down-cutting of the major rivers below present sea level, followed by drowning. Port Cygnet is an example of a drowned estuary slowly filling with silt. There is evidence of a post-glacial high sea level about one metre above present high-water which has been named the Milford Level by Davies (1959).

The straight course of the Huon River west of Ranelagh [EN025383] may be fault controlled. Its course at Ranelagh has been changed to the south by Tertiary basalt, and at Ironstone Creek [EN044345] downstream from Huonville, resistant Jurassic dolerite and probable faulting has been responsible for a swing to the south-west. Along the shores of the Huon estuary, river gravel is found to a height of 30 m around Huonville, Cradoc, Petcheys Bay [EN011177], near Beaupré

Point [EN050140], Deep Bay [EN092151] and at Randalls Bay [EN100120]. These gravels probably represent remnants of river terraces associated with higher interglacial sea levels, but owing to recent erosion and cultivation it is difficult to trace more than one terrace margin with any certainty. The latest development has been the construction of estuarine deltas and tidal flats at the head of Port Cygnet near the mouths of Agnes and Nicholls Rivulets, and in the Huon River.

East of the Huon–Derwent divide all streams drain into the Derwent River. Between Margate [EN220350] and Middleton [EN200133] Tertiary sand, clay, basalt and greybilly infill the old Tertiary landscape and now form a discontinuous belt of low-lying country marginal to the main Derwent Graben. At the head of North West Bay near Margate [EN220350] river terrace gravels, and later beach and tidal flat deposits point to a similar history as the Huon River.

North Bruny Island essentially presents a low, rounded topography of dolerite hills, but to the south in the vicinity of the isthmus, relief is very subdued with scattered remnants of a once much more extensive cover of Tertiary deposits overlain by widespread developments of Quaternary wind-blown sands. Similar deposits also occur extensively in the South Arm area [EN340359].

[M.J.C.]

STRATIGRAPHY

Parmeener Super-Group

LOWER DIVISION

Rocks of the Lower Parmeener Super-Group are magnificently displayed in a series of coastal sections about Port Cygnet and elsewhere in the Kingborough map sheet. Detailed mapping has revealed the presence of a previously undetected major hiatus in the sequence at Cygnet, and substantial facies changes and overstep occur as the sequence is traced northwards into the Hobart area (fig. 2). The stratigraphic relationships elucidated by the mapping have been confirmed in detail by a systematic drilling programme. These factors have necessitated a major revision of lithostratigraphic nomenclature. The changes are summarised below. The stratigraphic sequence within the Lower Parmeener Super-Group in the Kingborough map sheet is, from the top downwards (and with new formation names indicated by an asterisk):

*Abels Bay Formation

 Risdon Sandstone

*Minnie Point Formation
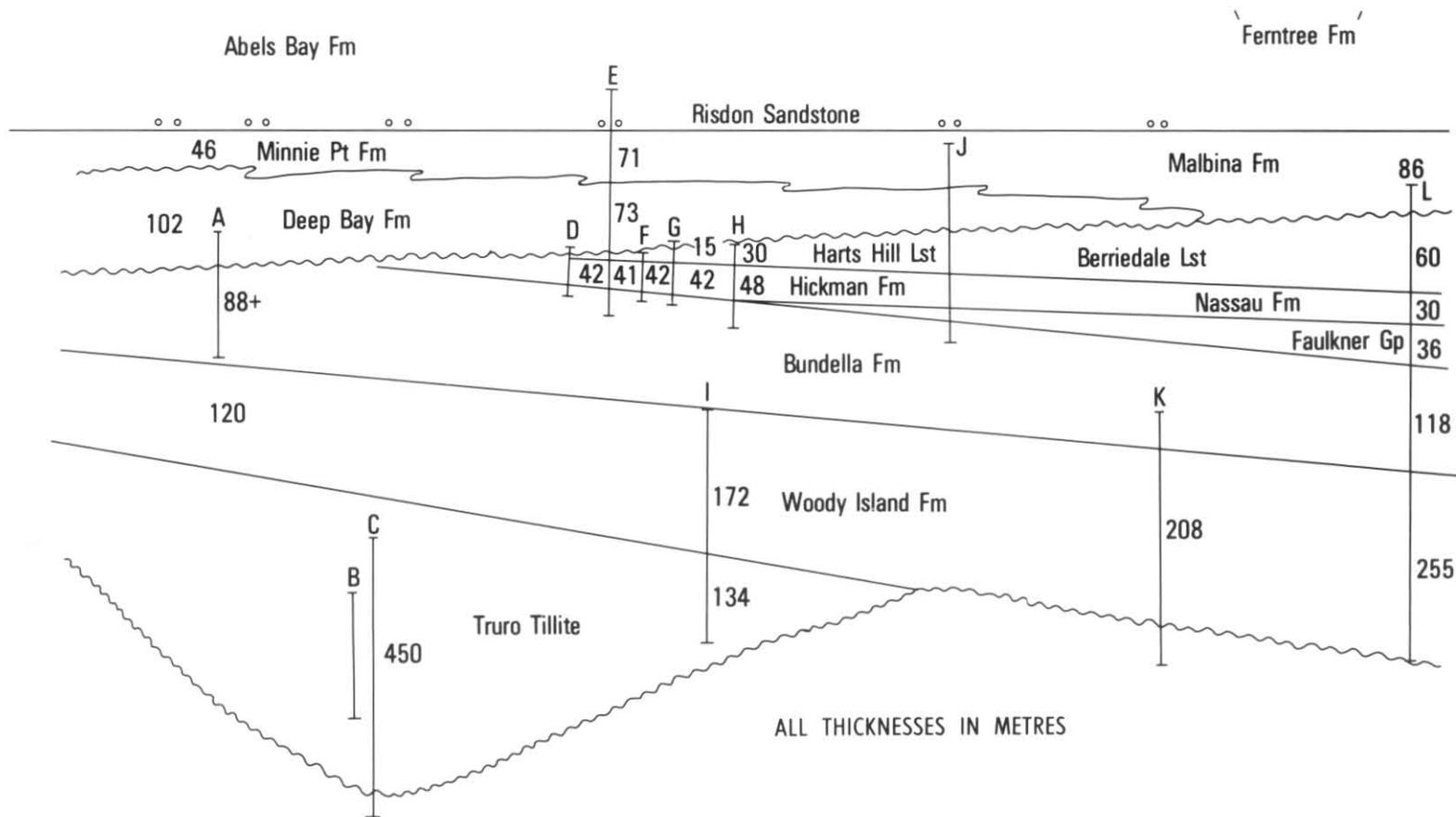
Figure 2. *Stratigraphic relationships, Lower Parmeener Super-Group, Cygnet to Granton. Diamond drill holes — A: Deep Bay, B: Silver Hill, C: Woodbridge, D: Palmers Road, E: Snug Tiers, F: Snug, G: Harts Hill No. 2, H: Harts Hill No. 1, I: Margate, J: Porter Hill (proposed), K: Glenorchy, L: Mt Nassau.*

*Deep Bay Formation

*Harts Hill Limestone

*Hickman Formation

Bundella Formation

Woody Island Formation

*Truro Tillite

Truro Tillite: This name is introduced to define the thick (450 m) sequence of basal tillite and other glacigene rocks as exposed through the Cygnet–Woodbridge–Oyster Cove areas in the southern half of the map sheet. The formation thins rapidly northwards. It is present in the Margate Bore [EN212362] but absent in the Glenorchy Bore [EN209562]. Previously this unit has been termed the Woodbridge Glacial Formation (Hills and Carey, 1949). However, the original definition contains significant errors of fact and interpretation which have resulted in much subsequent confusion. As defined (Hills and Carey, 1949 following Hogg, 1902; Voisey, 1938; Prider, 1948) the Woodbridge Glacial Formation was stated to occupy a stratigraphic position between the Cascades Group and the Ferntree Mudstone. Furthermore, it was considered to represent a period of Late Permian glaciation quite distinct from the Late Carboniferous Wynyard Tillite in north-west Tasmania (and elsewhere) which occupies a basal position within the Parmeener Super-Group. The original type section at Little Peppermint Bay, near Woodbridge [EN196215], is now known to be transected by a major fault and embraces beds belonging to the Minnie Point Formation, the Risdon Sandstone and the Abels Bay formation, as well as the basal tillite. Nowhere in the original type area does the tillite occupy a position between the Cascades Group and the Ferntree Mudstone. In the Woodbridge Bore at Little Peppermint Bay, which was completed in April 1984, the tillite was proved to rest on folded and cleaved Precambrian phyllite and mixtite; and on the hill slopes inland it is followed conformably by pyritic and glendonitic siltstone of the Woody Island Formation. It occupies a similar stratigraphic position below the Woody Island Formation throughout the Cygnet and Oyster Cove areas although the basal unconformity is nowhere exposed.

In general substance these facts have been recognised for many years so that the Woodbridge Glacial Formation of the Hobart area has been re-named the Malbina Formation (Banks and Read, 1962), and the Woodbridge Group of the Central Plateau area (McKellar, 1957) has been re-named the Poatina Group (Bravo and Pike, 1969). These usages (and many others) of the terms

Woodbridge Glacial Formation and Woodbridge Group involved gross mis-correlations. It was further noted (Banks and Read, 1962) that the Malbina Formation displayed no evidence to support an increase in glacial activity. In view of the foregoing it is considered that the name Woodbridge Glacial Formation best be allowed to lapse.

Hickman Formation: This name is introduced to define a formation of siltstone and granule conglomerate which is well developed in the Snug–Harts Hill area in the northern parts of the map sheet. The formation is wholly marine and lies conformably between the Bundella Formation below and the Harts Hill Limestone above. It is the age equivalent of both the freshwater Faulkner Group and the Nassau Formation of the Hobart area.

Harts Hill Limestone: This name is introduced to define a relatively thin unit of bioclastic limestone which occurs in a very restricted area at Harts Hill, near Margate [EN205344]. It is the age equivalent of the Berriedale Limestone of the Hobart area, at least in part, but lateral continuity has not been established. To the south, both the Harts Hill Limestone and the Hickman Formation are absent due to overstep by the Deep Bay Formation.

Deep Bay Formation: This name is introduced to define a formation of richly-fossiliferous siltstone and fine-grained sandstone which rests with pronounced para- or disconformity on an incomplete Bundella Formation in the Cygnet area. To the north it oversteps progressively younger units and rests successively on the Hickman Formation and the Harts Hill Limestone near Margate. The lower part of the Deep Bay Formation is younger that any part of the Cascades Group of the Hobart area, and older than any part of the Malbina Formation. The upper part of the Deep Bay Formation is the age equivalent of the lower Malbina Formation. The Deep Bay Formation includes those rocks assigned by previous workers to the Grange Mudstone, with the latter being regarded as the lateral facies and age equivalent of the Berriedale Limestone. This view can no longer be sustained, at least within the area of the Kingborough map sheet. Recent drilling of the type section of the Cascades Group at Mt Nassau [EN515266] proves that the Grange Mudstone does not there exist (Clarke and Farmer, 1982). The relationship of occurrences of so-called Grange Mudstone with the Berriedale Limestone over the southern part of the Hobart map sheet remain to be determined. Certain occurrences such as that on the Huon Road, South Hobart at EN225495 belong with the Deep Bay Formation.

Minnie Point Formation: This name is introduced to define a formation of coarse-grained, pebbly sandstone and subordinate siltstone which occurs between the Deep Bay Formation below and the Risdon Sandstone above. It is the age equivalent of the higher part of the Malbina Formation of the Hobart area. Together, the Minnie Point Formation and the higher part of the Deep Bay Formation are the age equivalents and facies variants of the Malbina Formation.

Abels Bay Formation: This name is introduced to define a formation of poorly fossiliferous, pebbly, fissile and non fissile siltstone and fine-grained sandstone which lies conformably between the Risdon Sandstone below and the Cygnet Coal Measures above. It corresponds essentially to the Ferntree Mudstone (*sensu* Banks, 1952) of the Hobart area which, however, lacks a stratotype. The Ferntree Group of the Central Plateau area (McKellar, 1957) has been re-named the Bogan Gap Group (Bravo and Pike, 1969) since Poatina is too far removed from the original reference area; the sequence differs significantly lithologically and embraces older rocks. As defined herein the Abels Bay Formation includes the original type section of the Cygnet Coal Measures (Banks and Naqvi, 1967). The once productive coal measures sequence at Mt Cygnet, however, is developed in the Barnetts Member of the Springs Sandstone (*sensu* Banks and Naqvi, 1967).

[M.J.C.]

TRURO TILLITE (Pt)

The Truro Tillite, here defined, takes its name from the settlement at Truro [EN050223] near Cygnet. The formation consists of more than 450 m of unfossiliferous, unstratified, matrix-supported glaciogenic diamictite with subordinate laminite sequences and minor sandstone and conglomerate beds. The Truro Tillite is overlain conformably by the Woody Island Siltstone and although the base is unknown in the type area, evidence from the Woodbridge Bore [EN193226] and surrounding areas indicates that it rests with profound landscape unconformity on Lower Palaeozoic and older rocks. The boundary of the tillite with the Woody Island Siltstone is taken as being marked by the highest common appearance of pebbles, and the base of the formation by the underlying unconformity. The formation is known over most of the Kingborough Quadrangle, and its lateral equivalents extend into the surrounding areas. The age of the tillite has not been directly determined but correlation with other areas suggests a Late Carboniferous (Stephanian) age.

The Truro Tillite is the basal formation of the Parmeener Super-Group and takes its name from

the settlement at Truro [EN050223] near Cygnet. The formation consists almost entirely of dark grey, massive, unstratified, poorly-sorted, matrix-supported (disrupted framework) diamictite of glaciogenic origin. Pebble-free or pebble-poor banded mudstone and laminate (?rhythmite) sequences, up to several metres in thickness, form a minor, but characteristic, element within the formation. Where clasts are found within the laminite sequences they are usually restricted to granule size particles.

In addition to the laminite sequences a borehole on Silver Hill Road [EN051218], Cygnet, proved, within the main body of the tillite, a sequence of fairly fine-grained, cross-bedded sandstone resting on a clast-supported (continuous framework) conglomerate without the usual fine-grained matrix of sedimentary particles normally associated with the tillite part of the formation.

The fabric of the tillite matrix surrounding the clasts usually consists of poorly-sorted material dominantly of silt, clay and rock flour. The microscopic characters of the tillite are given by Leaman and Naqvi (1968).

The clasts in the tillite vary greatly in size, shape, and composition. In size they range from granules through boulders to large blocks but with pebbles and cobbles by far the most common and conspicuous. Very large erratics are extremely rare and very few exceed 300 mm in length. Most of the pebbles are well rounded or sub-rounded but there are many which are sharply angular. Edges and corners are often smooth while the faces are humped, planar, of sometimes gently concave. Striae occur, particularly on some of the larger erratics, but are rare.

Compositionally the pebbles commonly include slate, quartzite, granite, schist and many other resistant igneous, sedimentary and metamorphic rock types. Many of the rock types can be closely matched with Lower Palaeozoic and older rocks exposed in western Tasmania and this suggests a likely source for most of the material in the tillite.

Although the tillite is remarkably uniform over most of its distribution and is almost always matrix dominated, there is some minor variation in the ratio of erratics to matrix both laterally and vertically through the sequence.

The tillite where fresh is usually uniformly dark grey but quickly weathers to pale grey, buff or brown. Weathering is aided by the very fine-grained nature of the matrix and the resulting ready availability of minerals for chemical weathering. The speed of the process is probably further enhanced by the development of incipient jointing

resulting from stress release during removal of overburden by erosion or the action of man. On weathering the matrix of the tillite becomes friable and breaks down to fine mud. Deeply decomposed pebbles within the tillite at many localities point to post-depositional *in situ* chemical weathering of some intensity, probably associated with a varying water table.

Where seen in large outcrops and cuttings the tillite often displays well-developed low-frequency jointing which gives the otherwise unstratified tillite an irregular, joint-bounded, block-like appearance. There may be several joint sets in a single exposure. Examples of such jointing can be seen to advantage in road cuts immediately to the north of Woodbridge [EN195215] (plate 2).

At some localities, for example the areas on either side of Jetty Road at Lymington, the tillite shows the effects of contact metamorphism caused by the intrusion of massive Jurassic dolerite and a later, probably more effective, fluid-rich Cretaceous syenite. At some distance from the major intrusions the matrix of the tillite shows obvious signs of baking and becomes hard and brittle. Pebbles develop conspicuous reaction haloes which become more marked as the rocks are progressively baked. Close to the heat source contrast between pebbles and enclosing matrix is almost lost. Freshly broken surfaces of the metamorphosed tillite appear fine-grained and homogeneous although on fairly deeply weathered surfaces 'ghosts' of pebbles can be distinguished.

In areas closely intruded by igneous bodies, particularly syenite, it may be difficult to distinguish between highly-altered country rock and intimately intruding igneous bodies. Thus at Lymington, Leaman and Naqvi (1968) included much of this kind of country within their 'hybrid zone' between dolerite and syenite. Careful search, however, usually reveals sufficient vestiges of structures to indicate the sedimentary origin of metatillites.

Similar intense baking resulted in the generation of reaction haloes in the tillite immediately above the dolerite in the Margate Bore [EN212362] and in the Woodbridge Bore [EN195215].

Other indications of contact metamorphism include the presence of high temperature pyrrhotite commonly found in the tillite of the Cygnet area and well seen around Crooked Tree Point [EN075188] where the distribution centres on a high intensity magnetic field possibly indicating a local 'hot spot' (Leaman and Naqvi, 1968).

In a quarry on Wattle Grove Road [EN036203] the syenite-baked tillite contains unusual, small, partly decomposed pebbles with hollow centres. Some of

these hollow-centred pebbles contain clusters of small, transparent, acicular, pyramid-ended, quartz crystals.

Parmeener Super-Group tillite was generally assumed to be of terrestrial origin (see Banks, 1962) but after carefully study of models of glacial deposition Carey and Ahmad (1961) concluded that the tillite originated as lodgement moraine emplaced below sea-level by wet-base glaciers.

Acanthomorph acritarchs, believed to be wholly marine, found within the tillite sequence in northern and western Tasmania (Truswell, 1978) have also been used to support a marine origin for the tillite as a whole. In addition, a marine origin for the tillite also allows easy explanation of its great thickness (in excess of 450 m); a thickness far in excess of any known continental tillite.

Although a suggested marine origin might be appropriate for most of the tillite there are no adequate lithological criteria for distinguishing between marine and terrestrial tillites. Simple lithological examination fails to separate them and there can therefore be no locality by locality identification of the depositional environment of the tillite. The essential feature which dominates all tills is the glacial transport of the material. The depositional environment is not usually discernible and must always be secondary to the transporting mechanism as an influence on the fabric and character of the tills.

Accepting that most of the tillite is of marine origin there is nevertheless some evidence to suggest that at least part could be terrestrial. The presence of pebble-free laminite sequences within the main body of the tillite strongly suggests deposition by slow settling in ponded bodies of water under near-stagnant or quiet-water conditions such as those found in large ponds or lakes. Similarly the presence of cross-bedded sandstone and continuous-frame-work conglomerate, up to several metres in thickness, within the tillite sequence might indicate running water and terrestrial glacio-fluvial activity rather than sub-glacial marine deposition.

The great thickness of tillite probably indicates a fairly long period of deposition, perhaps with several minor advances and retreats, and there could well be room in this series of events to accommodate sediments deposited in both terrestrial and marginal marine environments. How much of the sequence is marine and how much terrestrial remains to be determined.

The Truro tillite is widely distributed across the Kingborough Quadrangle, and the lateral equivalents of it extend far beyond. In the southern part of the map sheet extensive areas of outcrop are to be

Plate 2. *Massive, unbedded Truro Tillite at Little Peppermint Bay, Woodbridge. The hammer handle rests on the largest clast present in the exposure.*

found around Cygnet [EN065212], Woodbridge [EN195215] and south of Underwoods Hill [EN175245] to the west of Kettering.

Apart from a small area of tillite east of Paradise Hill at EN077374 which is thought to be a raft within dolerite, no surface exposures of tillite are known in the northern half of the map sheet, where the rocks exposed at surface are all much higher in the stratigraphic sequence, but a borehole at Margate [EN212362] encountered tillite at a depth of 172 m and went on to prove more than 130 m of baked tillite without finding a base to the formation; clear evidence of tillite as far north as the northern edge of the map sheet.

Continuation of the basal tillite far beyond the confines of the map sheet is well documented but to the north and east the tillite apparently thins and disappears. A bore at Glenorchy (Hobart Sheet; EN209562) penetrated as far as the Lower Palaeozoic basement but failed to find tillite in its expected position at the base of the Parmeener Super-Group. A thin pebbly sequence found at this level represents a basal conglomerate rather than a tillite. Tillite has not been recorded to the east of the Kingborough map sheet although stratigraphic successions suitable for its appearance are well known.

The dark grey pebbly Truro Tillite is overlain by lighter grey, pebble-free mudstone and siltstone of the Woody Island Siltstone. At their boundary the formations grade into one another but the transition is rapid and for all practical purposes the top of the Truro Tillite is taken as being marked by the latest (highest) common appearance of pebbles. Pebbles usually become smaller and fewer as the boundary is approached. The boundary between the two formations is well exposed in the area of Crooked Tree Point [EN075188], south of Cygnet, where the two formations can be seen to grade into one another imperceptibly. Beds to within a few metres of either side of the Truro Tillite–Woody Island Siltstone boundary can be seen in roadside exposures on Wattle Grove Road [EN030203].

Neither the base of the formation nor its relationship to the underlying rocks is anywhere exposed within the area of the map sheet but comparison with surrounding areas, where the relationship is known, and with the Woodbridge Borehole indicate the presence of a profound landscape unconformity with the tillite resting on folded and eroded Lower Palaeozoic or older rocks.

The best section in the type area, around Cygnet, is composite, consisting of both surface exposures and subsurface cored material. The upper part if the tillite is exposed in the hills immediately to the west of the township where more than 180 m of

tillite can be seen in the numerous roadside exposures in the area transected by the Wattle Grove, Silver Hill and Kings Hill roads. The general lithology of the tillite, although, as throughout most of the area, somewhat baked, can be examined in detail in a quarry alongside Wattle Grove Road [EN036203].

A further 212 m of tillite was proved in a bore adjacent to Silver Hill Road [EN051217]. Assuming the absence of any major faulting this gives a minimum aggregate thickness of some 400 m for the tillite in the Cygnet area. At Little Peppermint Bay [EN193226] immediately north of Woodbridge a recent fully-cored borehole proved a thickness of 316 m of tillite. A further 130 m of tillite occur above the collar of the hole to give an aggregate thickness of about 450 m; this is the greatest known thickness in south-eastern Tasmania.

Palaeontology and age

Heavy carbonisation of the microfloral element of the biota (Dr E. M. Truswell, pers. comm.), resulting from Jurassic and Cretaceous intrusions, prevents direct determination of the age of the Truro Tillite. Equivalent beds elsewhere in Tasmania, e.g. Hellyer Gorge, have, however, yielded characteristic Stage 1 Potonieisporites microfloral assemblages (Truswell, 1978).

The macrofossil evidence in the Cygnet area inferentially points to a similar age for the tillite. The brachiopod Streptorhynchus sp. nov. which is confined to the Early Tamarian (=Faunizone 1 of Clarke and Banks, 1975; Clarke and Farmer, 1976) is found in large numbers towards the base of the Bundella Mudstone at Green Point [EN076181], Wheatleys Bay [EN029166] and elsewhere. Streptorhynchus sp. nov. is further reported with a Stage 2 microflora in Tasmanites shale at Latrobe (Clarke and Farmer, 1976; Truswell, 1978). Since the Truro Tillite lies some considerable distance stratigraphically below the Streptorhynchus horizon of Green Point and elsewhere, the tillite must all belong to either Stage 1 or Stage 2 microfloral zones both of which are of Late Carboniferous (Stephanian) age (Balme, 1980). The Truro Tillite would therefore appear to be wholly Carboniferous in age.

[N.F.; M.J.C.]

WOODY ISLAND SILTSTONE (Pw)

The type area for the Woody Island Siltstone (Banks et al., 1955) is Satellite Island [EN180035], formerly Woody Island, about a kilometre offshore from Alonnah, Bruny Island, and only a short distance (13 km) beyond the southern boundary of the Kingborough map sheet. The stratotype consists

of 26 m of thick-bedded, blue-grey, pyritic siltstone with numerous glendonites, rare dropstones and a few marine fossils. The fossils include *Eurydesma hobartensis hobartensis* (Johnston) and some scattered crinoid columnals. Large lenticular concretions of calcite, up to 4 m in diameter, are present. The basal beds of the Woody Island Siltstone on Satellite Island are not exposed. The formation is overlain in the type area by the Sunset Bay Sandstone.

The geographic location of the Woody Island Siltstone sequence on Satellite Island is somewhat anomalous in that it consists of a small area of very low Parmeener Super-Group beds entirely surrounded by rocks stratigraphically much higher in the succession. The structural relationship of the island and its rocks to the surrounding land areas is not known but presumably involves much faulting.

Correlates of the Woody Island Siltstone are distributed widely over the region covered by the Kingborough map sheet. The main areas of outcrops are centred around Cygnet [EN065210], Oyster Cove [EN180265] and the country immediately inland from Peppermint Bay at EN183222 and EN195240. A small area of outcrop of Woody Island Siltstone is known at Margate [EN212362] but only the very highest part of the formation is exposed. A bore at this location, however, proved the full thickness of the formation.

In the Cygnet area the Woody Island Siltstone characteristically consists of 120–140 m of monotonous, dark grey, thick- to massive-bedded mudstone and siltstone. Scattered dropstones, almost always small, and usually of quartz or quartzite, are sometimes seen. Fossils are rare or absent throughout the sequence except in the highest 10 m where elements of a limited macrofauna are found.

Glendonites occur sporadically throughout the formation and in places are abundant; they are present as single crystals, intergrown twins, and stellate clusters. Glendonites, first described by David *et al.* (1905), were long believed to be calcite pseudomorphs after glauberite, but more recent work (Kemper and Smitz, 1975) suggests thenardite as the more likely original mineral. Structurally glendonites often consist of a thick inner core of calcite with a thin rim or outer coating of pyrite. In some glendonites the calcite appears to be of two generations. Glendonites appear to be largely confined to this part of the sequence in Tasmania though they are known from much higher stratigraphic horizons elsewhere in Australia.

Nearly spherical pyrite nodules are common in some parts of the Woody Island Siltstone and where contact metamorphism has been fairly intense, as at Crooked Tree Point [EN075188], pyrrhotite, which crystallises at a comparatively high temperature, may be developed. Where highly baked the rock usually takes on a dark, even, fine-grained appearance and becomes greatly indurated and brittle. Syenite-induced contact metamorphism at Shag Point [EN066160] has produced a light, spotted hornfels over a considerable area of outcrop.

In thin section the rock consists of equidimensional quartz anhedra (typically 50–100 μm) in a matrix of fine-grained (5–30 μm) colourless sericitic material with traces of plagioclase. A slight tendency of the sericite to form roughly oblong to square patches (150–300 μm) suggests that at least some of it may be pseudomorphing andalusite. The rock can probably be characterised as a spotted quartz andalusite hornfels much altered to sericite. The development of abundant secondary sericite obscures much of the original mineralogy.

Where fresh the Woody Island Siltstone appears to be compact, massive and durable, but it readily fractures into small angular fragments which often cover the surface of the outcrop. The dark grey siltstone quickly weathers and changes its colour to pale grey, buff or cream and further weathering produces large quantities of clay. This susceptibility to deep and rapid weathering ensures that only actively eroding coastal sections and new exposures show fresh rock; elsewhere the country underlain by Woody Island Siltstone rocks is characterised by poor exposure and thick, usually cream coloured, clays and soils. Weathering of glendonitic mudstone rapidly removes the calcite of the glendonites and leaves the angular cavities so often seen in outcrop (plate 3). Where in contact with the sea, as at Shag Point, honeycomb weathering may develop.

In thin section typical Woody Island Siltstone rocks consist mainly of clay and silt grade material with some quartz grains. The silt content of the rock may be much altered to secondary micaceous material.

The Woody Island Siltstone is underlain, transitionally, by the Truro Tillite and is overlain conformably by the Bundella Mudstone.

The boundary between the Woody Island Siltstone and the Truro Tillite is well seen at Crooked Tree Point [EN075185] where the two formations grade into one another. Beds stratigraphically near this boundary also occur on Silver Hill Road [EN038215], on Wattle Grove Road [EN030203] and on Tobys Hill Road [EN076216].

Beds spanning the Woody Island Siltstone-Bundella Mudstone boundary are best seen in a fault-bounded block at Wheatleys Bay [EN018168]

Plate 3. *Massive-bedded Woody Island Siltstone, Wheatleys Bay. The cavities are moulds of glendonites.*

where they are fully exposed in the cliffs and on the foreshore. Only the upper part of the Woody Island Siltstone is exposed. The major part of the succession consists of featureless, dark grey, glendonitic mudstone and siltstone but towards the top becomes lighter in colour and contains scattered fossils. The fauna is fairly restricted both in number of individuals and variety of species but includes *Eurydesma hobartensis, Trigonotreta stokesi* Koenig and stenoporid bryozoans.

The base of the Bundella Mudstone is marked by the incoming of a coarse-grained sandstone succeeded by beds of much greater lithological variety than any in the Woody island Siltstone. The appearance of the sandstone coincides with greatly increased fossil abundance and a notable increase in faunal diversity. In marked contrast to the Woody Island Siltstone the Bundella Mudstone is characterised by abundant dropstones. Coarse sandstone similarly marks the base of the Bundella Judstone on Silver Hill [EN035218] where the sandstone is crowded with juvenile gastropods, probably early growth stages of *Peruvispira*.

The major part of the Woody Island Siltstone can be seen to advantage in roadcuts and quarries around the old Livingstone mine on Tobys Hill

Road [EN083219]. The surface exposures are usually weathered but the fresh rock can be examined in the mine adit. The formation is heavily intruded by a variety of syenite dykes. Faulting in the area repeats the lower part of the Woody Island Siltstone. The boundary with the Bundella Mudstone occurs at EN084219 where the pale grey unfossiliferous, pebble-free Woody island Siltstone is overlain by highly-fossiliferous, dropstone-rich siltstone of the Bundella Mudstone.

At Shag Point [EN066166] there are excellent foreshore exposures of 60–70 m of Woody Island Siltstone. The top and base of the formation are not seen owing to faulting and dolerite intrusion. The section is heavily intruded by syenite dykes and the sediments have been partly baked. The sedimentary rocks are mainly massive, well-jointed, buff and brown weathering, grey, unfossiliferous siltstone and sandy siltstone. Widely spaced jointing (2 m) gives the outcrop a blocky appearance. The development of Liesegang ring patterns is common.

Along the southern side of Shag Point [EN064158] the succession is unusual. Green-grey massive siltstone exposed here contains thin bands with small (up to 150 mm) scattered pebbles. At the same location large (1–2 m) ellipsoidal calcitic and

ferruginous–weathering concretions are common and in this respect the Shag Point succession resembles the type section on Woody Island. These large concretions are possibly the 'large quartzite boulders' of Leaman and Naqvi (1968).

Further sections in the Woody Island Siltstone can be seen in roadcuts along Sunday Hill Road [EN015190–EN021195] but the section is massively intruded by syenite both as dykes and sills. Woody Island Siltstone also caps Mt Windsor [EN028185] where it is again heavily intruded by syenite. Other small areas of Woody Island Siltstone are known in the Cygnet area but all are poorly exposed.

Apart from the country around Cygnet the only other large-scale occurrences of Woody Island Siltstone are to be found on the flank of the D'Entrecasteaux Channel in the region of Oyster Cove [EN187272] and Peppermint Bay [EN195215] near Kettering. Outcrops are everywhere poor. There are no well-displayed coastal sections. Faulting confines Woody Island Siltstone sections to the lower slopes of hilly country inland where mantling by talus and thick soil development obscures most of the rocks. There are however a few small widely scattered areas of outcrop.

There is a small area of Woody Island Siltstone spanning Pullens Road and Llantwit Road [EN186217]. In this area the formation clearly overlies the Truro Tillite but the top of the section is not seen, being faulted out. Small outcrops of weathered, pale grey, pebble-free mudstone and siltstone can be seen on the roadside at EN186217 and EN182227. Pale grey siltstones were also encountered in two shallow bores. NF17 [EN186215] and and NF22 [EN183221].

A little further north, immediately to the north of Creek Road, the top of a small hill [EN188233] is covered by baked, dark grey pebble-free, unfossiliferous mudstone float almost certainly derived from underlying Woody Island Siltstone.

Much pale grey to cream pebble-free siltstone float around EN195240 is indicative of Woody Island Siltstone in this vicinity. A large area of Woody Island Siltstone is also known to occur in a belt of country stretching from Oyster Cove [EN187272] through the steep south-eastward facing slopes of Underwoods Hill [EN173256] to Farewell Hill [EN158243]. The thickness of the formation at Underwoods Hill and at Farewell Hill is 120–140 m. Lithologically the formation consists of unfossiliferous, pebble-free, grey mudstone and siltstone underlain by Truro Tillite and overlain by pebbly, fossiliferous Bundella Mudstone.

Grey and brown weathering, unfossiliferous, pebble-free siltstone and mudstone are exposed in

roadcuts around Oyster Cove [EN187272] and in the thick bush-covered area immediately to the south there is much siltstone float of typical Woody Island Siltstone type.

There are no known large areas of Woody Island Siltstone outcrop to the north of the Cygnet and Oyster Cove districts but mapping unexpectedly revealed a small patch of fault bounded siltstone of this formation on the northern edge of Margate [EN212363]. The outcrop consists of only a few metres of featureless, dark grey, pebble-free siltstone exposed in a small cliff. At the top of the exposed sequence the beds have yielded *Schizodus australis*, and *Peruvispira* occurs abundantly; the remainder of the outcrop is unfossiliferous. The Woody Island Siltstone is overlain by the Bundella Mudstone and this outcrop must lie on or very close to the boundary between these stratigraphic units.

A borehole, NF87, subsequently drilled at this spot began at the Bundella Mudstone-Woody Island Siltstone boundary and went on to prove 172 m of Woody Island Siltstone resting on Truro Tillite. The bore began in pale grey siltstone which darkened downwards away from the weathered zone. The succession consisted mainly of monotonous, fairly featureless siltstone with minor developments of speckling and lamination. Only a single small quartzite dropstone was encountered. A few patches of bioturbation were observed. The rocks were progressively baked and spotted downwards. The spotting is accounted for by the presence of a large, steeply inclined (45°) dolerite body, encountered lower in the hole.

The 172 m thickness for the Woody Island Siltstone at Margate represents a considerably increase on the 120–140 m average thickness in the Cygnet and Oyster Cove districts. Northward thickening of the succession continues into the Hobart region where a bore at Glenorchy [EN210562] proved a thickness of 208 m for the formation. Still further north a bore at Mt Nassau [EN515266], near Granton (Clarke and Farmer, 1982), penetrated 254 m of typical Woody Island Siltstone without finding a base to the formation. This thickness is the greatest yet encountered for the Woody Island Siltstone.

The conditions under which the Woody Island Siltstone were deposited are difficult to determine and modern analogues are hard to identify. Retreat of the ice was followed by an immediate eustatic rise in sea level and consequent rapid inundation of the region. Inundation was accompanied by long-term downwarping sufficient to accommodate the deep pile of Parmeener Super-Group sediments later deposited in the area. Any upward isostatic adjustment following removal of the ice must have been rapid compared to the much longer sedimen-

tational time scale. Isostatic adjustment must also have been small in amount in relation to the overall continued downwarping implied by sediment thickness.

Lack of lithological variety and general absence of sedimentary structures indicative of bottom traction or current movement of any kind suggests deposition in the quiet undisturbed waters of a barred-basin with restricted circulation. Patches of fine lamination, as at Margate, may also indicate slow sediment settling in quiet waters. Absence or paucity of dropstones indicates an environment of deposition sufficiently separated from the open sea to exclude floating ice and its contained debris. Depth of water is uncertain.

The severely restricted nature of the fauna, both in variety and distribution, implies isolation from fully marine conditions. This isolation may result from a physical barrier, which only allowed inter-mittent development of fully marine conditions or from a chemical barier, such as hyposalinity, which may also have precluded the development of a fully marine fauna.

The abundance of pyrite nodules in many sections and the presence of carbonaceous matter in some has been interpreted as evidence of a reducing environment (Banks, 1962).

Glendonites, widespread, and sometimes abundant, are usually taken to signify deposition under cold-water conditions (Banks, 1962) and it is noteworthy that sea water when concentrated by freeze con-centration early becomes saturated with sodium sulphate (Matsubaya et al., 1979). It is also pertinent that thernardite has been recorded as a common mineral in such cold desert environments as present-day Artarctica (Keys and Williams, 1981; Matsubaya et al. (1979) and Pleistocene Canada (Cole, 1926). Suess et al. (1982) have presented a convincing demonstration that glendonites are probably pseudomorphs of calcite after calcium carbonate hexahydrate. Large euhedral crystals of the latter are presently forming at sub-zero tempera-tures in organic-rich muds on the Antarctic Shelf. The analogy with the depositional environment of the Woody Island Siltstone is particularly appro-priate.

Palaeontology and age

The age of the Woody Island Siltstone cannot be directly determined within the Kingborough area but consideration of the evidence provided by its lateral equivalent the Quamby Mudstone gives an indirect age for the formation. A Stage 2 microflora occurs in *Tasmanites* shale near the base of the Quamby Mudstone of northern Tasmania (Clarke

and Farmer, 1976, Truswell, 1978). In a bore at Golden Valley in northern Tasmania (Clarke, 1968) the Quamby Mudstone contains a Stage 3a microflora towards the top and a Stage 2 microflora towards the base (Truswell, 1978). Since the Carboniferous-Permian boundary lies between Stage 2 and Stage 3 microfloras (Balme, 1980) then this boundary must occur in the lower half of the Quamby Mudstone. Lateral equivalence of the Quamby Mudstone and the Woody Island Siltstone would then suggest that the Carboniferous-Permian boundary lies in a similar position within the Woody Island Siltstone. The occurrence of *Streptorhynchus* sp. nov. and other fossils in the basal parts of the overlying Bundella Formation indicates that no part of the Woody Island Formation is younger than Early Tamarian (Faunizone 1).

(N.F.; M.J.C.]

BUNDELLA MUDSTONE (Pb)

The Bundella Mudstone was first named by Banks, Hale and Yaxley in 1955 and later defined by Banks and Hale (1957) from exposures in road cuts on the Lyell Highway [EN140667] in the neighbourhood of Mt Nassau.

The formation, as exposed, consists essentially of olive-green, brown, and grey weathering fissile and non-fissile, often richly-fossiliferous siltstone with subordinate sandstone members. The fossils are all marine and include among the more common forms (Banks and Hale, 1957) *Stenopora tasmani-ensis* Lonsdale, *Eurydesma cordatum* Morris and *Keeneia platyschismoides* Etheridge. Dropstones of varied composition occur throughout the sequence.

The type section has a minimum exposed thickness of 43 m and is immediately overlain by the Geiss Conglomerate, the basal unit of the freshwater Faulkner Group. The base of the Bundella Mud-stone is nowhere exposed in the type area being obscured by alluvium. No complete, well-exposed, structurally undisturbed section is known within the Hobart area (Leaman, 1976).

Information concerning the nature and thickness of the Bundella Mudstone can, however, be supplemented by means of a recent bore at Mt Nassau [EN515266] within the type area for the formation (Clarke and Farmer, 1982). This bore penetrated the whole of the Bundella Mudstone, which had a thickness of 117·5 m, and was overlain by the Faulkner Group dominantly of flaser-bedded, carbonaceous, and micaceous siltstone and sandstone beds, and underlain by dark grey, pebble-free, glendonitic siltstone of the Woody Island Siltstone. The contact of the Bundella

Mudstone with the overlying Faulkner Group is marked by a conspicuous, 250 mm thick, granule conglomerate with a siltstone matrix and numerous large (40 mm) pebbles. The boundary is abrupt.

Lithologically the Bundella Mudstone, as seen in the bore, consists of a fairly uniform sequence of fossiliferous, medium grey to dark grey, in places heavily bioturbated siltstone with more-sandy siltstone and patches of granule conglomerate scattered throughout. Thin (50–150 mm) bands of bioclastic limestone occur towards the base. Dropstones are common throughout and there is much disseminated pyrite. The rich fauna includes *Stenopora*, *Trigonotreta stokesi* Koenig, *Eurydesma*, *Ambikella*, *Strophalosia*, *Deltopecten illawarensis* (Morris) and crinoid fragments.

Extensive fossil collecting has established a characteristic and easily recognisable faunal assemblage for the Bundella Mudstone. Fossils are common to abundant at most localities and there are almost always sufficient elements of the fauna present to readily identify the formation. The characteristic elements include *Trigonotreta stokesi*, *Strophalosia subcircularis* Clarke, *Ambikella konincki* (Etheridge), *Pseudosyrinx allandalensis* Armstrong, *Eurydesma*, coarsely ribbed *Deltopecten* and a large species of *Keeneia* which reaches dimensions much greater than any found in the overlying formations. Other important fossils in the Bundella Mudstone include *Ambikella elongata* (McClung and Armstrong), *Phestia darwini* (de Koninck), *Schizodus australis* (Runnegar), *Merismopteria* sp., *Myonia elongata* Dana, *M. morrisi* (Etheridge), *Stutchburia* spp. *Peruvispira* sp., rare conulariids, *Stenopora tasmaniensis*, and a fairly wide range of fenestrate bryozoans. Ostracods are common in places and foraminifera are sometimes present.

The Bundella Mudstone can be traced southwards across the Hobart area into the country covered by the Kingborough map sheet where the formation is widely distributed and often well exposed. Some of the best exposed sections are found in the region centred on Cygnet [EN065210] where there are not only many inland exposures but also a number of excellently exposed coastal successions.

Lithologically the Bundella Mudstone in the Cygnet area consists mainly of hard, compact, massive to finely-laminated, mudstone, siltstone and sandy siltstone with subordinate fine-grained silty sandstone beds and a few, thin, coarser grained sandstone members. The mudstone and siltstone members of the succession are usually heavily bioturbated. Some of the beds have a speckled appearance. Where fresh the rocks are normally medium grey to dark grey but occasionally have a slight greenish tinge. Where weathered the colours are predominantly brown or buff. Some of the coarser sandstone members of the succession are cross-bedded and some of the fine sandstone units include alternations of laminated siltstone and sandy siltstone which give the beds a striped appearance. Dropstones occur frequently throughout the entire sequence and in places are abundant; there is great variety of both size and lithological type.

Disseminated pyrite occurs throughout the succession but is usually more closely associated with the mudstone element of the sequence. Some pyrite occurs along joints, and calcite joint infillings are fairly common.

Fossils form a conspicuous part of the succession, often occur in great profusion, and the more massive forms such as *Eurydesma* may make up a considerable part of some rock units.

Although there is some lithological variation within the Bundella Mudstone it is usually fairly minor in character and is largely confined to variation in bed thickness, fissility, and frequently repeated gradual transitions from mudstone to siltstone to sandy siltstone. Little or no lateral change in sedimentary rock type is observable. The overall effect is one of the widespread long-continued uniformity of sedimention with far less variation than is found in, for example, the overlying Deep Bay Formation. This overall uniformity together with a somewhat limited fauna and a fairly broadly uniform fossil distribution throughout the formation suggests slightly deeper water deposition than is found in the more lithologically varied higher Permian formations within the Kingborough region.

Despite the great amount of Bundella Mudstone exposed in the Cygnet area there is still some doubt as to the exact thickness of the formation since no complete, well-exposed, fault-free section is known and no bore penetrates the full thickness of the formation. The nearest approach to such a section occurs in the Tobys Hill Road area [EN088223] where field mapping suggests 80–100 m as a fair estimate of the thickness. As a result of faulting almost all other exposed sections lack either a top or a base or both.

The Bundella Mudstone is underlain conformably by the Woody Island Siltstone. The base of the Bundella Mudstone is clearly seen at Wheatleys Bay [EN018168] where it is marked by a prominent bed of coarse-grained sandstone. This sandstone marks the change from monotonous, poorly-fossiliferous pebble-free siltstone of the Woody Island Siltstone below to the comparatively lithologically more varied, highly fossiliferous, dropstone-rich sequence of mudstone, siltstone and sandstone above (plates 4,5). Fossils from the

Plate 4. *Richly fossiliferous Bundella Mudstone, Wheatleys Bay.*
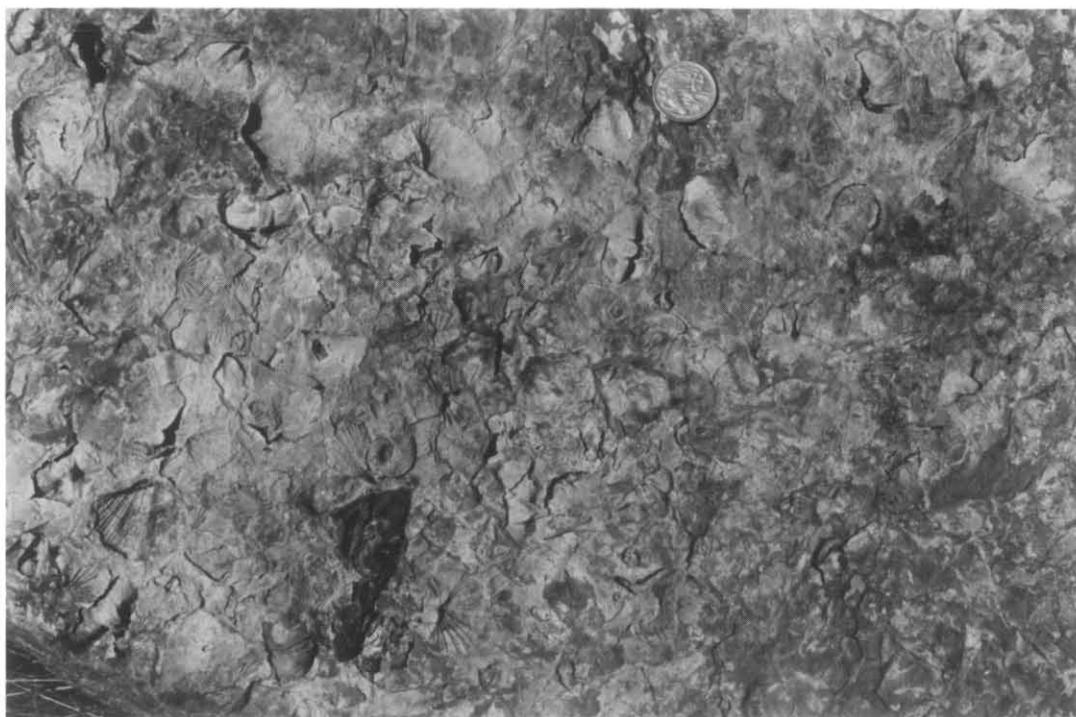
Plate 5. *Richly fossiliferous Bundella Mudstone, Wheatleys Bay. Bedding plane with abundant* Ambikella, Pseudosyrinx, Strophalosia, Trigonotreta, Deltopecten, Eurydesma, Keeneia *and others.*

coarser sandstone and siltstone beds towards the base of the formation include *Trigonotreta stokesi, Pseudosyrinx allandalensis, Ambikella elongata, Strophalosia, Eurydesma, Megadesmus pristinus* Runnegar, *Promytilus, Merismopteria*, coarsely ribbed *Deltopecten*, and rare specimens of *Streptorhynchus* sp. nov. Stenoporid and fenestrate bryozoans are fairly common. The presence of *Megadesmus pristinus* and *Streptorhynchus* sp. nov. indicates that the basal part of the succession is of Early Tamarian age.

The base of the Bundella Mudstone can again be seen at the tip of Green Point [EN076171]. Here the sedimentary rocks are highly baked and splintery as a result of syenite intrusions. The fauna is, however, still clearly recognisable as a typical Bundella Mudstone fauna and includes abundant *Streptorhynchus*.

Beds probably belonging to the very top of the Woody Island Siltstone can be seen on the north side of the tip of Green point. The remainder of the Green point peninsula is made of Bundella Mudstone rocks but they are relatively unbaked and deeply weathered with a consequently less well-preserved fauna.

On Silver Hill [EN035218] the base of the Bundella Mudstone is again marked by a prominent coarse-grained sandstone followed by a richly-fossiliferous mudstone-siltstone sequence with a characteristic Bundella Mudstone fauna.

On Tobys Hill Road beds very near the base of the Bundella Mudstone can be seen at [EN083219] where there are alternations of brown weathering, dropstone-rich, highly-fossiliferous, mudstone, siltstone and sandstone beds which yield *Megadesmus pristinus, Promytilus* and *Schizodus australis*.

Well-exposed, but incomplete, faulted and syenite-intruded sections of typical fossiliferous Bundella Mudstone occupy the coast from Wheatleys Bay [EN018168] to a point about 2 km west of Poverty Point [EN035154] and further syenite-intruded sections are found along the coast from north of Langdons Point at EN067183 to the northern side of Copper Alley Bay [EN062169].

Areas of inland exposure occur in roadcuts and as natural outcrops on the eastern slopes of Silver Hill at EN035218 and EN038224 and down the western flanks of Coads Hill from EN022212 to EN011217.

The section along Tobys Hill Road from EN085219 to EN090222 is fairly well exposed in road cuts and gutters alongside the road and in outcrops near the road. The Bundella Mudstone here consists of alternations of richly-fossiliferous brown and green-brown weathering siltstone and less fossiliferous, sometimes micaceous and feldspathic sandstone. Dropstones of varied composition are common throughout the succession. The fauna includes *Eurydesma cordatum*, coarsely ribbed *Deltopecten, Ambikella konincki, Trigonotreta stokesi, Strophalosia subcircularis, Pseudosyrinx allandalensis, Keeneia ocula* (J. Sowerby), *Peruvispira, Stenopora tasmaniensis*, and fenestellid bryozoans.

At Deep Bay [EN077149] a bore, NF75, encountered 87·4 m of Bundella Mudstone, mainly bioturbated siltstone and mudstone, but with minor fine- to coarse-grained, sometimes cross-laminated sandstone members. The sequence is fossiliferous throughout, contains frequent dropstones, and is pyritic (Farmer 1979*a*).

Where contact metamorphosed, either by dolerite or syenite, the rocks are much darker than where unaltered. This contrasts markedly with some of the higher formations of the Lower Parmeener Super-Group such as the Deep Bay Formation where baking followed by weathering usually gives a cream or pale grey colour to the rocks. Where intensely baked the rocks of the Bundella Mudstone Formation become greatly indurated and splintery and may assume a fine-grained appearance easily mistaken for fine-grained varieties of igneous rock. Highly baked rocks at [EN064191] and in the surrounding area were considered to be hybrid igneous rocks (Leaman and Naqvi, 1968) but the presence of a relict 'ghost fauna' of brachiopods clearly shows the true nature of the original deposit.

Other areas showing features of intense metamorphism are to be found at Green Point [EN076171], in a small quarry on Copper Alley Bay [EN062169], in roadside exposures on the Nicholls Rivulet Road at [EN126243] and in a large raft or block of Parmeener Super-Group rocks closely surrounded by dolerite at Lower Wattle Grove [DN995208].

Throughout the whole of the Cygnet district the Bundella Mudstone is everywhere overlain paraconformably by the Deep Bay Formation. Nowhere is there any evidence for the presence of the freshwater Faulkner Group so prominent in the Hobart area nor of the Hickman Formation or the Harts Hill Limestone of the Snug–Oyster Cove area. The absence of these formations clearly indicates a hiatus of some magnitude between the Bundella Mudstone and the Deep Bay Formation in the Cygnet area.

The absence of formations in this part of the stratigraphic column is borne out by a study of the

fossil evidence. In the Cygnet area extensive fossil collecting has yielded evidence for the presence of Early and Middle Tamarian faunas but there is no faunal evidence to confirm the presence of Late Tamarian beds which are missing from the Bundella Mudstone in this area. Further, nowhere in the Cygnet area are there any faunal elements indicative of the Bernacchian Stage and it is quite clear that beds of the Bundella Mudstone, as old as Middle Tamarian are immediately and paraconformably overlain by beds of the Deep Bay Formation which contain abundant fossils characteristic of the Early Lymingtonian Stage.

The physical relationship of the Bundella Mudstone to overlying beds can be seen on the foreshore at Lower Wattle Grove [DN995208] (plates 6,7) where baked fossiliferous siltstone of the Bundella Mudstone is immediately overlain by several metres of massive-bedded, pebbly, marine, granule conglomerate and coarse-grained sandstone rich in *Eurydesma*. These coarse sandstone beds are in turn overlain by a short sequence of siltstone and sandy siltstone beds which have yielded species of *Sulciplica* and other fossils typical of the Deep Bay Formation. The sandstone and granule conglomerate beds probably represent the basal inshore-marine beds of an onlap succession marking the local base of the Deep Bay Formation. The siltstone succession immediately below the coarse-grained sandstone sequence contains a fairly typical Bundella Mudstone fauna which includes *Trigonotreta stokesi, Eurydesma, Deltopecten* and *Keeneia*.

Stratigraphic relationships similar to those at Lower Wattle Grove were again proved in a borehole at Deep Bay [EN077149] where 58.8 m of fossiliferous Deep Bay Formation beds rest directly on fossiliferous Bundella Mudstone without the intervention of any beds attributable to either the Hickman Formation or the Harts Hill Limestone. Neither was there any possible representative of Faulkner Group rocks. The basal member of the Deep Bay Formation consists of unfossiliferous, striped and wavy-bedded mudstone and sandstone with lenses of cross-laminated sandstone. There are no dropstones in the basal member and the boundary with the underlying Bundella Mudstone is quite sharp.

The paraconformable relationship of the Bundella Mudstone with the overlying beds may persist for 10 km eastwards from Cygnet as far as the Nicholls Rivulet Road at [EN153262] not far from Underwoods Hill. At this point the paddocks immediately to the north of the road contain large blocks of *Eurydesma*-bearing coarse-grained sandstone, the possible lateral equivalents of the basal sandstone beds of the Deep Bay Formation as seen at Lower Wattle Grove. The lithological resemblance is so close as to appear identical and the blocks occupy a position between proved sequences of richly-fossiliferous Bundella Mudstone to the south of the road and light grey highly-fossiliferous bryozoan mudstone of the Deep Bay Formation to the north of the road.

From Nicholls Rivulet Road [EN153262] Bundella Mudstone outcrops, often syenite-intruded, can be followed in roadside exposures almost as far as Oyster Cove [EN186272], but owing to the presence of major faulting the relationship of the Bundella Mudstone to the overlying beds in nowhere seen.

This lack of surface information is remedied by two boreholes, NF78 at Palmers Road [EN180289] and NF79 on Snug Tiers at [EN181281]. Both bores began well above the Bundella Mudstone and went on to prove the complete stratigraphic sequence as far as the higher beds of the Bundella Mudstone. The stratigraphic sequence proved in the bores is different from that proved at Cygnet in that beds of the Hickman Formation conformably overlie the Bundella Mudstone in this area. The paraconformity present at Cygnet is no longer developed. The Hickman Formation contains, among other fossils, specimens of *Cancrinella farleyensis* (Etheridge and Dun) and *Trigonotreta hobartensis* (Brown), the presence of which clearly indicate a Bernacchian age. The relative abundance of *Cancrinella* strongly suggests an Early Bernacchian age.

The Bundella Mudstone sequence of the Nicholls Rivulet Road–Palmers Road area terminates eastwards against a steep-sided dolerite intrusion; a southward continuation of the Red Hill–O'Briens Hill dolerite complex. In the country to the east of this complex there are a number of separate isolated areas of outcrop of Bundella Mudstone. The southernmost outcrops occur in the neighbourhood of Woodbridge where at [EN181219] there is much bryozoan siltstone float and a few small outcrops of fossiliferous siltstone with *Trigonotreta stokesi* and a few other poorly-preserved spiriferids. Other small outcrops in the area occur along the roadside around [EN186209].

There is a small isolated outcrop of highly-fossiliferous Bundella Mudstone in small cliffs along the side of the creek at [EN190237] but its structural relationship to the surrounding rocks is unclear and may involve complex faulting.

Bundella Mudstone is again well-seen in a quarry about a kilometre south of the Oyster Cove crossroads at [EN195263] where the rock is highly indurated, dark grey and brown, splintery, procellanous bryozoan siltstone. The fossils are mainly fenestellids and stenoporids but include small spiriferids, some specimens of poorly-preserved

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Plate 6. *Disconformity between the Bundella Formation and the Deep Bay Formation, Lower Wattle Grove.*
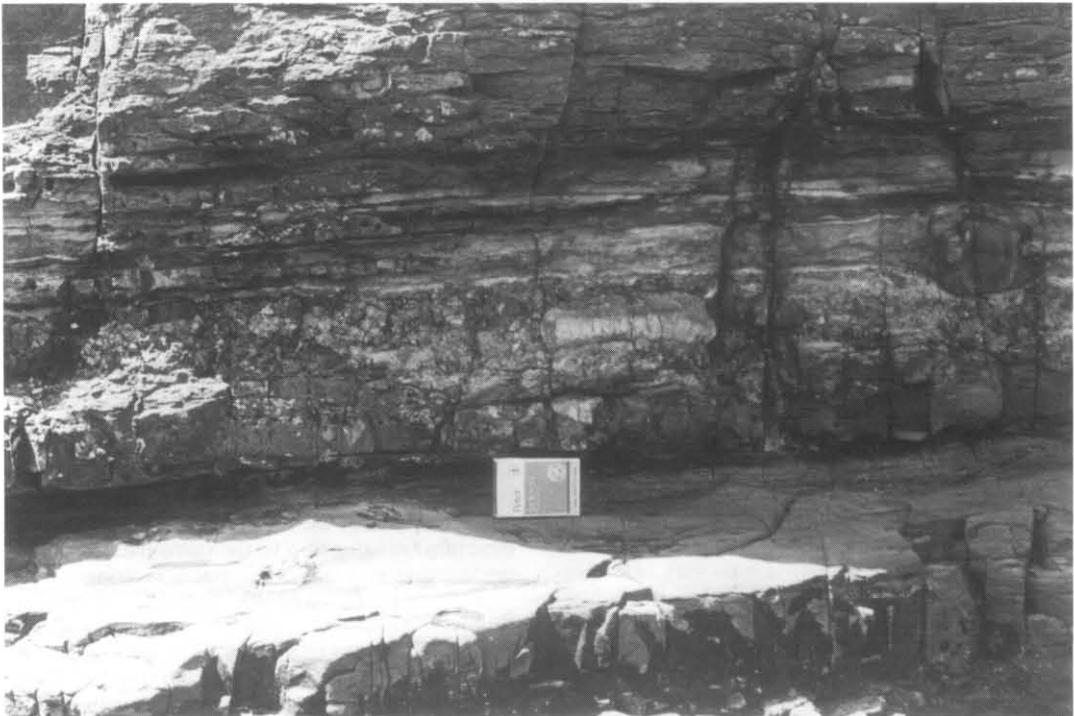
Plate 7. *Disconformity between the Bundella Formation and the Deep Bay Formation, Lower Wattle Grove.*

Eurydesma and fragments of *Deltopecten*. The beds dip steeply at 70° to the east and are underlain by fine-grained dolerite dipping 30–40° to the east. Coarser grained and fairly deeply rotted dolerite forms the western face of the quarry. In the eastern part of the quarry Bundella Mudstone is faulted against much lighter grey, heavily slickensided siltstone of the Deep Bay Formation.

The largest area of Bundella Mudstone to the east of the Red Hill dolerite complex is, however, that stretching from the Howden turn-off [EN221382] through the Harts Hill area [EN205345] to Snug Rivulet at [EN198310]. Roadside exposures in the vicinity of the Howden turn-off show several metres of highly-fossiliferous siltstone and sandy siltstone with slightly irregular rolling bedding. The outcrops contain a typical Bundella Mudstone fauna but faulting and the limited nature of the outcrops preclude exact location of the outcrops within the Bundella Mudstone sequence. Fossiliferous Bundella Mudstone can also be seen in the north-west corner of North West Bay [EN223374] where the prominent cliffs are constituted of rocks of this formation.

The base of the Bundella Mudstone, overlying a Woody Island Siltstone sequence, was encountered by a bore at Margate, NF87 [EN212363], and nearby creek sections in the Margate area provide outcrops within the main body of the formation.

The most significant information has, however, come from the Harts Hill area. Here a series of exploratory bores has provided definitive information on several formations. Two bores on Harts Hill, one at EN205342 and the other at EN203337 proved more than 40 m of the Hickman Formation resting conformably on Bundella Mudstone. A third borehole about 2 km south at [EN198319] proved a similar succession with 41 m of the Hickman Formation resting conformably on at least 26 m of Bundella Mudstone. The stratigraphic section in this area is the same as that at Palmers Road [EN180289] and Snug Tiers [EN181281]. The Bundella Mudstone of the Harts Hill area retains the characteristic lithology seen elsewhere in the Kingborough area and consists in the main of light grey to dark grey, brown weathering, bioturbate, fossiliferous, pyritic, laminated, massive or wispy bedded siltstone and sandy siltstone with some fine-grained sandstone layers. Dropstones are common throughout. The fauna includes the following: *Stenopora*, *Eurydesma*, *Deltopecten*, *Ambikella konincki*, *Trigonotreta stokesi* and *Keeneia*. Bryozoans are common and tend to dominate the fauna in terms of biomass. In places there is a considerable amount of comminuted shell debris.

In the Snug Rivulet area [EN198310] the Bundella Mudstone is fairly highly baked over most of its area of outcrop. The widespread baking which is evident at a great distance from any known dolerite contact suggests the presence of a flat-lying dolerite sheet not far below the present exposed surface.

The only other area of Bundella Mudstone of any size occurs towards the northern edge of the Kingborough sheet around Allens Rivulet [EN170385] where typical Bundella Mudstone lithologies and faunas are found in the creeks. Stratigraphic relationships are difficult to make out owing to the lack of suitable outcrop in critical localities.

Overall the Bundella Mudstone is remarkable for its widespread distribution, constant lithology, and abundant and easily recognisable fauna.

[N.F.]

Palaeontology and age

As noted previously, the Bundella Formation is richly fossiliferous at many horizons throughout. Forms present include:

> *Streptorhynchus* sp. nov.
> *Strophalosia subcircularis* Clarke
> *Strophalosia* sp. nov.
> *Ambikella elongata* (McClung and Armstrong)
> *Ambikella konincki* (Etheridge)
> *Notospirifer* sp. nov.
> *Pseudosyrinx allandalensis* Armstrong
> *Sulciplica* sp. nov.
> *Trigonotreta stokesi* Koenig
> *Fletcherithyris* sp.
> *Gilledia* sp.
> *Deltopecten illawarensis* (Morris)
> *Deltopecten waterfordi* Dickens
> *Etheripecten tenuicollis* (Dana)
> *Eurydesma cordatum* Morris
> *Eurydesma hobartensis hobartensis* (Johnston)
> *Megadesmus pristinus* Runnegar
> *Merismopteria* sp.
> *Myonia elongata* Dana
> *Myonia morrisi* (Etheridge)
> *Phestia darwini* (de Koninck)
> *Promytilus cancellatus* Maxwell
> *Schizodus australis* (Runnegar)
> *Stutchburia* sp.
> *Keeneia platyschismoides* Etheridge
> *Keeneia ocula* (J. Sowerby)
> *Peruvispira* sp.
> *Stenopora tasmaniensis* Lonsdale
> Fenestellids, colulariids, ostracods, foraminiferans.

The fauna of the main part of the formation is remarkably consistent in composition and can be

confidently assigned to the Middle Tamarian *cordatum* Zone. An abundance of *Strophalosia subcircularis, Ambikella konincki, Pseudosyrinx allandalensis, Trigonotreta stokesi,* coarsely ribbed species of *Deltopecten, Eurydesma* and large *Keeneia* is characteristic. Terebratulids are rare. At Wheatleys Bay [EN018168], Green Point [EN076171], Tobys Hill [EN083219], the coastal section to the south and west of Shag Point [EN064158], and Margate [EN212363] the basal few metres of the formation yield *Streptorhynchus* sp. nov., *Strophalosia* sp. nov., *Ambikella elongata, Megadesmus pristinus, Phestia darwini, Promytilus cancellatus* and *Schizodus australis.* The fauna indicates an Early Tamarian (Faunizone 1) age. At Green Point *Streptorhynchus* sp. nov. occurs in exceptional abundance in flinty hornfels. In the Harts Hill area [EN205342] and in a small quarry at [EN218377] near the northern margin of the map sheet the occurrence of *Notospirifer* sp. nov., *Sulciplica* sp. nov. and *Myonia elongata* indicates a Late Tamarian (Faunizone 3) age for the uppermost parts of the Bundella Formation. These parts are absent further to the south in the Cygnet area where a substantial paraconformity occurs between the Bundella Mudstone and the Deep Bay Formation.

[N.F.; M.J.C.]

FAULKNER GROUP

The Faulkner Group, of Banks and Hale (1957), consists of a number of thin, and probably imper-sistent, formations which have their stratotypes located on the northern flanks of Mt Faulkner around EN140540. The Faulkner Group is bounded by the Bundella Mudstone below and by the Rayner Sandstone above, and has a thickness of more than 30 m. As seen at outcrop the Faulkner Group consists mainly of a variable succession of conglomerate, pebbly sandstone, coarse quartz siltstone, flaggy micaceous siltstone, and sandstone. Carbonaceous siltstone, occasional plant fragments and scraps of coaly material are sometimes seen.

A recent borehole in the type area, at Mount Nassau [EN515266], penetrated the entire thickness (36·6 m) of the succession. The sequence is dominantly composed of dark grey to black, carbonaceous and micaceous siltstone with sub-ordinate light grey and dark grey irregularly bedded and striped quartzose siltstone and sandstone beds. Many of the siltstone units show hydroplastic deformation and there is much small-scale bio-turbation. Comparatively well-sorted sandstone and sandy siltstone units with pebble bands at the base are fairly frequent and highly-bioturbated speckled siltstone with dispersed granules is a common lithology.

The general absence of marine fossils in the Faulkner Group and the presence of coal and other carbonaceous material indicates transitional terres-trial, probably freshwater, deposition for some of the sequence but rolled and abraded umbonal fragments of *Eurydesma* and the presence of much finely comminuted shell debris at some horizons suggests marginal marine deposition in a shallow-water high-energy environment for at least part of the succession.

The Faulkner Group can be traced through the Hobart area southwards as far as Lower Sandy Bay [EN285475] beyond which it has no proven exist-ence. A number of boreholes in the Snug–Oyster Cove area failed to find any beds lithologically similar to the Faulkner Group though several bores passed through its expected stratigraphic position.

Further to the west, in the Cygnet area, three areas of supposed Faulkner Group rocks have previously been recorded (Leaman and Naqvi, 1968).

The first of these areas was located on the western slopes of Balfes Hill [EN053247]. The succession here is known to span beds ranging from the Minnie Point Formation through the Risdon Sand-stone to the Abels Bay Formation. Confirmation of a late Permian (Late Lymingtonian) age for the beds comes from the presence of a fauna with *Echinalosia ovalis* (Maxwell), *Terrakea brachy-thaera* (Morris), *Sulciplica transversa* Waterhouse and *Vacunella curvata* (Morris) only a few metres below the Risdon Sandstone. This succession, therefore, undoubtedly belongs towards the top of the Permian sequence and cannot in any way represent any part of the Faulkner Group.

A second area of supposed Faulkner Group rocks was located to the north of Deep Bay around [EN087164]. Roadcuts and small outcrops have, however, yielded fenestellid bryozoans completely out of keeping with a non-marine or even marginal marine origin expected for the rocks of the Faulkner Group. Lithologically the rocks closely resemble deeply weathered siltstone of the Deep Bay Formation.

The third area of reputed Faulkner Group rocks was mapped as lying immediately above the Bundella Mudstone in the Tobys Hill area [EN091222]. More recent investigation has failed to substantiate the presence of any rocks which could be assigned to this group.

If further evidence of absence is required this is provided by a borehole at Deep Bay [EN077149] and the stratigraphic section spanning the Bundella Mudstone-Deep Bay Formation interval at Lower Wattle Grove [EN995208]. Both these successions span the stratigraphic interval in which the Faulkner

Group must lie if present. Both failed to show any evidence of its presence.

In summary it can be said that nowhere in the area covered by the Kingborough map sheet is there any evidence for the presence of the Faulkner Group and that in many places it can be shown without doubt to be absent.

[N.F.]

HICKMAN FORMATION (Ph)

The Hickman Formation, here defined, takes its name from Hickman Road [EN203343] which runs along the western side of Harts Hill. The stratotype is located in the Harts Hill No. 1 Bore (NF 76 on the Kingborough map sheet) at [EN205342] the core from which is housed in the core library of the Tasmania Department of Mines. The formation has a thickness of 40 m in the type section, and consists of alternations of a variety of lithologies ranging from black, unfossiliferous, micaceous, pyritic mudstone through calcareous, marine fossiliferous, bioturbated siltstone and fine-grained, wispy-bedded, hydroplastically-deformed, silty sandstone to medium- and coarse-grained massive-bedded, poorly-sorted, quartzose sandstone. Pebble and granule conglomerate, usually with a sandy matrix, is interspersed through siltstone beds with much comminuted shell debris. Dropstones are present throughout much of the sequence. Parts of the succession are highly fossiliferous and contain a varied marine fauna. The fauna is characteristically dominated by Cancrinella farleyensis *(Etheridge and Dun). Although* Cancrinella *ranges into beds stratigraphically higher than the Hickman Formation nowhere does it occur in anything like such great profusion and this abundance serves to characterise the formation.*

The Hickman Formation conformably overlies the Bundella Mudstone and is conformably overlain by the Harts Hill Limestone. Faunal evidence suggests assignment to the Early Bernacchian Stage (Clarke and Farmer, 1976; Clarke, in Clarke and Baillie, 1984).

The Hickman Formation derives its name from Hickman Road which runs along the western side of Harts Hill [EN203343] where massive, grey and buff weathering, siltstone beds of the formation are somewhat indifferently exposed in the roadside gutters. Exposure is everywhere poor but the position of the formation on Harts Hill can be delineated by means of blocks of *Cancrinella*-bearing siltstone float scattered in profusion over the hillside as high as the base of the Harts Hill Limestone.

Poor outcrop is to some extent compensated for by information provided by bores. A section in one of these bores, Harts Hill No. 1 Bore (NF 76 on map) at [EN205342] has been chosen as the stratotype. In the type section the Hickman Formation is conformably overlain by the highly fossiliferous bioclastic calcarenite of the Harts Hill Limestone and conformably underlain by the Bundella Mudstone which usually contains forms such as *Trigonotreta stokesi* and *Ambikella konincki* in sufficient numbers for ready identification of beds.

In the type section the Hickman Formation has a thickness of 40 m and consists of a variety of lithologies some of which may be repeated. The following major lithological types are present in the sequence: dark pyritic mudstone; massive grey, bioturbated, fossiliferous siltstone; unfossiliferous micaceous siltstone alternating with irregular granule conglomerate layers and patches; fairly uniform wispy-bedded siltstone; fine-grained, silty sandstone; medium- to coarse-grained, poorly-sorted quartz sandstone; pebble and granule conglomerate with an irregular sandstone matrix. Details of individual beds and their thicknesses can be obtained from the bore record (Farmer, 1979*d*).

Scattered marine fossils throughout most of the succession together with the presence of fairly numerous dropstones indicate a marine environment of deposition for the sequence. The presence of large quantities of broken and rolled shell material at many horizons suggests relatively shallow water conditions as does the presence, in both sandstone and siltstone, of many unornamented smooth-shelled *Bairdia*-like ostracods. Paucity of quiet-water bryozoan species may also indicate turbulent high-energy shallow water conditions of deposition.

Fossils in the Harts Hill No. 1 Bore are well preserved and include the following: *Cancrinella farleyensis*, *Wyndhamia dalwoodensis* Booker, *Ambikells ovata* (Campbell), *Sulciplica*, *Deltopecten*, *Etheripecten*, *Stutchburia*, *Streblopteria*, many specimens of juvenile *Peruvispira* and some crinoid debris. Fragments of *Gangamopteris* were also observed.

A second borehole at [EN203337] a little further south along the crest of Harts Hill also proved the full thickness of the Hickman Formation, here lithologically similar to that in the Harts Hill No. 1 Bore but with a slightly increased thickness of 42 m. A fauna similar to that in Harts Hill No. 1 was obtained but with the addition of *Eurydesma*.

Collection of the fauna from Hickman Formation outcrops along the lower slopes of Harts Hill [EN203343] has yielded a larger, more varied and much more representative fauna than that provided by the type section in the bores.

The fauna, both in the boreholes and at outcrop, is dominated by *Cancrinella farleyensis* which occurs in great profusion. Although *Cancrinella* continues on into higher parts of the succession nowhere does it occur in such great abundance and this abundance together with the total absence of *Terrakea*, in lithologies where *Terrakea* would be expected to occur, almost certainly places the fauna of the Hickman Formation within the Early Bernacchian Stage (Clarke and Farmer, 1976).

The only other clearly exposed beds of the Hickman Formation occur 2 km south of Harts Hill at [EN200319] where very poorly-fossiliferous mottled sandy siltstone is exposed in a low roadside cutting. About 50 m uphill to the west there is much cream weathering siltstone float rich in *Cancrinella farleyensis*. At this same locality buff weathering siltstone torn from outcrop by the roots of overturned trees are also extremely rich in *Cancrinella* and undoubtedly indicate the presence of beds belonging to the Hickman Formation.

A bore (NF 80, [EN198319]), located above the *Cancrinella* beds, passed through 51·7 m of beds which could perhaps belong to the Hickman Formation but some doubt must remain as to the assignment of the top 10 m of this bore from which there was poor recovery. The upper part of the succession, to a depth of 30 m, is mainly grey, fossiliferous, bioturbated siltstone darkening down-wards and at the same time becoming less fossili-ferous. Disseminated pyrite is fairly common in this part of the sequence. The lower part of the succession consists of mottled, dark grey, heavily bioturbated siltstone with comminuted shell debris and some dropstones. This lower part of the succession closely resembles the mottled siltstone in the roadcuts lower down the hill at EN200319. The bore continued on to show the Hickman Formation resting without any apparent break on the Bundella Mudstone below.

The somewhat ill-defined Snug Stage of Lewis (1946), which immediately underlies the Berriedale Limestone and its correlates has its type area in this vicinity on Snug Falls Road, possibly around [EN195310], and it may be that part or all of the Snug Stage falls within the bounds of the Hickman Formation though from the description given it could be that the Snug Stage also includes part of the underlying Bundella Mudstone which is also exposed in this area.

The only other information concerning the Hickman Formation as developed within the Kingborough area is provided by two boreholes, one at Snug Tiers [EN180289], and the other at Palmers Road [EN181281].

The Snug Tiers bore proved a long sequence of Parmeener Super-Group strata among which is the Hickman Formation with a thickness of 30·5 m and, so far as can be seen from a borehole, conformably overlain by the Deep Bay Formation, and underlain, also conformably by the Bundella Mudstone. Lithologically the formation consists of beds ranging from black, unfossiliferous, laminated mudstone through mottled, bioturbated, siltstone with much dispersed granular material and shell debris to beds of alternating siltstone and cross-bedded fine-grained grey sandstone. Detailed thicknesses and lithologies for the individual beds can be obtained from the original record (Farmer, 1979g).

The Palmers Road bore at [EN181281] proved 42 m of Hickman Formation beds resting on fossili-ferous Bundella Mudstone. Rocks of the Hickman Formation consist almost entirely of siltstone and sandy siltstone with a few, thin, granule conglom-erate beds. Much of the sequence is fossiliferous and bioturbated and some parts show conspicuous hydroplastic deformation. Small dropstones are fairly common and there are some pyrite segrega-tions. Fossils retrieved from the bore include species of *Cancrinella*, *Fletcherithyris*, *Wyndhamia*, *Megadesmus*, *Etheripecten*, *Peruvispira* and a limited quantity of bryozoan material.

To the south and west of the Palmers Road area nothing further is known of the Hickman Formation and at Cygnet and the surrounding area the formation is clearly absent since the Early and Middle Lymingtonian Deep Bay Formation rests paraconformably on the Early and Middle Tamarian Bundella Mudstone.

To the north of the area covered by the King-borough map sheet there is a little more information. *Cancrinella*-rich gritty sandstone beds and siltstone beds are known from the Whitewater Creek area south of Kingston (Clarke and Banks, 1975) but the area is structurally much broken by block faulting and the stratigraphic relationships of the beds are still unknown.

Comparison of the Hickman Formation as found in the Harts Hill area with the Nassau Siltstone as proved in the Mt Nassau bore (Clarke and Farmer, 1982) shows a very close lithological similarity between the Nassau Formation and the Hickman Formation and there seems little doubt that the Nassau Formation is the part equivalent of the Hickman Formation.

Recent investigation of faunas towards the base of the Hickman Formation in its type area [EN205342] has revealed the presence of *Ambikella branx-tonensis* (Etheridge) for the first time in Tasmania. This indicates the presence of the *branxtonensis*

Zone (Lower Farley Formation) of the Sydney Basin (Runnegar and McClung, 1975). Hitherto, marine equivalents of the *branxtonensis* Zone have been unknown in Tasmania where they are largely represented by non-marine, or at best marginally marine strata of such units as the Faulkner Group, Liffey Sandstone and Mersey Coal Measures (Clarke and Farmer, 1976).

Consideration of all the evidence available suggests that the Hickman Formation in the Harts Hill area is in part the lateral equivalent of the Nassau Formation and the presence of *Ambikella branxtonensis* suggests that the basal part probably contains the time equivalents of the Faulkner Group. The thin (3 m) massive-bedded, coarse-grained sandstone and granule conglomerate of the Rayner Sandstone which immediately underlies the Nassau Formation is unknown at Harts Hill but a unit of this thickness and nature might well be expected to be laterally impersistent and any lateral equivalents of this formation could well lie within the apparently unbroken Hickman Formation succession.

In conclusion it should be noted that the Hickman Formation includes the probable correlates of the Nassau Formation and the Rayner Sandstone as well as the probable marine time equivalents of the essentially non-marine Faulkner Group.

Palaeontology and age

The Hickman Formation yields a rich and well-preserved fauna. Forms present include:

> *Cancrinella farleyensis* (Etheridge and Dun)
> *Echinalosia preovalis* (Maxwell)
> *Wyndhamia dalwoodensis* Booker
> *Ambikella branxtonensis* (Etheridge)
> *Ambikella ovata* (Campbell)
> *Notospirifer* sp. nov. A. aff. *hillae* Campbell
> *Notospirifer* sp. nov. B. — a coarsely plicate form
> *Sulciplica stutchburii* auctt.
> *Trigonotreta cracovensis* (Wass)
> *Trigonotreta hobartensis* (Brown)
> *Fletcherithyris farleyensis* (Etheridge)
> *Fletcherithyris parkesi* Cambell
> *Gilledia* sp.
> *Atomodesma (Aphanaia)* sp.
> *Deltopecten squamuliferus* (Morris)
> *Etheripecten farleyensis* (Etheridge)
> *Etheripecten* sp.
> *Eurydesma hobartensis hobartensis* (Johnston)
> *Megadesmus gryphoides* (de Koninck)
> *Megadesmus nobilissimus* (de Koninck)
> *Merismopteria* sp.
> *Myonia elongata* Dana
> *Promytilus* sp.
> *Streblopteria* sp.
> *Stutchburia* sp.
> *Undopecten fittoni* (Morris)
> *Keeneia ocula* (J. Sowerby)
> *Keeneia*? sp. nov. — a form with coarse frilly ornament
> *Peruvispira* sp.
> *Mooreoceras* sp.
> *Paraconularia derwentensis* (Johnston)
> Fenestellids
> *Stenopora* spp.
> Smooth ostracods
> Wood

The overall composition of this fauna clearly demonstrates a Bernacchian age (Clarke and Farmer, 1976). Furthermore the conspicuous absence of the linoproductid *Terrakea* and the aulostegid *Taeniothaerus*, in lithologies in which they would be expected to occur, strongly suggests an Early rather than Late Bernacchian age. The occurrence of *Ambikella branxtonensis*, which is recorded for the first time in Tasmania, from the lower part of the formation, followed by *Ambikella ovata* in its upper part, indicates a firm correlation with the succession of faunas in the Sydney Basin Farley Formation (Runnegar and McClung, 1975). These distributions demonstrate that both Subzone 4a and Subzone 4b (Clarke *in* Clarke and Baillie, 1984) of the Early Bernacchian Stage are represented within the Hickman Formation. Elsewhere in Tasmania the earliest Bernacchian is usually represented by non-marine rocks. *Notospirifer* aff. *hillae* and *Myonia elongata* are known from Late Tamarian beds on Maria Island, and in the Beaconsfield and Lake River areas of northern Tasmania, and further demonstrate the continuity of marine sedimentation between the Tamarian and Bernacchian Stages. *Fletcherithyris parkesi* and *Megadesmus nobilissimus* are both recorded for the first time below the base of the Lymingtonian Stage.

In summary the Hickman Formation represents the age equivalents of the Faulkner Group-Nassau Formation interval in the Mt Nassau, Granton area, and the Boullanger Formation-Skipping Ridge Formation interval on Maria Island.

[N.F.; M.J.C.]

HARTS HILL LIMESTONE (Pl)

The Harts Hill Limestone, here defined, takes its name from Harts Hill [EN205343] about 2 km south-west of Margate where it forms a very poorly-exposed capping along the crest of the hill. The stratotype is composite and is located in the Harts Hill No. 1 Bore (NF 76 on the Kingborough map sheet) [EN205342] and the Harts Hill No. 2

Bore (NF 77 on the Kingborough map sheet) [EN204340], the cores from which are housed in the core library of the Tasmanian Department of Mines. The formation consists of 16–30 m of buff weathering, pale grey and dark grey, richly-fossiliferous, bioclastic, lutite and arenite grade limestone interbedded with subordinate dark-grey to black, calcareous and sandy bioturbated siltstone, and minor shaley partings. Dropstones are present but they are not particularly common; generally they are pebble-sized with rare cobbles. The formation overlies the Hickman Formation conformably, and is followed by the Deep Bay Formation with apparent conformity. Faunal evidence demonstrates a Late Bernacchian (Faunizone 5) age for the Harts Hill Limestone.

The Harts Hill Limestone derives its name from Harts Hill [EN205343] about 2 km south-west of Margate where it forms a very poorly-exposed capping along the crest of the hill. The formation consists of 16–30 m of buff weathering, pale grey and dark grey, richly-fossiliferous, bioclastic, lutite and arenite grade limestone interbedded with subordinate dark-grey to black, calcareous and sandy bioturbated siltstone, and minor shaley partings. Dropstones are present, but they are not particularly common; generally they are pebble-sized with rare cobbles. The Harts Hill Limestone conformably overlies the Hickman Formation, and is followed by the Deep Bay Formation with apparent conformity.

No real outcrop of the limestone occurs but the crest of the hill is occupied by numerous scattered blocks of limestone as large as 700 mm in diameter. The distribution of the boulders and soil type gives a reasonably accurate indication of the distribution of the formation. Because of the elevated position of the outcrop, the limestone has been weathered deeply to a soft friable marl, which in places, forms a cap of appreciable thickness over the solid rock. The depth of the marl varies considerably from place to place as it forms pockets in the unweathered limestone. At one time a small quarry was worked at the northern extremity of the ridge. Here the deposit is a random jumble of very highly-weathered and rotten blocks which may represent a sink hole or spelean deposits possibly formed as a result of Tertiary weathering.

Harts Hill No. 1 Bore proved a sequence 30·05 m in thickness consisting predominantly of light grey and dark grey, buff weathering bioclastic calcarenite with thin calcareous mudstone and bryozoal mudstone, interbedded with dark-grey to black siltstone and laminated siltstone. Dropstones are sparse in the core. The base of the formation is gradational and is placed at the base of the first substantial bed of limestone which is 650 mm in thickness. Fossils are abundant and forms identified include *Cancrinella farleyensis, Terrakea, Wyndhamia dalwoodensis, Ambikella, Sulciplica tasmaniensis, Trigonotreta hobartensis, Deltopecten, Etheripecten, Eurydesma, Peruvispira*, fenestellids and *Stenopora*. Smooth ostracods are abundant at several horizons.

Harts Hill No. 2 Bore proved a thickness of 16·34 m of the Harts Hill Limestone between the Deep Bay Formation above, and the Hickman Formation below. Both its lower and upper boundaries are transitional and apparently conformable. Lithologies and fossils are essentially similar to those developed in the Harts Hill No. 1 Bore. The information provided by these two bores demonstrates a very rapid, lens-like, lateral thinning and transition which accounts for the failure of the limestone to appear elsewhere in the neighbourhood. In addition, a few kilometres to the south and south-west, bores at Snug [EN198319], Palmers Road (NF 79) [EN181281], and Snug Tiers (NF 78) [EN180289], demonstrate the absence of the Harts Hill Limestone and a reduced thickness of the underlying Hickman Formation, probably because of the northward overstep of the Deep Bay Formation (fig. 2).

Fossils are abundant in the Harts Hill Limestone but are not easily extracted. *Taeniothaerus subquadratus* (Morris) has not been recorded but the combined presence of *Ambikella ovata, Cancrinella farleyensis* and the linoproductid *Terrakea* demonstrates a Late Bernacchian (Faunizone 5) age. The Harts Hill Limestone lithologically resembles and is of the same age as the Berriedale Limestone of the Granton–Berriedale–Glenorchy area. Lateral continuity, however, has not been established. A recent fully-cored bore at Mt Nassau (Clarke and Farmer, 1982) demonstrated the absence of the so-called Grange Mudstone in the type section of the Cascades Group (Banks and Hale, 1957), and until such time as the detailed stratigraphical relationships are established through the Hobart area, separate nomenclature is preferred for the Harts Hill area.

Analyses of four samples of limestone from Harts Hill showed calcium carbonate contents of 72·4 to 81·7%, and an analysis of the decomposed marl contained 77% calcium carbonate (Hughes, 1957).

Palaeontology and age

Fossils are abundant throughout the Harts Hill Limestone but they are difficult to extract from the surface blocks and limestone developments in the bore core. Leached siltstone intervals in the cores are more satisfactory. Forms identified include:

> *Cladochonus nicholsoni* (Etheridge)
> *Euryphyllum* sp.

Terrakea sp.
Wyndhamia dalwoodensis Booker
Ambikella ovata (Campbell)
Sulciplica tasmaniensis (Morris)
Trigonotreta hobartensis (Brown)
Deltopecten limaeformis (Morris)
Etheripecten sp.
Eurydesma hobartensis hobartensis
    (Johnston)
Megadesmus nobilissimus (de Koninck)
Peruvispira sp.
Fenestellids
Stenopora spp.
Ostracods, crinoid debris

This assemblage with the combined presence of *Ambikella ovata, Sulciplica tasmaniensis, Trigonotreta hobartensis* and the linoproductid *Terrakea* indicates a Late Bernacchian (Faunizone 5) age despite the apparent absence of the zonal index *Taeniothaerus subquadratus. Terrakea* is unknown below the Late Bernacchian in Tasmania, and *Ambikella ovata* is replaced by *Ambikella plana* (Campbell) in the uppermost beds of the stratotype on Maria Island (Clarke, *in* Clarke and Baillie, 1984). Much more varied Late Bernacchian faunas occur in the Berriedale Limestone of the Granton–Berriedale–Glenorchy area, in limestone developments on Forestier Peninsula (Gulline, 1982), Maria Island (Clarke and Baillie, 1984), and at many localities in north-eastern Tasmania.

[N.F.; M.J.C.]

DEEP BAY FORMATION (Pd)

The Deep Bay Formation, here defined, takes its name from Deep Bay, Port Cygnet [EN085155]. The stratotype is composite and consists of the shore sections exposed between EN085153 and EN073143, and the Deep Bay Bore (NF 75) [EN077149] the core from which is housed in the core library of the Tasmania Department of Mines. The formation has a thickness of 102 m in its type section and consists essentially of alternations of thin- to medium-bedded, poorly-sorted, indurated siltstone, fine-grained sandstone and subordinate mudstone, with occasional thin, impersistent pods and stringers of feldspathic granule conglomerate, and shaley partings. Bioturbation is frequently present and compact, laminated bryozoal siltstone is prominent at certain intervals. The basal few metres consist of coarse-grained sandstone, conglomerate and granule conglomerate with subordinate flaser-bedded, striped mudstone and siltstone with lenses of cross-laminated sandstone. Thin, impersistent developments of impure limestone occur at Silver Hill [EN021233]. Dropstones are abundant throughout. Most of the formation is richly-fossiliferous and preservation is excellent.

In its type section and throughout the Cygnet area the Deep Bay Formation rests paraconformably on an incomplete Bundella Formation. To the north and north-west, however, the formation progressively oversteps the uppermost parts of the Bundella Formation, the Hickman Formation and the Harts Hill Limestone. It is overlain conformably by the Minnie Point Formation. Faunal evidence demonstrates an Early to Middle Lymingtonian age (Faunizones 6–8) for the Deep Bay Formation.

The Deep Bay Formation derives its name from Deep Bay, Port Cygnet where most of the sequence is exposed in a series of excellent shore platform and cliff sections. Although the lowermost part of the formation is nowhere exposed in this area, the deficiency is essentially remedied by a fully cored bore (NF 75) [EN077149] which was collared a few metres above the lowest exposed beds. The lithological sequence encountered in the bore agrees closely with an exposed shore platform section at Lower Wattle Grove [DN995208] and developments elsewhere. In this account the lithological and palaeontological characters of the Deep Bay sections are somewhat generalised as in the previously published account of Clarke and Banks (1975) and Clarke and Farmer (1976). Dr Farmer's detailed measured sections are tabulated in Appendix 1, and details of the Deep Bay Bore are given in Farmer (1979*a*).

Throughout the main part of the Deep Bay section the rocks maintain a very consistent strike, and dip uniformly at low angles to the south-east. The stratigraphically lowest beds occur at low water at the unnamed point at EN078152. From here southwards the middle and upper parts of the Deep Bay Formation occur in unbroken sequence as far as the base of the Minnie Point Formation [EN073143] where a small fault repeats a few metres of the succession. Exposure is virtually continous except for small gaps on the shore platform caused by seasonal variations in deposits of shore sand and gravel. Complementary exposure in the low cliffs behind the shore platform demonstrates the absence of faulting.

The lowest 7–8 m of beds exposed consist of alternations of thin- to medium-bedded, medium grey and brown, light weathering, hard, indurated fine-grained sandstone with subordinate softer siltstone and minor shaley partings (plate 8). Beds range in thickness from 150 mm to 600 mm but are typically 250–300 mm thick. Some beds are bioturbated, and others are laminated. Sorting is poor, and impersistent pods and stringers of sand- and granule-sized detritus are common. Dropstones are abundant. They are typically of pebble and cobble size. The largest seen has a maximum dimension of 350 mm. Compositionally they are

Plate 8. *Deep Bay Formation, Deep Bay. The base of the exposed section.*

mostly quartzite, but vein quartz, black and grey slate and igneous rocks also occur. Fossils are abundant and well preserved. Many are entire, but some are broken and fragmented. Particularly characteristic are large numbers of articulated *Megadesmus gryphoides*, smooth ostracods and clusters of the small gastropod *Peruvispira*, the latter in the impersistent coarser-grained pods and stringers. *Deltopecten, Etheripecten, Eurydesma, Myonia, Streblopteria, Stutchburia, Echinalosia, Wyndhamia*, a variety of spiriferids, terebratulids, fenestellids and *Stenopora* are also common.

These beds are overlain by about 6 m of pale grey, massive, unbedded *Stenopora* mudstone and fine siltstone. Large branching colonies of *Stenopora* occur in profusion. Fenestellids are also common and *Eurydesma* and *Sulciplica* are present. The mudstone and fine siltstone which occupies the interstices within the *Stenopora* framework frequently shows hydroplastic and other soft sediment structures. It is possible that the bryozoal framework served as a sediment trap during an interval of low energy sedimentation. The base of the bed is sharp but gently undulates, probably through differential compaction. Dropstones were not observed.

The following 21 m of beds consist of medium grey to buff and cream coloured, fissile and non-fissile siltstone interbedded with subordinate light grey,

fine-grained sandstone. The fine-grained sandstone and much of the siltstone is tough and indurated, and sometimes has a porcellanous appearance. In places the siltstone is deeply weathered and is soft and friable. These deeply weathered intervals range in colour from mottled grey and buff through reddish orange to very ochreous. Bioturbation is prominent in some beds, whereas others are distinctly laminated with layers of fenestellid bryozoans. Bedding is thin to medium. Sorting is generally poor, and irregular pods and stringers and dispersed grains of coarser-sand and granule-sized detritus are often present in the siltstone intervals. Pebble- and cobble-sized dropstones of quartzite and slate occur throughout and are abundant at several levels. Fossils are also abundant throughout. Complete specimens are not uncommon but most are broken and disarticulated. Strophalosiids sometimes occur in growth position. The commoner forms include fenestellids, *Stenopora*, strophalosiids, *Terrakea*, a variety of spiriferids including fasciculate forms, *Sulciplica, Ambikella, Notospirifer* and *Punctospirifer*, terebratulids, *Astartila, Megadesmus, Myonia*, pectenids, *Schizodus, Streblopteria, Stutchburia, Keeneia* and *Peruvispira*. *Eurydesma* is reasonably common at the base of this sequence but is relatively rare towards the top.

The next 20 m of beds consist of alternations of grey, buff and brown, very fine- to medium-grained

sandstone with subordinate hard, compact or softer, fissile, friable siltstone. Bedding is thin to medium. Weathering colours range from creamish grey, through reddish orange to darkly ochreous. Mottling occurs in places and some of the sandstone beds have a rubbly appearance. Worm burrows and other bioturbation structures are commonly present. Sorting is generally poor and irregular pods and stringers are characterised by small, glassy quartz granules and small pebbles of quartzite and black slate. Larger pebble- and cobble-sized dropstones are present throughout and occur in some abundance at several horizons. Fossils are also abundant in most beds. Complete specimens are not uncommon, but much of the material is broken and comminuted. The bellerophont monoplacophoran *Warthia* occurs for the first time, *Promytilus* is particularly common and rare michelinoceratid nautiloids are also present. *Eurydesma* has not been recorded above the basal few metres of this unit, whereas *Deltopecten* remains abundant.

The uppermost 8 m of the Deep Bay Formation consist of hard, grey, buff weathering siltstone and sandy siltstone with bands of more pebbly sandstone at the base, followed by medium grey to dark grey, laminated fenestellid siltstone. The latter is friable when weathered and has thin, soft sandy beds in places; and near its top, thin irregular ribs of harder siliceous siltstone have a flaggy appearance. The topmost unit consists of brown and buff coloured, laminated siltstone and sandy siltstone which becomes markedly sandier towards the top. Dropstones are conspicuous. Fossils both complete and much broken are abundant and include fenestellids, strophalosiids, spiriferids, terebratulids, pectenids, *Myonia* and gastropods.

East of the unnamed point at EN078152 where the lowermost beds are exposed, part of the sequence is repeated. This is not due to faulting but is caused by the form of the shoreline relative to the strike of the beds. Exposure is excellent and superior to that of the equivalent stratigraphic interval south of the point. Overall lithological characters are basically similar but a detailed bed by bed comparison of the two sections indicates significant variations in thickness and rock type (see Appendix 1). The prominent *Stenopora* horizon is well displayed in the lower part of the cliff at EN080152. Towards the eastern end of the section abrupt changes in strike and much steeper dips are clear evidence of faulting. Exposure is terminated by beach sand and gravel and Tertiary silcrete at Elizabeth Point [EN085152].

The lowermost parts of the Deep Bay Formation were proved in a bore (NF 75) [EN077149] where the Bundella Formation was encountered at a depth of 53·28 m (Farmer, 1979a). The basal bed of

the Deep Bay Formation is 460 mm thick and consists of medium grey, striped and flaser-bedded silty mudstone and siltstone. The rock consists of grey mudstone, with thin (up to 10 mm but mainly 2·5 mm thick) laminations and lenses of cross-laminated sand grade material. Pebbles and fossils are absent. About 10% of the rock overall is composed of sand grade material. The boundaries with the beds above and below are sharp. Then follows about 3 m of medium to dark grey siltstone with pebbles, cobbles and much granule-sized material which gives the rock a speckled appearance. A fragment of *Stenopora* occurs at 51·72 m, and 700 mm of very coarse-grained, pebbly sandstone with abundant spiriferid and other shell debris occurs from 52·12 m. Bioturbation occurs throughout. Then follow about 37 m of thin- to medium-bedded siltstone with minor mudstone. The colour ranges from medium to dark grey. Some beds are massive and of uniform lithology with few pebbles and rare fossils. Others are more variable with much bioturbation and irregular pods and stringers of coarser-grained, granule-sized material and abundant pebbles. Fossils are abundant in these beds and include fenestellids, *Stenopora, Wyndhamia, Ambikella, Trigonotreta, Sulciplica*, pectenids (including *Deltopecten, Etheripecten* and *Streblopteria*), *Eurydesma, Keeneia* and *Peruvispira*. Smooth ostracods are abundant at several intervals, 6·17 m of medium to dark grey, silty, *Stenopora* and fenestellid mudstone occurs between 7·70 m and 13·87 m. *Stenopora* and fenestellids are overwhelmingly predominant but rare specimens of *Wyndhamia, Ambikella*, small lamellibranchs and small *Keeneia* also occur. This unit is considered to be the same interval as the prominent *Stenopora* mudstone unit which is exposed in the shore platform and cliff sections below the drill site, and if so, the Deep Bay Formation has a total thickness of about 102 m in its type section.

The basal beds of the Deep Bay Formation and its paraconformable contact with the underlying Bundella Formation is well-exposed in a coastal shore platform at Lower Wattle Grove [DN995208]. Here several metres of massive-bedded, pebbly, marine conglomerate, granule conglomerate and coarse-grained sandstone rich in *Eurydesma* and other fossils, together with subordinate flaser-bedded siltstone and fine-grained sandstone, is overlain by thin- to medium-bedded siltstone and sandy siltstone which yield *Sulciplica, Ambikella brevis* and other fossils typical of the Deep Bay Formation. The sandstone, conglomerate and granule conglomerate beds probably represent the basal inshore-marine beds of an onlap succession marking the local base of the Deep Bay Formation. The siltstone sequence below contains a typical Bundella Formation fauna which includes *Pseudo-*

syrinx, Trigonotreta stokesi, Deltopecten, Eurydesma and very large *Keeneia*.

The paraconformable relationship of the Deep Bay Formation with the underlying Bundella Formation persists for more than 10 km eastwards from Cygnet as far as the Nicholls Rivulet Road [EN153262] not far from Underwoods Hill. At this point the paddocks immediately to the north of the road contain large blocks of *Eurydesma*-bearing, coarse-grained sandstone similar to the basal beds at Lower Wattle Grove. The lithological resemblance is so close as to appear identical and the blocks occupy a position between proved sequences of richly-fossiliferous Bundella Formation to the south of the road and light grey highly fossiliferous bryozoal siltstone and mudstone at the Deep Bay Formation to the north of the road.

The upper half of the Deep Bay Formation is also well-exposed in a coastal section north-west of Poverty Point [EN040142]. Several gaps and small faults are present in places and produce some uncertainty as to exact stratigraphic relationships. Furthermore, most of the internal and external moulds of the fossils have a ferruginous coating, and overall the section is inferior to that at Deep Bay. Lithological types, however, are generally similar and include compact, grey siltstone, sandy siltstone and fine-grained sandstone, all with abundant dropstones. Thin (up to 75 mm) beds and irregular pods of coarser-grained, granule-sized detritus occur in places, and worm tubes and other biogenic structures are common. Compact, grey, laminated bryozoal siltstone is probably more prevalent than in the Deep Bay section. Small-scale ripple-drift is present in some of the fine-grained sandstone beds.

The Deep Bay Formation is present in its entirety in the Snug Tiers Bore (NF 78) [EN180289], and has a thickness of 96·5 m which is slightly less than in its type section at Deep Bay. Lithologies are similar and consist of alternations of thin- and medium-bedded, light to dark grey siltstone, sandy siltstone and fine-grained sandstone with minor mudstone. Several intervals are characterised by wispy bedding, and pods and stringers of coarser-grained, granule-sized detritus occur more especially towards the base of the formation. Many beds are heavily bioturbated, and pebble- and cobble-sized dropstones occur throughout. Most beds are richly fossiliferous with *Stenopora*, fenestellids, *Wyndhamia dalwoodensis, Terrakea, Ambikella*, fasciculate spiriferids, *Sulciplica tasmaniensis, Deltopecten, Etheripecten, Keeneia, Peruvispira* and smooth ostracods abundant at many levels. Both the upper boundary with the Minnie Point Formation and the lower boundary with the underlying Hickman Formation are apparently conformable, but inferentially the latter is paraconformable.

The Deep Bay Formation occurs widely around the flanks of the Cygnet Dome in the region of Thomas Hill [EN100167], Pig and Whistle Hill [EN120205], Tobys Hill [EN100228], The Galleries [EN090239], south of Balfes Hill [EN053247], Dillons Hill [EN027235] to Glaziers Bay [EN005245] on the Huon River. In the eastern half of this tract the Deep Bay Formation is intruded by a thick, sheet-like body of Jurassic dolerite, and in the western half it is associated with numerous thin dykes and thicker, sill-like sheets of Cretaceous syenite so that the effects of thermal metamorphism are always in evidence. Characteristically these developments of the Deep Bay Formation present a pale grey, creamy white, sometimes greenish-tinged appearance, with the degree of metamorphism producing moderately- to intensely-baked hornfels. Fossils are always abundant but are difficult to extract and poorly-preserved in flinty hornfels. Excellently preserved internal and external moulds, however, can be obtained from slightly weathered, lower grade hornfels at many localities. Preservation of this type characterises the smaller areas of Deep Bay Formation outcrop in the vicinity of Woodstock [EN033316] and east and west of Ranelagh [EN025383] on the Huon River.

Small areas of Deep Bay Formation outcrop occur near Woodbridge and Little Oyster Cove [EN210253]. Exposure is generally poor except for the coastal section at Little Oyster Cove, but again the proximity of substantial dolerite and lesser syenite has resulted in moderate to intense hornfelsing.

Large areas of Deep Bay Formation outcrop occur on the lower slopes of Red Hill west of Electrona [EN210330] and in the tract of country around Nierinna [EN175357] to Allens Rivulet [EN167375]. Exposure is excellent in a number of natural cliff sections, creeks and road cuttings. Again the proximity of very substantial dolerite and granophyre through the O'Briens Hill [EN185295]–Red Hill–Knotts Hill–Hickmans Hill [EN185375] region has resulted in more or less intense thermal metamorphism.

Along the eastern shore of Piersons Peninsula in the region south of Flowerpot Point [EN167381] to Lucas Point [EN175346], and inland above Piersons Point [EN179332], the Deep Bay Formation is exposed mainly in cliff sections which also display a series of spectacular dolerite intrusions. Thermal metamorphism is again intense.

Substantial areas of Deep Bay Formation occur along the east coastal tracts of North Bruny Island between Trumpeter Bay [EN323213] in the north and as far south as the southern margin of the map sheet, together with several smaller areas inland. The entire outcrop is underlain by a thick, sheet-

like body of dolerite and thermal metamorphism is always moderate to intense. At Variety Bay [EN337167] intensely-baked, finely-laminated bryozoal hornfels forms the predominant part of a 30 m sequence exposed in the cliff sections.

A thin, localised development of impure limestone (Pdl) occurs at Silver Hill [EN021233]. Outcrop is poor and no *in situ* bedrock is exposed. However, several small depressions are littered with blocks of impure limestone. These depressions may result from the trial pits which indicated to Everard (*in* Hughes, 1957) a lens about 2 m thick and 20 m long. All the surrounding exposures are of moderately baked, pale grey and cream, richly-fossiliferous siltstone typical of the Deep Bay Formation. The limestone is dark grey in colour but weathered surfaces are almost white. It is impure and contains little more than 50% calcium carbonate (Everard, *in* Hughes, 1957) and is essentially fine-grained, but contains considerable bioclastic debris as well as abundant larger fossils. Dropstones of quartzite and slate up to cobble size are reasonably common, and granule- and sand-sized grains of quartz and feldspar are present. In thin section the limestone is seen to consist largely of cryptocrystalline calcite with much bioclastic debris. Angular quartz grains are common with subordinate altered feldspar. Everard (*in* Hughes, 1957) noted the presence of minute grains of limonite and an overall pale limonitic staining in the samples he examined. Fossils are common and include *Stenopora*, fenestellids, *Wyndhamia dalwoodensis, Terrakea*, fasciculate spiriferids, *Sulciplica tasmaniensis, Ambikella* brevis, terebratulids, *Etheripecten, Keeneia* and smooth ostracods. Banks (*in* Hughes, 1957) also records *Eurydesma*.

In summary the Deep Bay Formation is therefore characterised as a sequence of richly-fossiliferous alternations of thin- to medium-bedded, poorly-sorted siltstone, sandy siltstone and fine-grained sandstone with subordinate mudstone deposited in a shallow-water, near-shore environment which oscillated between periods of low to moderate energy conditions. Where metamorphosed it can be readily distinguished from fossiliferous and unfossiliferous hornfels of formations lower in the succession by its fossil content and its light grey and creamy white to green-tinged appearance. A thin, small-scale lensoid development of impure limestone occurs at Silver Hill.

Palaeontology and age

As already noted the Deep Bay Formation is richly fossiliferous at many levels throughout. In intensely baked hornfels extraction is difficult and preservation is poor, but otherwise preservation is excellent. Many specimens, notably strophalosiids and various spiriferids which often occur in growth position, are complete and articulated, whereas others are broken and rolled. It is noteworthy that all samples (*e.g.* the Deep Bay Bore) treated for palynological residues have yielded intensely carbonised spores and pollen (Dr E. M. Truswell pers. comm.), so that the entire formation has been subjected to a substantial background heat flow doubtless caused by the fluid-rich Cretaceous syenite intrusives. Macrofossils recorded include:

> *Gertholites [Thamnopora] wilkinsoni* (Etheridge)
> Solitary rugosans — poorly-preserved moulds
> *Paraconularia derwentensis* (Johnston)
> *Orbiculoidea* sp.
> Davidsoniacean gen. nov. homeomorphic with impunctate *Schuchertella*
> *Echinalosia preovalis* (Maxwell)
> *Wyndhamia dalwoodensis* Booker
> *Terrakea brachythaera* (Morris)
> *Terrakea concava* Waterhouse
> *Cleiothyridina* sp.
> *Fusispirifer avicula* (Morris)
> *Fusispirifer* sp. nov. — a form with obsolescent ornament
> *Sulciplica phalaena* (Dana)
> *Sulciplica stutchburii* auctt.
> *Sulciplica tasmaniensis* (Morris)
> *Sulciplica transversa* Waterhouse
> *Trigonotreta cracovensis* (Wass)
> *Trigonotreta lethamensis* (Waterhouse)
> *Trigonotreta wairakiensis* (Waterhouse)
> *Ambikella brevis* (McClung and Armstrong)
> *Ambikella ingelarensis* (Campbell)
> *Ambikella magna* (Campbell)
> *Ambikella plana* (Campbell)
> *Ambikella plica* (Campbell)
> *Ambikella undulosa* (Campbell)
> *Ambikella etheridgei* (McClung)
> *Notospirifer* sp. nov. — a coarsely plicate species
> *Pseudosyrinx* spp.
> *Punctospirifer etheridgei* Armstrong
> *Fletcherithyris amygdala* (Dana)
> *Fletcherithyris parkesi* Campbell
> *Gilledia oakiensis* Campbell
> *Gilledia ulladullensis* Campbell
> *Astartella* sp.
> *Astartila intrepida* (Dana)
> *Atomodesma (Aphanaia)* sp.
> *Deltopecten illawarensis* (Morris)
> *Deltopecten limaeformis* (Morris)
> *Deltopecten multicostatus* (Etheridge and Dun)
> *Deltopecten squamuliferus* (Morris)
> *Etheripecten farleyensis* (Etheridge and Dun)
> *Etheripecten tenuicollis* (Dana)
> *Eurydesma hobartensis hobartensis* (Johnston)

Megadesmus gryphoides (de Koninck)
Megadesmus nobilissimus (de Koninck)
Merismopteria macroptera (Morris)
Myonia carinata (Morris)
Myonia corrugata Fletcher
Promytilus [Volsellina] mytiliformis
  (Etheridge)
Schizodus spp.
Streblopteria sp.
Stutchburia spp.
Undopecten fittoni (Morris)
Vacunella curvata (Morris)
Keeneia ocula (J. Sowerby)
Peruvispira spp.
Walnichollsia subcancellata (Morris)
Warthia micromphala (Morris)
Michelinoceratids
Bransonia sp.
Stenopora spp.
Fenestellids
Smooth ostracods
Wood and plant fragments, crinoid debris

The stratigraphical palaeontology of the Deep Bay section has previously been discussed in some detail by Clarke and Banks (1975) and Clarke and Farmer (1976). Those authors assigned the Deep Bay Formation to their Faunizones 6–8, or the Early to Middle Lymingtonian Stage, an interval broadly coeval with the *plana–brevis–undulosa* Zones of Runnegar and McClung (1975) based on sequences in the Sydney and Bowen Basins. These conclusions remain essentially valid although a considerable amount of further collecting and an analysis of collections made independently by Dr Farmer necessitate minor amendments in faunal distributions. Notable examples are *Fusispirifer avicula* and *Punctospirifer etheridgei*. The former now has the start of its range lowered to Unit 46A of the Deep Bay Formation, and *Punctospirifer etheridgei*, previously restricted to a thin interval within the overlying Minnie Point Formation, is now known to occur rarely through Units 13D–27D (See Appendix 1). The latter distribution is of local significance only since *Punctospirifer etheridgei* is known to range throughout the Bernacchian to Early and Middle Lymingtonian on Maria Island (Clarke, *in* Clarke and Baillie, 1984) and elsewhere in Tasmania. Other amendments to the vertical distributions of the various species are very minor, and *Eurydesma* has not been found above its previously known highest occurrence.

A detailed analysis of occurrences of the spiriferid *Ambikella* within the Deep Bay Formation indicates that Faunizones 6–8 as originally defined on gross faunal characters (Clarke and Banks, 1975), are not necessarily exactly synonymous with the *plana–brevis–undulosa* Zones of Runnegar and McClung (1975) although the latter have not been defined

other than on theoretical grounds. *Ambikella plana* commences its range in the Late Bernacchian on Maria Island (Clarke, *in* Clarke and Baillie, 1984), and *Ambikella brevis* ranges beyond the limits of Faunizone 7 as originally defined by Clarke and Banks (1975). Forms referrable to *Ambikella brevis* occur through most of the Deep Bay Formation but the lowermost beds up to Units 9C, 9D, and 11D are characterised by more abundant specimens of morphologies comparable with *Ambikella plana* and *Ambikella plica*. Thereafter *Ambikella brevis* dominates successive populations, but individual specimens morphologically identical with *Ambikella plana* persist as high as Unit 23D. Similarly *Ambikella undulosa* first appears in Unit 26A, but this species does not become predominant until Unit 34A and it persists into the overlying Minnie Point Formation. *Ambikella brevis* ranges as high as Unit 46A. Forms with long, subparallel dorsal adminicula referrable to *Ambikella ingelarensis* occur sparingly throughout. *Ambikella magna* also occurs rarely but does not become a characteristic faunal component until the overlying Minnie Point Formation. A coarsely plicate new species of *Notospirifer* (listed as *Martiniopsis* sp.nov. in Clarke and Banks, 1975) occurs within the interval of Units 22D–33D.

Other faunal distributions are essentially those given by Clarke and Banks (1975). Particularly characteristic is the profusion of articulated *Megadesmus gryphoides, Sulciplica stutchburii, Peruvispira* and smooth ostracods towards the base of the Deep Bay section. Some beds are dominated by bryozoans and others by *Wyndhamia dalwoodensis* often in growth position, but typical assemblages are dominated by a variety of spiriferids with subordinate molluscans, productids, terebratulids and other biota.

A detailed analysis of the faunas in the lowermost parts of the Deep Bay Formation encountered in the Deep Bay Bore is less easy, but the overall faunal assemblage is similar to that of the exposed section. *Ambikella plana* and *Ambikella* cf. *plica* occur in the bore core, but it may be significant that *Ambikella brevis* is the only *Ambikella* species recorded from the basal beds exposed at Lower Wattle Grove.

In summary therefore the Deep Bay Formation is referred to the Early and Middle Lymingtonian Stage (Clarke and Farmer, 1976). The basic faunal assemblages, denoted Faunizones 6–8 by Clarke and Banks (1975), are retained and are considered to be essentially coeval with the interval spanned by the *plana–brevis–undulosa* Zones of Runnegar and McClung (1975). However, exact equivalence of the interval as a whole, or the constituent zones, is not implied. Indeed, the lowest part of the *plana* Zone is represented within the stratotype of the

Bernacchian Stage on Maria Island (Clarke, *in* Clarke and Baillie, 1984), and the upper part of the *undulosa* Zone occurs within the overlying Minnie Point Formation. Inferentially the paraconformity at the base of the Deep Bay Formation in the Cygnet area also embraces some part of the earliest Lymingtonian Stage, but this is currently beyond the limits of faunal resolution.

[M.J.C.]

MINNIE POINT FORMATION (Pm)

The Minnie Point Formation, here defined, takes its name from Minnie Point, Port Cygnet [EN073140]. The stratotype is that section exposed about Minnie Point between EN073143 and EN076140. The formation has a thickness of 46 m in its type section where it consists of medium- and massive-bedded, poorly-sorted, pebbly sandstone, with subordinate, dark grey, poorly-sorted, thin- to medium- to massive-bedded, pebbly siltstone which characterises the upper part of the formation. Coarser, granule-sized feldspathic and other clastic detritus characterises many of the sandstone beds. Several beds are soft, friable and very porous due to decomposition of the feldspars. Other beds, particularly those of siltstone, are hard and compact. Worm burrows and other biogenic structures are abundant in the upper part of the formation. Pebble- and cobble-sized clasts occur abundantly throughout, both scattered and in winnowed concentrations.

In its type section the Minnie Point Formation rests with apparent conformity on the Deep Bay Formation, and is followed conformably or disconformably by the Risdon Sandstone. Another well-exposed section at Poverty Point [EN044142] differs significantly from the type section and as mapped through the map sheet, the Minnie Point Formation displays rapid lateral facies change and may embrace several minor disconformities or non-sequences within it. It represents shallow water, near-shore sedimentation in a low to moderate energy environment. Faunal evidence demonstrates a late Middle to Late Lymingtonian age (Faunizones 9-10) for the Minnie Point Formation.

The Minnie Point Formation derives its name from Minnie Point, Port Cygnet where it is almost wholly exposed in a series of excellent shore platform and cliff sections. In this account the lithological and faunal characters of the Minnie Point Formation are somewhat generalised as in the previously published account of Clarke and Banks (1975) and Clarke and Farmer (1976). Dr Farmer's detailed measurements of the section are tabulated in Appendix 2.

The basal bed of the formation consists of 910 mm of coarse-grained poorly-cemented, deeply weathered, fossiliferous sandstone. Pebbles are numerous and sorting is poor. The fossils include small gastropods and much fragmented spiriferids and pectenids. Next follows 150 mm of well-rounded pebble conglomerate with clasts of granite, quartzite and low grade slate and hornfels. This bed is overlain by 25 m of interbedded, medium- to thick-bedded, fine- to medium-, coarse- to very coarse-grained, poorly-sorted, pebbly sandstone with subordinate pebble conglomerate and irregular lenses, pods and stringers of feldspathic granule conglomerate. Some beds are hard and compact, but the majority are soft and very porous as a result of feldspar decomposition. Colours range from medium grey to brown to almost white. Bioturbation is present in some beds but is generally rare. Fossils are more or less abundant throughout and typically consist of broken and rolled fragments of large, thick-shelled spiriferids and pectenids. Complete specimens, however, do occur and include *Ambikella undulosa* and the burrowing clam *Vacunella curvata*, the latter probably in life orientation. Well preserved, articulated *Punctospirifer etheridgei* occurs in some abundance in very coarse-grained feldspathic sandstone and granule conglomerate within Unit 56 about 9 m above the base of the formation. *Sulciplica transversa*, *Wyndhamia dalwoodensis*, *Fletcherithyris parkesi* and *Gilledia ulladullensis* are also common at this level. Well preserved and articulated *Ambikella magna*, *A. undulosa*, *Sulciplica phalaena* and other fossils occur in abundance through a 200 mm interval in Unit 61, and very irregular tongues and stringers within Unit 65 are crowded with the small bivalve *Atomodesma (Aphanaia)* sp. *Ambikella isbelli* occurs for the first time in this bed. The general lithological characters through this interval indicate very shallow water, sublittoral, on-shore sedimentation. The uppermost 2 m of beds (Units 67-74) consist of alternations of thin-bedded, dark grey, compact, coarse-grained, laminated, pebbly siltstone, medium- and fine-grained, indurated, brown, pebbly sandstone, and fine-grained, rubbly sandstone which represents a transition into the upper part of the formation.

The remainder of the formation (Units 75-85) consists of 18 m of dark grey, thin- to medium-bedded, poorly-sorted, compact, pebbly siltstone and sandy siltstone (Units 75-78), passing up into more massively-bedded intervals of a similar lithology (Units 79-82). Pebble bands are common, and cobble-sized clasts are scattered throughout. Sorting is very poor and worm and molluscan burrows and other biogenic structures are very common. The topmost beds (Units 83-85) consist of medium-bedded, medium and dark grey, poorly-sorted, heavily bioturbated, carbonaceous

Plate 9. *Poorly-sorted, bioturbated sandstone. Minnie Point Formation, Minnie Point.*

sandstone with thin intervals of dark grey, compact, pebbly siltstone and sandstone, and minor carbonaceous mudstone (plate 9). In places a thin (200 mm thick) band of hard sandstone occurs at the base of Unit 85, but traced laterally over a distance of 30 m it thins out and disappears. Fossils are generally uncommon, but occur scattered throughout and in some abundance at restricted intervals. *Fusispirifer avicula, Sulciplica transversa, Astartila intrepida, Myonia corrugata* and *Warthia micromphala* occur in some abundance near the base of Unit 79. Units 83–84 are more richly fossiliferous and *Echinalosia ovalis, Terrakea brachythaera*, very large and alate *Fusispirifer avicula* and *Sulciplica transversa, Astartila intrepida*, very large *Etheripecten leniusculus, Megadesmus grandis, Myonia carinata, M. corrugata, M. triangulata, Vacunella curvata, Keeneia, Peruvispira, Walnichollsia subcancellata* and *Warthia micromphala* occur in profusion.

At Poverty Point [EN044142] the Minnie Point Formation is again well exposed. Although the section contains several faults of unknown throw which preclude an exact stratigraphic comparison, it is evident that the section shows significant differences when compared with the type section at Minnie Point. The section commences with an irregular bed of ferruginous sandstone rich in *Ambikella undulosa* and rarer *A. magna*. This basal bed is overlain by 8 m of poorly-fossiliferous, alternating, bioturbated sandy siltstone and silty sandstone, with a prominent 25 mm thick bed of cobble conglomerate about 800 mm above the base. A characteristic interval of 1·5 m of dark red and maroon weathering sandstone crowded with the small bivalve *Atomodesma (Aphanaia)* sp. then occurs, and is almost certainly the equivalent of Unit 65 in the type section. This bed apart, the basal sequence of the Poverty Point section is lithologically unlike the basal part of the type section, and is considerably thinner. The stratigraphic attenuation is from 24 m at Minnie Point to 8 m at Poverty Point. Palaeontological correlation, however, is reasonably certain and indicates that the basal parts of the Poverty Point section correspond to the interval represented by Units 60–65 in the type section. If this is so, the basal part of the Minnie Point Formation as developed in the type section (Units 49–59) is absent at Poverty Point. A non-sequence or disconformity is therefore inferred at the base of the formation at Poverty Point. The remainder of the sequence at Poverty Point consists of 32 m of alternating, medium- and massive-bedded, dark grey, poorly-sorted, bioturbated siltstone and sandy siltstone with irregular, thin bands of sandstone. Dropstone pebbles and cobbles of many lithologies are abundant. The thickness of 32 m is probably excessive because of repetition by faulting. These uppermost parts of the Minnie Point Formation at Poverty Point again differ from their stratigraphic equivalents at Minnie Point in being apparently unfossiliferous. The

richly-fossiliferous beds a few metres below the Risdon Sandstone are definitely not present at Poverty Point. It is uncertain whether this is due to facies change or non deposition, but the former explanation is favoured.

Around the flanks of the Cygnet Dome the Minnie Point Formation is rarely well exposed, but in general the occurrences conform in thickness and lithology to the overall bipartite subdivision of the type section. At Balfes Hill [EN152247] the upper part of the formation is well exposed in road cuttings. Here about 20 m of beds consist mainly of medium and dark grey, poorly-sorted, heavily bioturbated siltstone with subordinate fine- and medium-grained sandstone. Pebbles occur throughout and dispersed granule-sized quartz and other detritus is conspicuous in places. *Echinalosia ovalis, Terrakea brachythaera, Vacunella curvata* and other fossils occur abundantly in the topmost metre or so immediately beneath the overlying Risdon Sandstone.

North of the Cygnet Dome, in the north-west corner of the map sheet in the area north of Woodstock [EN033316] and near Ranelagh [EN025383] on the Huon river, the Minnie Point Formation shows a considerable increase in thickness to about 80 m. Lithologically it is more uniform and consists essentially of monotonous, medium-bedded, poorly-sorted, mottled siltstone and sandy siltstone with subordinate fine-grained sandstone. Dispersed granule-sized quartz and other detritus is common in many beds. Pebble- and cobble-sized dropstones are abundant and bioturbation is intense at certain levels. Fossils are uncommon throughout most of the formation, and they are frequently much broken. However, the richly-fossiliferous horizon with *Echinalosia ovalis* and other fossils near the top of the formation is invariably present.

To the north-east of Cygnet the Minnie Point Formation was encountered in its entirety in the Snug Tiers Bore (NF78)[EN180289] where it has a thickness of 71·34 m, which is substantially greater than at Cygnet. The basal 17 m consist of medium and dark grey, medium- and coarse-grained, bio-turbated sandstone with much dispersed granule-sized detritus, and subordinate, thin siltstone intervals. A few thin and irregular carbonaceous partings are present. Pebble-sized dropstones occur throughout. Fossils, which are often fragmented, occur at many intervals and include fenestellids, *Sulciplica*, fasciculate spiriferids, pectenids and *Peruvispira*. These basal beds are overlain by 11 m of medium grey, wispy-bedded, bioturbated siltstone and sandy siltstone. Dropped pebbles occur throughout. A 30 mm band near the middle of the unit contains moulds of small shells and plant fragments. Fragments of spiriferids occur in the

lower half of the unit as a whole. The main part of the formation is 39·35 m thick and consists of medium to light grey, wispy-bedded, bioturbated siltstone with disseminated pyrite, small dropped pebbles and much granule-sized quartz debris. It is mainly unfossiliferous but fragments of spiriferids and other fossils occur sporadically, particularly towards the base. Much of the core has a mottled appearance due to the large quantity of granular quartz fragments. The uppermost 4 m of beds consist of alternations of richly-fossiliferous, light grey siltstone, medium-grained sandstone and minor mudstone. Dropstones are small and uncommon. The fossils are mostly complete and include *Echinalosia ovalis* and *Terrakea brachythaera* in growth position. The lower boundary with the underlying Deep Bay Formation and the upper boundary with the overlying Risdon Sandstone are both conformable, although the latter is abrupt. The section in the Snug Tiers Bore is lithologically intermediate between the Minnie Point Formation as developed in the Cygnet area and the Malbina Formation of the Hobart area.

The formation retains these characters in the outcrop from the lower slopes of Red Hill [EN194330] west of Electrona, through Nierinna [EN175357] to Allens Rivulet [EN167375] on the northern margin of the map sheet.

The uppermost richly-fossiliferous parts of the Minnie Point Formation are well exposed immediately below the Risdon Sandstone at Cape Direction [EN343340], where *Echinalosia ovalis, Terrakea brachythaera, Fusispirifer avicula, Sulciplica transversa, Astartila intrepida, Megadesmus grandis, Merismopteria macroptera, Vacunella curvata, Warthia micromphala* and many other fossils occur in profusion.

On North Bruny Island small areas of Minnie Point Formation occur inland and north of Quarantine Bay [EN275252], north of Barnes Bay [EN295263], at Trumpeter Bay [EN320205], inland from Variety Bay and on the western slopes of Wilson Hill [EN295135]. Nowhere is there a complete section and thermal metamorphism is always more or less in evidence. Overall those parts of the sequence which are exposed appear to be rather more sandy than elsewhere.

The Minnie Point Formation as mapped through the map sheet therefore presents a varied sequence of poorly-sorted sandstone and siltstone. In the Cygnet area the formation is considerably thinner than elsewhere, and at Poverty Point the lowermost part of the formation is absent. Traced to the north and north-east the formation thickens considerably and develops a more uniform aspect, and is transitional into developments characteristic of the Malbina Formation of the Hobart area. Every-

40
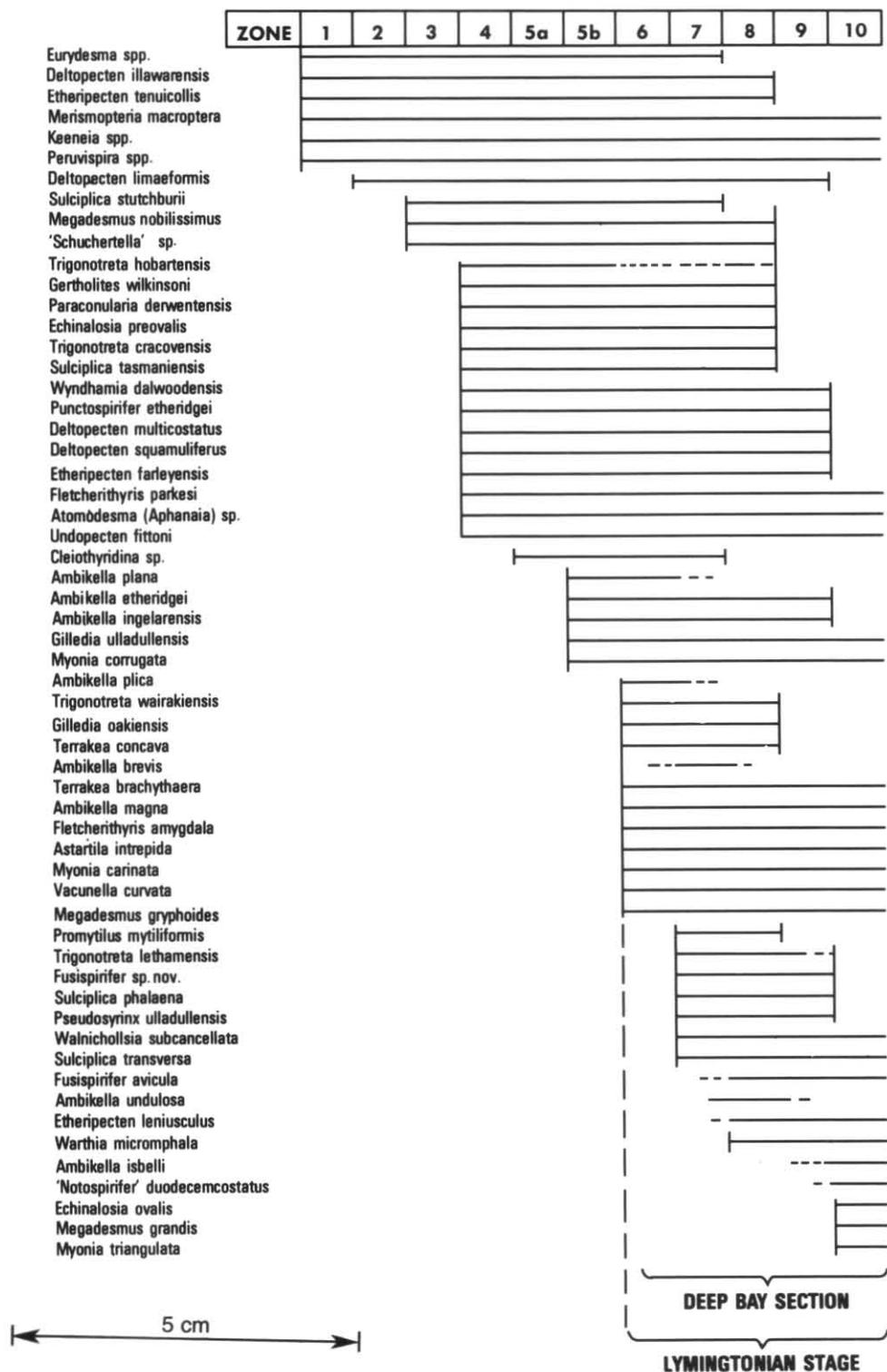
Figure 3. *Range chart, Lymingtonian Stage.*

where except at Poverty Point the uppermost few metres of the formation are richly fossiliferous and yield *Echinalosia ovalis* and many other fossils. This development together with the overlying Risdon Sandstone forms an important field marker horizon. Facies changes are frequent and sometimes abrupt, and sorting is always poor. A considerable proportion of the sequence has been heavily reworked during sedimentation by infaunal biogenic activity. The Minnie Point Formation is therefore considered to represent shallow-water, near-shore sedimentation in a low to moderate energy environment. Overall the depositional environment is thought to differ little from that of the underlying Deep Bay Formation. In conversation the late Dr Farmer stated that he considered that the Minnie Point Formation was in part the lateral equivalent of the Deep Bay Formation, which implies sediment derivation from two separate source areas.

Palaeontology and age

The Minnie Point Formation is usually more or less fossiliferous throughout, but apart from a few limited intervals, abundance is less and preservation is poor compared with the Deep Bay Formation. At many horizons individual specimens are much broken and rolled and cannot be specifically determined. The following forms occur:

> *Echinalosia ovalis* (Maxwell)
> *Wyndhamia dalwoodensis* Booker
> *Terrakea brachythaera* (Morris)
> *Fusispirifer avicula* (Morris)
> *Sulciplica phalaena* (Dana)
> *Sulciplica transversa* Waterhouse
> *Trigonotreta lethamensis* (Waterhouse)
> *Ambikella etheridgei* (McClung)
> *Ambikella* sp. *globosa* (Campbell)–*oviformis* (M'Coy) group
> *Ambikella isbelli* (Campbell)
> *Ambikella* cf. *isbelli* (Campbell)
> *Ambikella magna* (Campbell)
> *Ambikella undulosa* (Campbell)
> '*Notospirifer*' *duodecemcostatus* (M'Coy)
> *Pseudosyrinx* cf. *ulladullensis* (Armstrong)
> *Punctospirifer etheridgei* Armstrong
> *Fletcherithyris amygdala* (Dana)
> *Fletcherithyris parkesi* Campbell
> *Gilledia ulladullensis* Campbell
> *Astartila intrepida* (Dana)
> *Atomodesma (Aphanaia)* sp.
> *Deltopecten limaeformis* (Morris)
> *Deltopecten multicostatus* Fletcher
> *Deltopecten squamuliferus* (Morris)
> *Etheripecten leniusculus* (Dana)
> *Etheripecten subquinquelineatus* (M'Coy)
> *Megadesmus grandis* (Dana)
> *Merismopteria macroptera* (Morris)
> *Myonia carinata* (Morris)
> *Myonia corrugata* Fletcher
> *Myonia triangulata* (Waterhouse)
> *Schizodus* sp.
> *Stutchburia compressa* (Morris)
> Stutchburia costata (Morris)
> *Undopecten fittoni* (Morris)
> *Vacunella curvata* (Morris)
> *Keeneia* sp.
> *Peruvispira* sp.
> *Walnichollsia subcancellata* (Morris)
> *Warthia micromphala* (Morris)
> *Stenopora crinita* Lonsdale
> Fenestellids
> Wood, plant debris

The vertical distributions of the more important species are given in Figure 3. The stratigraphical palaeontology of the Minnie Point Formation has been previously discussed in some detail by Clarke and Banks (1975) and Clarke and Farmer (1976). Those authors assigned the Minnie Point Formation to their Faunizones 9–10, or the late Middle to Late Lymingtonian Stage, an interval broadly coeval with Faunas IVA–IVC in the Bowen Basin, Queensland (Dickins *et al.*, 1964), and inferentially with the *isbelli–ovalis* Zones of Runnegar and McClung (1975) based on sequences in the Sydney and Bowen Basins. These conclusions are considered to remain essentially valid. However, further collecting necessitates certain minor amendments to faunal distributions, and it is apparent from the accounts of Clarke and Banks (1975) and Clarke and Farmer (1976) that an equation of Faunizones 9–10 with the *isbelli–ovalis* Zones was somewhat broadly conceived rather than exact in detail. For instance, Faunizone 9 or the *magna–dalwoodensis* Zone of Clarke and Banks (1975) was essentially characterised by the acme of *Ambikella magna* and the continued persistence of *Wyndhamia dalwoodensis* and *Deltopecten* spp., together with the absence of many species typical of earlier intervals such as *Sulciplica tasmaniensis*, *Trigonotreta cracovensis*, *Gertholites [Thamnopora], Bransonia* and *Paraconularia derwentensis*. *Ambikella undulosa* was recorded from the lower part of the Zone, and *Ambikella isbelli* from near the top. All these distributions remain unaltered (see figure 3). It has already been noted that *Fusispirifer avicula* (previously used as an index for Faunizones 9–10) is now known to range as low as the *brevis* Zone within the Deep Bay Formation. Similarly the base of Faunizone 10 or the *ovalis–Megadesmus grandis* Zone of Clarke and Banks (1975) was not drawn at the first occurrence of these two species, which occurs some 20 m higher in the sequence, but immediately above the last occurrences of *Deltopecten* spp. and *Wyndhamia dalwoodensis*. Faunizones 9–10 (and Faunizones 6–8), although individually renamed by Clarke and Farmer (1976), were retained in their original faunal characters to

define the reference section of the Lymingtonian Stage.

In summary therefore the faunas of the Minnie Point Formation are assigned to the late Middle Lymingtonian (Faunizone 9) and Late Lymingtonian (Faunizone 10) as essentially conceived by Clarke and Banks (1975). In the Deep Bay section *Deltopecten* spp. and *Wyndhamia dalwoodensis* do not overlap the range of *Ambikella isbelli*, but the section is poorly fossiliferous through the interval where this would be expected to occur. On Maria Island (Clarke, *in* Clarke and Baillie, 1984), at Friendly Beaches and elsewhere in Tasmania the association is a characteristic one, and is additionally typified by the acme of *Ambikella magna*. The correlation with Faunas IVA–IVC of Dickins *et al.* (1964) is retained in broad outline. Similarly the faunas of the Minnie Point Formation are correlated with the upper part of the *undulosa* Zone, the *isbelli* Zone and the lower part of the *ovalis* Zone of Runnegar and McClung (1975).

[M.J.C.]

RISDON SANDSTONE (Pr)

The Risdon Sandstone was first named by Carey (1947) and later defined by Banks and Hale (1957) from exposures in road cuts on the north-east side of Risdon Creek on the eastern shore of the Derwent River.

The formation consists of thick-bedded, poorly-sorted, pebbly, feldspathic sandstone. It is unfossiliferous in its type section but worm tubes are present at Mt Nassau (Banks and Hale, 1957) and large spiriferids occur at Mt Dromedary (McDougall, 1959) and elsewhere. The type section is about 3 m thick and is overlain transitionally by fissile and non-fissile, poorly-sorted, mottled, bioturbated siltstone of the Ferntree Formation. The base of the Risdon Sandstone is usually abrupt but at Lachlan [EN013578] it interdigitates with siltstone rich in *Echinalosia ovalis* and *Terrakea brachythaera* in growth position (Leaman, 1976).

Mapping indicates that the Risdon Sandstone constitutes a widespread, distinctive and invaluable field marker horizon throughout the Hobart and most of the adjoining Sorell map sheets. Northwards it thins out and disappears north of Mangalore on the Brighton map sheet. Similarly in thins out and disappears eastwards so that it is absent at Eaglehawk Neck and on Maria Island. Traced southwards into the Kingborough map sheet, however, it thickens and becomes coarser-grained and is even more conspicuous. Some of the best exposed sections occur in the cliffs and shore platforms about Port Cygnet [EN070160], but it also crops out boldly inland and serves as an excellent field marker horizon.

At Kangaroo Bay [EN075140] the Risdon Sandstone consists of 7–8 m of very coarse-grained, poorly-sorted, essentially quartzose sandstone with numerous pebbles of quartz and quartzite particularly in the lower part (plates 10,11). The basal 300 mm consist of pebble conglomerate with pebbles up to 75 mm in diameter, which rests on siltstone of the Minnie Point Formation without great irregularity. Most of the formation is strongly current-bedded and consists of alternating finer and coarser bands of material parallel with the cross-stratification. Pebbles occur in bands and lenses, and are also scattered throughout. The grain size decreases towards the top of the formation. The uppermost part of the formation and its boundary with the overlying Abels Bay Formation is obscured by beach sand and gravel. Measurements of the cross bedding indicate currents in a wide arc from south of east to south of west.

Other well-exposed coastal sections occur at Poverty Point, Beaupré Point, Deep Bay Point, Little Peppermint Bay near Woodbridge, Little Oyster Cove and Cape Direction.

At Poverty Point [EN044142] the formation is 6–7 m thick and consists of conglomeratic, current-bedded, coarse-grained sandstone with pebbles of quartzite, slate and phyllite. The cross-stratification again indicates currents from a general southerly vector.

At Beaupré Point [EN046145] 6–7 m of beds are exposed and consist of wedge-shaped units of current-bedded, interdigitated, coarse-grained sandstone and pebble and granule conglomerate. The pebbles are mostly quartz and quartzite and are well-rounded.

A similar thickness occurs at Deep Bay Point [EN081161] where the formation consists of coarse-grained, pebbly sandstone and conglomerate. Individual current-bedded units are 600–900 mm thick. Some units are very conglomeratic, and others are much finer in grain-size. The succession overall becomes finer-grained upwards. The pebbles are more or less well-rounded and are mostly quartz and quartzite but slate and phyllite also occur.

At Little Peppermint Bay near Woodbridge [EN197224] the Risdon Sandstone has a much reduced thickness of 2 m and consists of fine- to medium-grained, current-bedded sandstone with conglomerate bands up to 150 mm thick. Most of the clasts are quartzite. The richly-fossiliferous uppermost part of the underlying Minnie Point Formation occurs directly below and is crowded with *Terrakea brachythaera*. *Echinalosia ovalis* is rare at this locality.
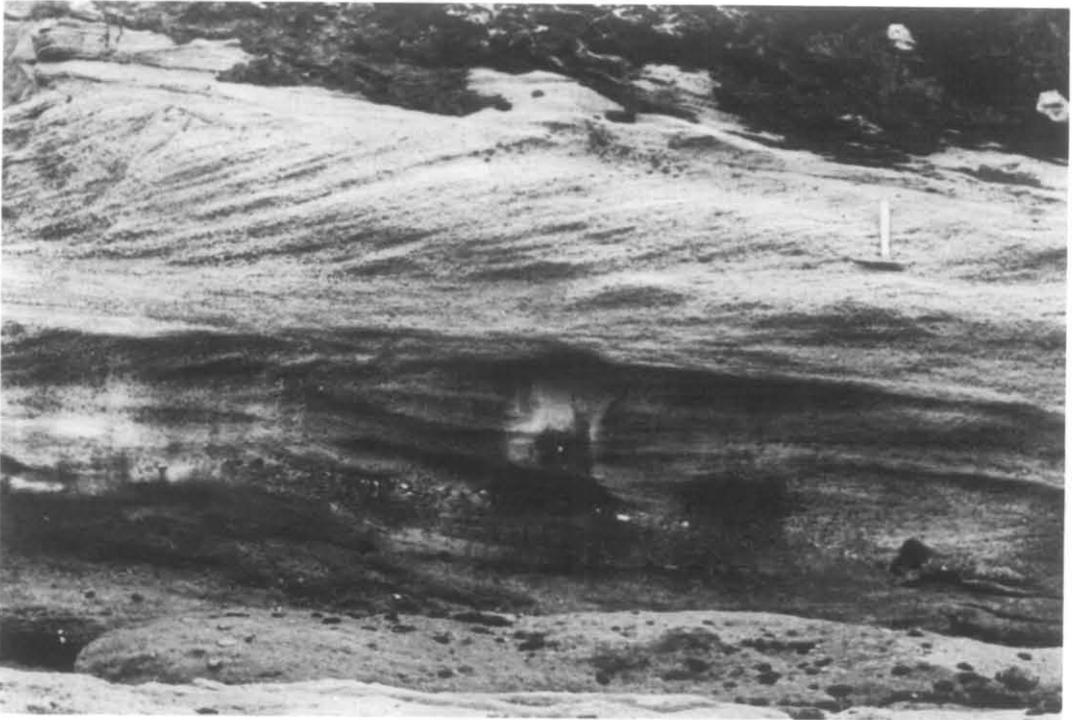
Plate 10. *Coarse-grained, cross-bedded quartz sandstone. Risdon Sandstone, Kangaroo Bay.*
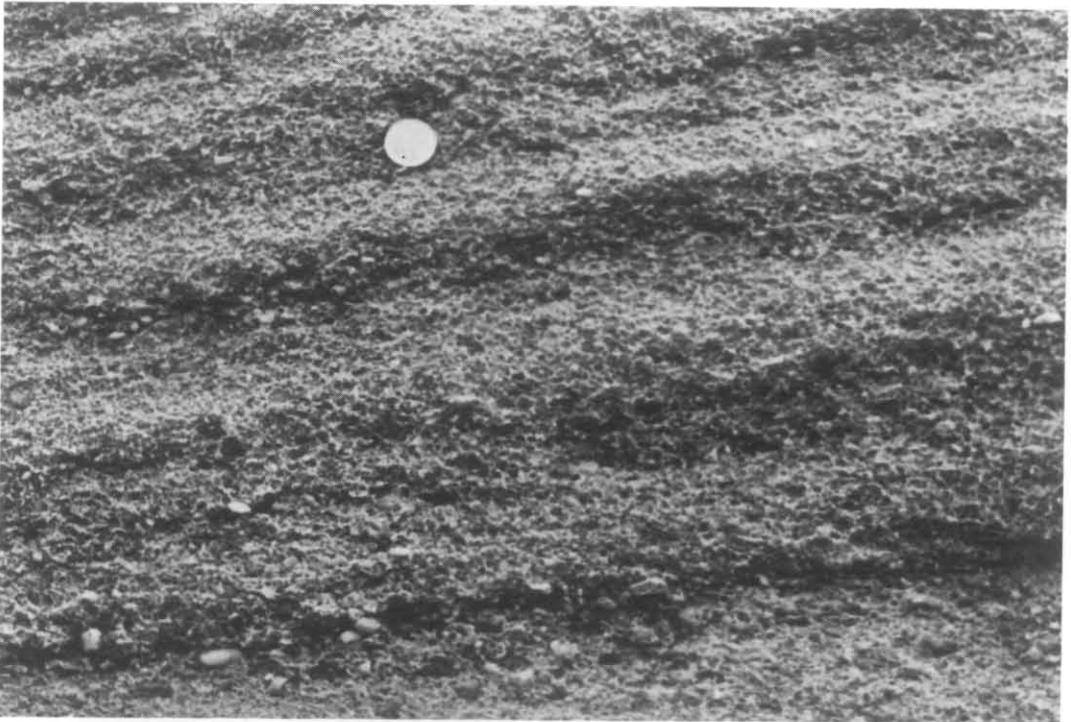
Plate 11. *Coarse-grained, cross-bedded quartz sandstone. Risdon Sandstone, Kangaroo Bay.*

At Little Oyster Cove [EN215254] the formation again has a substantially reduced thickness of 3–4 m. Here a basal pebble conglomerate 150–300 mm thick with clasts mainly of quartz and quartzite, is overlain by coarse-grained, current-bedded quartz sandstone which is noticeably less pebbly than in the Cygnet area. The uppermost part of the underlying Minnie Point Formation is very similar to the section at Deep Bay.

At Cape Direction [EN343340] the Risdon Sandstone is about 3·5 m thick and consists of two almost equal beds of medium- and coarse-grained, poorly-sorted, feldspathic sandstone. Pebbles are less abundant than in the Cygnet area. Calcareous nodules up to 100 mm in diameter also occur here. The carbonate occurs mainly as cement.

The Risdon Sandstone was encountered in its entirety in the Snug Tiers Bore (NF78) [EN180289] where it is 8·44 m thick. It consists of 3·82 m of cross-bedded, coarse-grained, conglomeratic sandstone and coarse-grained feldspathic sandstone; 200 mm of very coarse-grained sandstone with wisps of lenses of intermixed siltstone; 590 mm of dark grey, heavily bioturbated siltstone which is coarser towards the base where it contains dispersed white granules; and 3·83 m of very coarse-grained, feldspathic sandstone with wisps of carbonaceous and muddy material, and very coarse-grained, pebbly sandstone in the lowest 400 mm (Farmer, 1979g).

At Snug Falls [EN157297] the basal conglomerate is 2 m thick and may overlie the Minnie Point Formation conformably. The upper surface of the Minnie Point Formation is a strongly undulating surface of megaripples with wavelengths of 20 m and amplitudes of 2 m on which the conglomerate rests as a series of cross-bedded layers or lenses down opposite sides of the rises of the undulating surface. These cross-bedded lenses consist of alternations of conglomerate, sandstone and siltstone which become thinner at the top of rises and the bottom of hollows in the undulating surface of the Minnie Point Formation, and thicken on the sides of the megaripples. In general the grain-size of the lenses becomes finer upwards until at the top of the 2 m thick conglomeratic unit of sandstone there are shales containing abundant carbonaceous material. The upper limit of these cross-bedded lenses is marked by a 200 mm thick pebble conglomerate which is similar to the basal conglomerate at the base of the Risdon Sandstone at many other localities. This section of the basal beds at Snug Falls is considered to represent an unusually complete record of sedimentation whereas most other sections contain a basal pebble conglomerate which represents a period of reworking. Above the basal unit is a massive bedded sandstone about 3 m thick which is separated from another massive-bedded sandstone of similar thickness by a thin, fine-grained silty sandstone about 100 mm thick.

These two massive sandstone beds, although somewhat reduced in thickness, are very distinctive over the outcrop in the northern parts of the map sheet through Nierinna [EN175357], south of Huonville [EN045335], at Ranelagh [EN025383], near Piersons Point [EN280332], and at Cape Direction [EN343340]. The lower unit is much coarser grained than the upper unit but compositionally they are similar. The intervening silty sandstone is never thicker than 150 mm and is frequently much thinner. The thickness varies greatly, even locally.

Around the flanks of the Cygnet Dome in the area of Harveys Hill [EN085145], Thomas Hill [EN102166], Tobys Hill [EN102244], Balfes Hill [EN152247] and Black Jack Ridge west of Lymington [EN032169] and [EN050160], the Risdon Sandstone crops out boldly on the hillsides. Most localities are characterised by a basal closed framework conglomerate with pebbles mostly of quartz and quartzite, but also some slate and phyllite. The bed usually rests on an irregular surface of the Minnie Point Formation. In one substantial cliff-like exposure on Thomas Hill [EN120174] the basal conglomerate ranges in thickness from 150–300 mm over a distance of about 20 m, and in one place thins out completely. The main part of the formation everywhere in the Cygnet area consists of cross-bedded, coarse-grained sandstone with lenses and bands of pebble conglomerate. The uppermost part of the formation is rarely seen in inland exposures. An exception is on Tobys Hill [EN102244] where it is seen to grade transitionally into the overlying Abels Bay Formation in cuttings alongside a logging track.

On North Bruny Island the Risdon Sandstone consists of poorly-sorted, medium-grained, feldspathic sandstone. It has a reduced thickness of 3–4 m and cross-bedding was not observed. Locally, as for example along part of the outcrop on the eastern slopes of Church Hill [EN332135], it disappears completely.

The Risdon Sandstone is therefore characterised as a thin, but lithologically distinctive field marker horizon which consists predominantly of coarse-grained, current-bedded, quartzose and feldspathic sandstone with subordinate lenses and beds of pebble conglomerate, and minor siltstone and sandy siltstone. It is thickest, coarsest and current-bedding is most strongly developed in the Cygnet area. In a generalised sense the formation thins, becomes finer grained and current-bedding is less in evidence towards the north and east. However, lateral variations are often rapid, even on a local scale. The largest scale cross-bedding occurs in the

coarser conglomeratic units. The cross-bedded units are usually less than one metre thick and individual cross laminae up to 10 mm thick. The cross-bedded units may overlie one another but are often separated by flat-bedded units. Worm burrows and other biogenic structures sometimes disrupt the original framework. Measurements at Kangaroo Bay and Poverty Point, where three dimensional current-bedding can be seen, indicate derivation from a general southerly vector.

The sphericity and roundness of grains show no coherent vertical or lateral change. The roundness of sand grains remains remarkably constant throughout the map sheet. Most grains vary from angular to sub-rounded.

The Risdon Sandstone as a unit is a well-sorted sandstone (using the terminology of Beard and Weyl, 1973) but the degree of sorting ranges from poorly sorted to well sorted. There appears to be no significant lateral change in sorting.

In most samples matrix makes up less than 5% of the rock but it is difficult to determine exactly due to the alteration of feldspar to sericite and clay minerals.

Both the upper and lower units of the Risdon Sandstone are dominantly feldspathic litharenites (terminology of Folk, 1968) ranging from lithic arkose to litharenite to quartz arenite. They are composed of quartz, rock fragments and feldspar with only minor amounts of other accessory minerals. Quartz is the dominant mineral and forms 50-90% of the rock. Rock fragments are usually more abundant then feldspar and range from 15-40%. They are generally similar to the larger clasts and include chert, sandstone, siltstone, quartzite, slate and granitic and volcanic rocks. In contrast to the larger clasts, the granitic and volcanic rock fragments usually make up over half of the total rock fragments, whereas sedimentary rock fragments are normally less than 10% of the total. Feldspar content ranges between 5-20%. Plagioclase is predominant with some microcline. Alteration to sericite and clay minerals is common. The overall composition and mineralogy of the Risdon Sandstone indicate an immature rock (Folk, 1951) derived from a source area composed predominantly of metamorphic, plutonic and volcanic rocks.

At most localities the Risdon Sandstone rests on an uneven surface of the underlying Minnie Point Formation and is characterised by a well-developed, re-worked basal conglomerate. In these sections it is thought to be disconformable. At Snug Falls, however, the basal sequence is considered to be complete and the relationship conformable.

The depositional environment of the Risdon Sandstone has occasioned a wide variety of explanations. These include deposition from turbidity currents (Banks, 1962), beach deposits (Leaman and Naqvi, 1968), a condensed diachronous shelf deposit of a transgressive sea (Jago, 1972) and an off-shore barrier bar succeeded by back barrier bar, restricted lagoonal deposits of the Abels Bay Formation (Rigg, 1970). The latter is preferred here. The sequence from the upper part of the Minnie Point Formation through the Risdon Sandstone into the Abels Bay Formation is regressive from open marine, through off-shore barrier bar into restricted brackish estuarine or back barrier coastal lagoon.

Worm burrows and other biogenic structures occur in some abundance at certain localities, but in essence the Risdon Sandstone is poorly fossiliferous and yields no internal evidence of its age through the map sheet. However, it is of Late Lymingtonian (Faunizone 10) age since rich faunas with *Echinalosia ovalis* and many other fossils occur above and below it.

[N.F.]

ABELS BAY FORMATION (Pa)

The Abels Bay Formation, here defined, takes its name from Abels Bay, Port Cygnet [EN075131]. The stratotype is that section exposed at Abels Bay between EN077140 and EN078127. The formation has a thickness of 145 m in its type section and may be as thick as 175 m elsewhere. It consists of alternations of thin- to medium-bedded, poorly-sorted, pebbly, fissile and non-fissile, fine-grained sandstone and sandy siltstone. Coarser, granule-sized quartz, feldspar and other clastic detritus characterises many of the sandstone beds. Bioturbation is common at many intervals and is often intense. Sandy siltstone predominates in the lower two-thirds of the formation and fine-grained sandstone in the upper third. The uppermost few metres consist of dark grey, carbonaceous mudstone with occasional siltstone bands and convolute laminae. Nodular developments of convolute bedding may be as large as 600 mm × 300 mm. The topmost 300 mm of beds consist of striped sandstone and siltstone with individual laminae 3–5 mm thick.

Both the lower and upper boundaries of the Abels Bay Formation are transitional and conformable. The formation represents regressive, shallow-water, brackish estuarine, or coastal lagoonal sedimentation in a low energy environment, with rare intervals of more normal salinities. Faunal evidence demonstrates a Late Lymingtonian age (Faunizone 10) for the Abels Bay Formation.

The Abels Bay Formation derives its name from Abels Bay, Port Cygnet where is is almost wholly exposed in a series of unfaulted shore platform and cliff sections. Dr Farmer's detailed measured section is tabulated in Appendix 3.

At Kangaroo Bay [EN077139] at the northern end of the section the boundary between the underlying Risdon Sandstone and the Abels Bay Formation is obscured by beach sand and gravel. However, exposures elsewhere at Tobys Hill [EN102244] and the Snug Tiers Bore [EN180289], show it to be transitional with the uppermost massively-bedded part of Risdon Sandstone passing imperceptibly into medium grey, bioturbated, mottled silty mudstone and siltstone with small dropped pebbles and small-scale cross-lamination in places. The lowest beds exposed at Abels Bay consist of interbedded dark grey, pebbly siltstone and subordinate hard, fine-grained sandstone. The sandstone interbeds are about 300 mm thick and the siltstone beds are almost double this thickness. Then follows interbedded compact, medium and dark grey, fine-grained sandstone with surbordinate silty sandstone and siltstone. The siltstone interbeds are about 300 mm thick, the sandstone intervals 600 mm thick. Above this a thick sequence of predominantly fissile and non-fissile, poorly-sorted, thin- and medium-bedded, pebbly siltstone with subordinate fine-grained, silty sandstone and sandstone continues as high as Unit 141. Bioturbation is common and is sometimes intense. Pebbles, both dispersed and in bands, are common. Significant fine-grained sandstone developments within this essentially siltstone sequence include Units 106, 111–116, 126–127, 132–133 and 135. Large cobbles and small boulders of quartzite and granitic rocks are conspicuous in Units 111–112.

Units 142–168 consist predominantly of thin- and medium-bedded, fine-grained, hard and compact, fissile and non-fissile, pebbly sandstone with minor, thin siltstone partings. Bioturbation is common and frequently gives the rocks a mottled appearance. Coarser-grained granule-sized quartz, feldspar and other clastic detritus characterises many of the sandstone beds. Unit 164 consists of massive-bedded, fine-grained, silty sandstone (5·18 m) with very thin (5 mm) siltstone partings. Units 169–171 consist of dark grey siltstone and siltstone with very thin ribs of silty sandstone. Pebbles and biogenic structures are common.

The uppermost beds (Unit 172) consist of dark grey, carbonaceous mudstone with occasional lighter-coloured siltstone bands and arenaceous convolute laminae. Nodular areas of convolute bedding with dimensions up to 600 mm x 300 mm are common. A few scraps of woody carbonaceous material also occur. The lower part of the sequence grades transitionally into 1·52 m of laminated sandy siltstone with the topmost 300 mm consisting of soft, striped beds of sandstone and siltstone. Individual laminae are 3–5 mm thick. Pebbles are sparse and always small. Worm tubes and other biogenic structures are present.

Unit 172, which has a total thickness of 6·4 m, has been designated as the type section of the Cygnet Coal Measures (Leaman and Naqvi, 1968; Banks and Naqvi, 1967). This is no longer tenable since recent drilling of the once productive coal section at Mt Cygnet [EN126183] has proved that the worked seam (among others) occurs within a sequence of massive- and cross-bedded, poorly-sorted, feldspathic sandstone (Farmer, 1979h). Unit 172 occurs below the coal measures sequence in the borehole and is here regarded as the final regressive phase of the marine and brackish marine Abels Bay Formation. At Sandrock Bay (formerly Coal Mine Bay) [EN077126] (plates 12,13) and elsewhere, the Barnetts Member of the 'Triassic' Springs Sandstone [sensu Leaman and Naqvi, 1967; Banks and Naqvi, 1967) is, in fact, the Cygnet Coal Measures (see later).

Fossils are uncommon throughout the type section but broken and rolled fragments of *Fusispirifer avicula*, *Sulciplica transversa* and *Ambikella* spp. occur in certain winnowed, pebbly bands. Broken *Astartila intrepida*, *Myonia*, *Stutchburia* and fragments of *Stenopora crinita* are often associated with the brachiopods. *Merismopteria macroptera* occurs abundantly at several levels in the upper third of the formation where articulated specimens of spiriferids, *Vacunella curvata* and the very large clam *Megadesmus grandis* also occur sporadically. The molluscans are probably in life orientation. Blocks and smaller fragments of fossilised wood also occur scattered throughout.

The Abels Bay Formation forms substantial areas of outcrop on Harveys Hill [EN090140], in the vicinity of Cradoc [EN023268] and Huonville [EN060380], on the higher mid-slopes of Mt Cygnet [EN115170], Mundys Hills [EN100260], Snug Tiers [EN170310] and the Woodbridge Hill–Heeneys Bluff area [EN140210] east of Nicholls Rivulet, as well as Collins Springs Hill [EN390370], South Arm [EN330353], Oyster Cove [EN220260], a down-faulted coastal strip from Deadmans Point [EN207237] to Peppermint Bay [EN195213], Birchs Bay [EN190196] and North Bruny Island. Everywhere it presents a monotonous sequence of poorly-fossiliferous, mottled, fissile and non-fissile, thin- to medium-bedded siltstone and fine-grained sandstone. Pebble- and cobble-sized clasts occur both as winnowed concentrations at many levels and scattered throughout. Worm tubes and other biogenic structures are common. Small-scale,
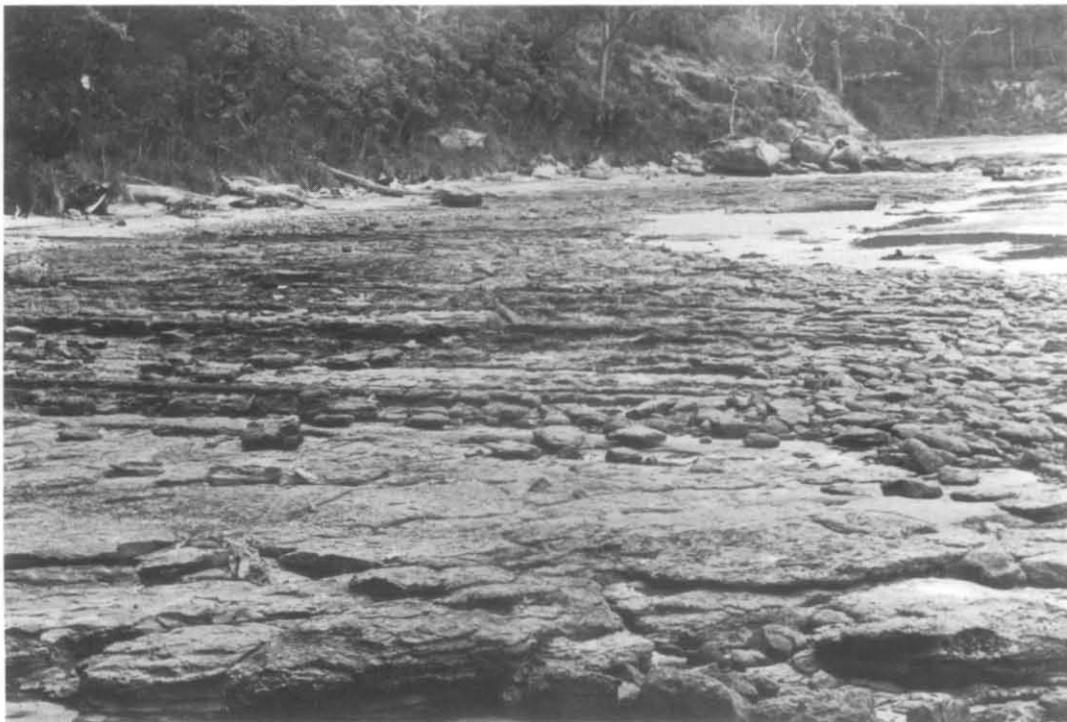
Plate 12. *Abels Bay Formation, Sandrock Bay.*
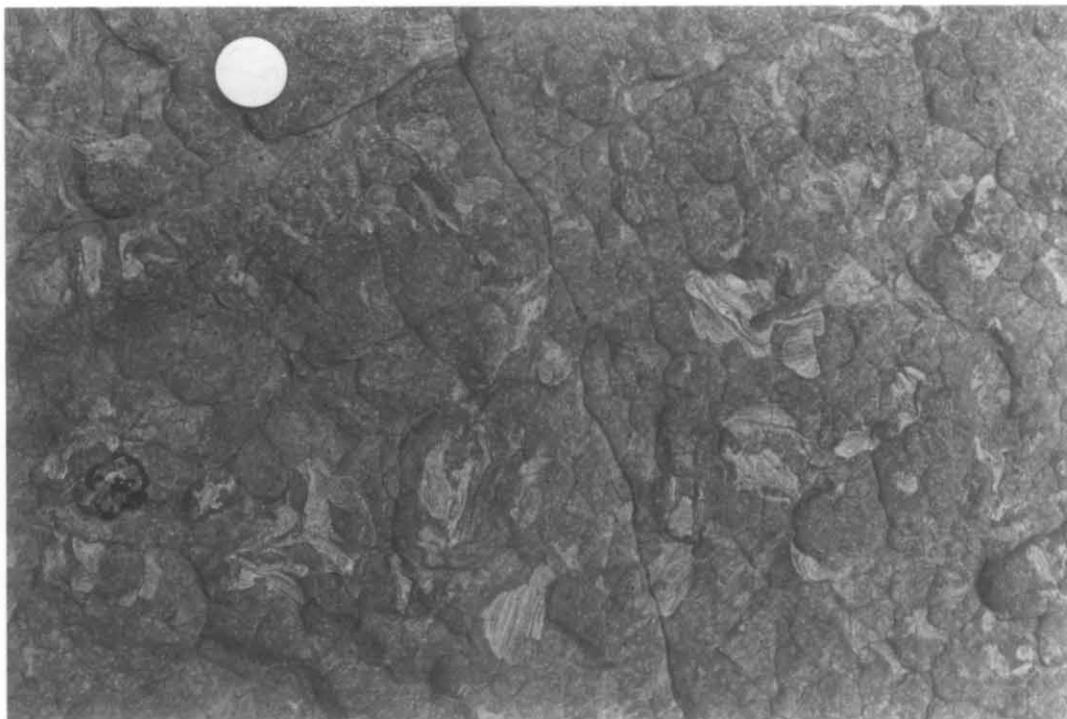
Plate 13. *Abels Bay Formation, Sandrock Bay. Hydroplastic structures in topmost beds.*

cross-lamination is present in some beds. Over much of the northern part of the map sheet the Abels Bay Formation and the upper part of the Minnie Point Formation are lithologically similar. The richly-fossiliferous horizon near the top of the Minnie Point Formation and the Risdon Sandstone, however, provide an invaluable field marker horizon. At Birchs Bay [EN197189] beds near the top of the formation contain an unusually high proportion of feldspathic material. The characteristic unit of carbonaceous mudstone and siltstone with convolute bedding structures at the top of the Abels Bay Formation is well exposed at Deep Bay [EN091153], south of Brooks Bay [EN027127], and at Yellow Point, Birchs Bay [EN197189].

Palaeontology and age

As noted previously, fossils are not common through most of the Abels Bay Formation. However, they occur in reasonable abundance through a zone 35–45 m below the top of the formation over a wide area in south-east Tasmania (Clarke, 1973). This horizon is well developed at the Blowhole and Flowerpot Point, Blackmans Bay [EN267381], and the coastal sections between South Arm [EN337358] and Cape Direction. A richly fossiliferous horizon 12–15 m below the top of the formation is known only at Yellow Point, near Birchs Bay [EN197189]. Forms recorded include:

Echinalosia ovalis (Maxwell)
Terrakea brachythaera (Morris)
Ambikella globosa (Campbell)
Ambikella magna (Campbell)
Ambikella cf. undulosa (Campbell)
Notospiriferid gen. nov. — like Notospirifer but with spinose micro-ornament and heavy umbonal cardinal ventral valve thickening
Fusispirifer avicula (Morris)
Sulciplica transversa Waterhouse
Pseudosyrinx sp.
Plekonella acuta Campbell
Fletcherithyris amygdala (Dana)
Fletcherithyris parkesi Campbell
Astartella sp.
Astartila intrepida (Dana)
Atomodesma (Aphanaia) sp.
Etheripecten leniusculus (Dana)
Megadesmus grandis (Dana)
Megadesmus gryphoides (de Koninck)
Merismopteria macroptera (Morris)
Myonia carinata (Morris)
Myonia triangulata (Waterhouse)
Pleurikodonta elegans Runnegar
Schizodus sp.
Stutchburia compressa (Morris)
Stutchburia costata (Morris)
Stutchburia cuneata (Dana)

'Stutchburia' edelfeldti (Etheridge)
Vacunella curvata (Morris)
Warthia micromphala (Morris)
Stenopora crinita Lonsdale
Gangamopteris sp.

This fauna with Echinalosia ovalis and Megadesmus grandis can be unequivocally assigned to the Late Lymingtonian Stage (Faunizone 10). Productids and strophalosiids are never common and molluscans predominate over brachiopods at most localities. An exception is at Birchs Bay [EN197189] where well-preserved terebratulids and notospiriferid gen. nov. occur in great abundance. This locality has also yielded a specimen of Plekonella acuta which is one of the few rhynchonellids known from the Permian of Tasmania. At Flowerpot Point [EN267381] the association of large numbers of articulated Merismopteria macroptera with large blocks of wood suggest that Merismopteria may have lived attached to logs. The wood may have been floating or lying on the substrate. The general rarity of marine fossils (apart from biogenic structures) throughout most of the Abels Bay Formation probably indicates restricted brackish water conditions. Even at those intervals where more normal marine salinities possibly prevailed, molluscans usually predominate over brachiopods.

[M.J.C.]

UPPER DIVISION

Rocks of the Upper Parmeener Super-Group are wholly of freshwater origin and consist predominantly of massive-bedded, quartz, feldspathic and lithic sandstone, with lesser developments of thinner-bedded siltstone, mudstone and thin, impure coal seams. Subordinate mud pellet and quartz pebble conglomerate also occur. The exposed portions are approximately 470–600 m thick, but no complete section is known. The Upper Parmeener Super-Group ranges in age from Late Permian to Middle or Late Triassic.

Five main areas of outcrop occur. These are:

(1) the area surrounding North West Bay from Blackmans Bay [EN265385] to Oyster Cove [EN220268], and the northern part of North Bruny Island [EN270290].

(2) the area between Woodbridge Hill [EN155220], Sandrock Bay [EN075125] and Middleton [EN200130].

(3) the area between Snug Tiers [EN150305], Herringback [EN113382] and Woodstock Hill [EN040290].

(4) the area west of the Huon River near Huonville [EN020360].

(5)   the area near Police Point [EN033118].

In each of these areas the oldest beds of the Upper Parmeener Super-Group can be observed to rest directly on the Abels Bay Formation, and the sequence passes upward to be everywhere capped by intrusive Jurassic dolerite. The youngest sequence of strata, which is about 290 m thick, is only exposed near Kaoota [EN133367] where it contains several thin, impure coal seams. The coal measures at Kaoota have been known for over a century (Thureau, 1881), and their *Dicroidium* flora (indicative of a Triassic age) was first recorded by Johnston (1888a). The coal measures at Mt Cygnet [EN132173] also drew early attention to the area (Thureau, 1881), and their Late Palaeozoic age based on their contained *Glossopteris* flora, together with their stratigraphical position immediately above the youngest glacio-marine beds of the Lower Parmeener Super-Group, was also established by Johnston (1888a).

Rocks of the Upper Parmeener Super-Group of the Kingborough map sheet have been grouped under three broad subdivisions. These are from the top downwards:

(1)   Kaoota Coal Measures — consisting dominantly of feldspathic and lithic sandstone with subordinate mudstone and thin workable coal seams and a Triassic macroflora (Rk).

(2)   Dominantly medium- to coarse-grained, quartz sandstone with subordinate mudstone and minor clay pellet and quartz pebble conglomerate (Rs).

(3)   Dominantly feldspathic sandstone with subordinate mudstone (Pf). This unit passes laterally into a coal measures facies with thin workable coals and a Permian flora — Cygnet Coal Measures (Pfc).

DOMINANTLY FELDSPATHIC SANDSTONE WITH SUBORDINATE MUDSTONE SEQUENCE (Pf)

In some areas this sequence overlies the glacio-marine Abels Bay Formation from which it is distinguished by the presence of well-sorted, current-bedded sandstone of freshwater origin, and by the absence of dropstones, marine fossils and biogenic structures in the mudstone beds. The high feldspar and/or matrix content of some sandstone beds, the presence of alternating feldspathic sandstone and mudstone beds, the presence of carbonaceous horizons, the fine- to medium-grained character of the sandstone beds and small

scale cross-bedding enable the separation of the sequence (Pf) from the overlying medium- to coarse-grained, quartz sandstone sequence (Rs). The feldspathic sandstone with subordinate mudstone sequence (Pf) passes laterally into a sequence with thin workable coals and a Permian flora; this sequence is the Cygnet Coal Measures (Pfc). These characters further distinguish the Cygnet Coal Measures from the overlying quartz sandstone sequence (Rs).

In other areas, as for example near Huonville [EN010358], the geological map shows the quartz sandstone sequence (Rs) as directly overlying the Abels Bay Formation. This situation arises where the soil, talus or vegetation cover is too thick to locate outcrops of the sequence (Pf), where the lithologies of the sequence (Pf) are not sufficiently distinct to separate from the lithologies of the quartz sandstone sequence (Rs), or where the sequence (Pf) is perhaps genuinely absent. In some areas where the sequence (Pf) has not been depicted on the map, as for example at EN090267 and EN030348, the basal beds of the quartz sandstone sequence (Rs) contain feldspathic sandstone.

Where present the sequence (Pf) and the Cygnet Coal Measures (Pfc) are generally 30–40 m thick, rarely 60 m thick. Near Nicholls Rivulet [EN119275] and in the Snug Tiers region [EN160315] they appear to be about 20 m thick.

The sequence (Pf) consists of feldspathic sandstone with layers crowded with abundant mica, graphite and carbonaceous flecks and fragments, and in some cases, interbedded shale, siltstone and mudstone. The sandstone is typically light grey to cream in colour, but weathers brown to buff and is occasionally mottled. Some sandstone is spotted grey-purple and brown. Exposures at Bull Bay [EN294293] on North Bruny Island include 6 m of sandstone; 13 m of soft, massive-bedded feldspathic sandstone overlying 0·6 m of black, carbonaceous shale east of Bligh Point [EN279296], and sandstone and siltstone 200 m further east. Near Cradoc Hill [EN056268] soft, deeply weathered feldspathic sandstone with black carbonaceous specks dispersed throughout is well exposed. The occurrence of 3–25 mm thick coal seams and coarse-grained sandstone and 'grits' reported by Nye (1931) may be close to this locality.

There has been considerable confusion as to which rock unit constitutes the Cygnet Coal Measures (Pfc). Early exploration and mining near Mt Cygnet [EN130170] revealed three thin coal seams in a sequence about 12 m thick (Thureau, 1881; Twelvetrees, 1902; Reid *in* Hills *et al.*, 1922; Bacon, 1983a). The uppermost seam was worked at the Mt Cygnet mine [EN126183] from where it thinned

from 1·03 m to 300 mm about 3 km north-east of Berrys Prospect. This seam was overlain by sandstone or thin carbonaceous shale, and the sandstone can still be observed near an old adit at EN142195. Although some early reports may not recognise the widespread faulting of the sequence, there seems to be general agreement that 7·70 m (Twelvetrees, 1902) or 6·30 m (Reid *in* Hills *et al.*, 1922) below the upper seam, a second 300 mm seam occurred, with a third 60 mm seam 3·70 m below the second seam. Thureau (1881) reported a sandstone post below the second seam. At Berrys Prospect 2·5 m of dull shale occurred below the upper seam and was underlain by 6·3 m of sandstone and then mudstone. Voisey (1938) described the Cygnet Coal Measures as a sandstone, siltstone and coal measures sequence. Subsequently Lewis (1946) applied the name Cygnet Coal Measures to grey carbonaceous siltstone which occurs at the top of the glacio-marine sequence in the Hobart area near Silver Falls Creek and Brushy Creek.

Upon cessation of mining at Mt Cygnet the area became revegetated and exposure is now very poor. In seeking a better exposed section of the Cygnet Coal Measures in the Cygnet area, Banks and Naqvi (1967) selected a sequence of grey carbonaceous siltstone with laminae and thin pods of sandstone at Sandrock Bay [EN075126] as a type section for the Cygnet Coal Measures. Their unit essentially conformed to the usage and character of the Cygnet Coal Measures as recognised by Lewis in the Hobart area. However, as mapping of the Kingborough map sheet progressed it became clear that the carbonaceous siltstone and fine-grained sandstone unit at Sandrock Bay was widely distributed, very uniform in character, and never contained coal seams. A fully cored borehole (NF85) at Mt Cygnet [EN126183] finally clarified the situation. It showed (Farmer, 1979*h*) that the coal seams at Mt Cygnet occur not in the carbonaceous siltstone unit previously defined as the Cygnet Coal Measures, but in a sequence of freshwater feldspathic sandstone and siltstone which occurs above. Thus Farmer (1979*h et seq.*) included the carbonaceous siltstone unit with abundant biogenic structures and dropstones within the glacio-marine Abels Bay Formation at the top of the Lower Parmeener Super-Group. The Cygnet Coal Measures were shown to occupy a basal position within the Upper Parmeener Super-Group. They are the lithostratigraphic unit defined as the Barnetts Member of the Springs Sandstone at Sandrock Bay by Banks and Naqvi (1967). The name Barnetts Member is thus redundant.

The fully cored borehole (NF85) at Mt Cygnet penetrated the old mine workings and proved a minimum thickness of 29 m for the Cygnet Coal Measures. Thin (50 mm) coal seams were found

1·53 m and 2·36 m below the uppermost worked seam, and a thicker (180 mm) seam occurs 4 m below the old workings. The coal seams are interbedded with black carbonaceous mudstone with plant fragments, and subordinate fine-grained sandstone and siltstone.

A similar association of rock types occurs in coastal sections 2 km south of Middleton [EN198114] (plates 14–16) where 170–220 mm of coal in part passes laterally into carbonaceous shale, and rests on about 2 m of laminated, dark cabonaceous shale. Coastal exposures immediately north of this locality consist of sandstone, black laminated siltstone with wash-outs and pebble conglomerate in places. Coal has been reported from the head-waters of Nicholls Rivulet [EN145502] and Randalls Bay [EN010117] (Reid, *in* Hills *et al.*, 1922; Thureau, 1881). Current exposures in the cliffs west of Randalls Bay exhibit sections up to 3·3 m thick of predominantly cosets of current-bedded sandstone which may overlie grey mudstone or shale and contain interbedded lenticular laminated shale and mud pellet conglomerate.

The most complete sections through the Cygnet Coal Measures are the fully cored borehole (NF85) at Mt Cygnet, and the coastal exposures at Sandrock Bay described herein (Appendix 4). The latter were described under the now redundant name Barnetts Member of the Springs Sandstone Formation by Leaman and Naqvi (1968) and Banks and Naqvi (1967). The borehole at Mt Cygnet proved a minimum thickness of the Cygnet Coal Measures of 29 m resting directly on the Abels Bay Formation. Both the top and bottom beds are exposed at Sandrock Bay but beach sand obscures part of the middle beds. The main coal bearing facies present in the borehole is not exposed at Sandrock Bay.

In places the basal unit at Sandrock Bay includes a thin lenticular bed of quartz pebble conglomerate overlain by sandstone with coalified wood fragments and other carbonaceous debris. Thin (70–100 mm) lenticular beds of black carbonaceous and coaly matter occur 0·9–1·2 m above the base of this sandstone (plates 17,18). Distinct patches of pink garnet occur in the basal unit (Banks and Naqvi, 1967). The succeeding 14–16 m of beds consist of current-bedded sandstone with siderite concretions with very thin siltstone interbeds, and lesser laminated, micaceous sandstone. Coal threads and stringers persist throughout the lowest current-bedded sandstone. Mud pellets are present in some layers. Banks and Naqvi (1967) noted a progressive reduction in feldspar content up through this interval (from 31 to 6%) and a corresponding increase in the quartz content (from 50 to 65%). The presence of ferruginous as well as sericitic
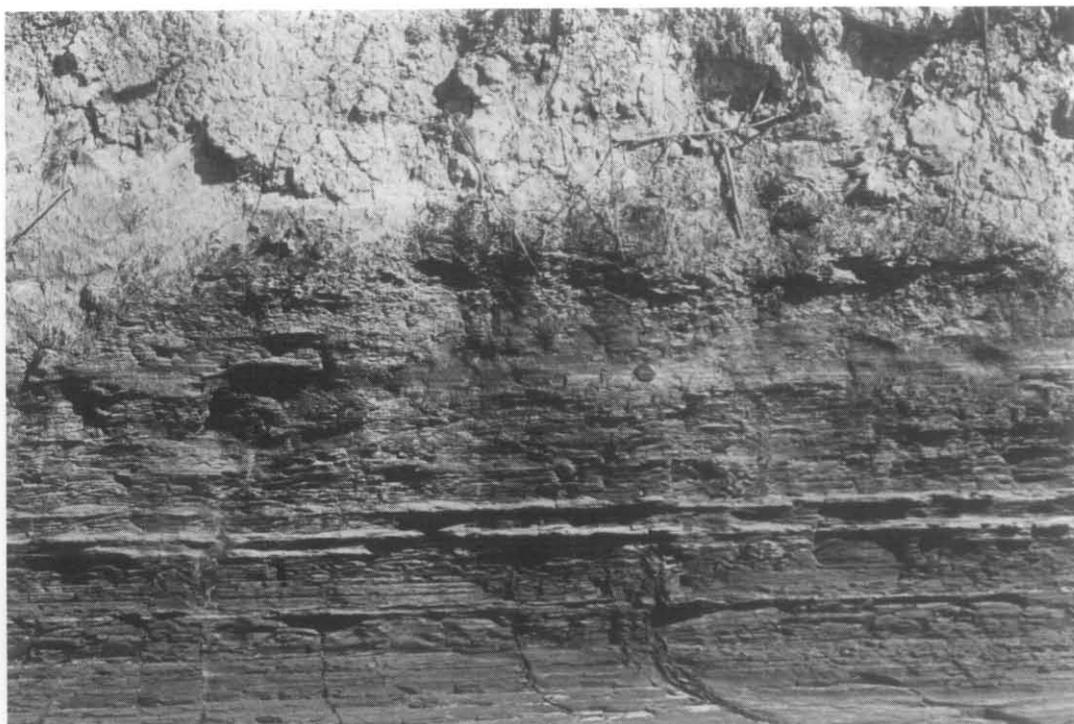
Plate 14. *Carbonaceous siltstone with coal seam indicated. Cygnet Coal Measures, Middleton.*
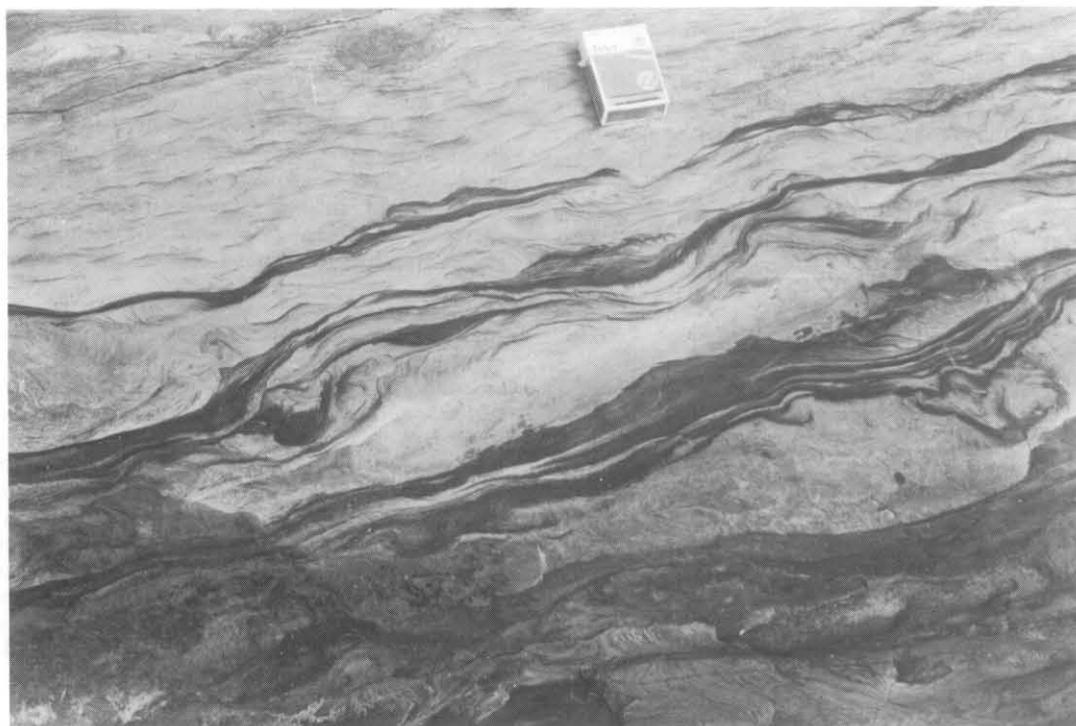
Plate 15. *Sedimentary structures, Cygnet Coal Measures, Middleton.*

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Plate 16. *Sandstone, conglomerate and carbonaceous siltstone. Cygnet Coal Measures, Middleton.*

cement or matrix totals 12–20%, muscovite 2–7% and lithic grains 0–5%. Much of the overlying 12–13 m interval consists of fissile, current-bedded sandstone containing quartz 80%, matrix 10–15%, feldspar 2% and muscovite 2%. The topmost unit is 1·5 m thick and consists of finely laminated and finely current-bedded, micaceous sandstone. Feldspar content is about 10% and the quartz and matrix contents are slightly less than in the underlying unit.

The cored sequence in the Mt Cygnet Borehole (NF85) differs from the Sandrock Bay section primarily in the presence of about 8 m of alternating black carbonaceous mudstone and thin coal seams, with subordinate grey siltstone and sandstone interbeds. Basal conglomerate is absent in the borehole section. Intervals of wispy-bedded or ripple current-bedded sandstone occur both above and below the interval with coal seams, and the feldspar and/or matrix content of the sandstone beds remains high throughout the borehole sequence. Other lithological associations exposed near the borehole site include interbedded medium-to fine-grained, current-bedded sandstone and grey shale and mudstone at EN148202, alternating 0·6 m thick sandstone and grey mudstone at EN147202, and alternating dark grey silty mudstone with laminated sandy siltstone and silty sandstone at EN126184. Massive outcrops of current-bedded and/or laminated sandstone occur at EN145202,

and outcrops with elephant skin jointing occur at EN131186.

Rocks similar to those of the upper parts of the Sandrock Bay section occur on the east side of Randalls Bay between EN102119 and EN104116 although more shale and siltstone are present. These rocks consist of fine- to medium-grained, current-bedded sandstone units 0·6 m thick or more, interbedded with laminated siltstone and mudstone.

Although ripple current-bedded sandstone intervals may be up to 4·5 m thick, laminated sandstone beds are seldom greater than 2·0 m thick. Cosets of current-bedding are rarely greater than one metre thick with the individual current-bedded layers typically 150 mm thick. Excellent examples occur at EN095116. Mudstone beds are generally less than 1·0 m thick. Current-bedding in the basal conglomerate at Sandrock Bay indicates currents flowing to 240° (Banks and Naqvi, 1967). Currents which deposited some overlying sandstone layers flowed to the south-east both at Sandrock Bay (Banks and Naqvi, 1967) and near Upper Woodstock [EN053306].

The Permian aspect of the flora of the Cygnet Coal Measures has been known for almost a century. Johnston (1888*b*) noted the presence of *Vertebraria australis* and *Gangamopteris spathulata* below the
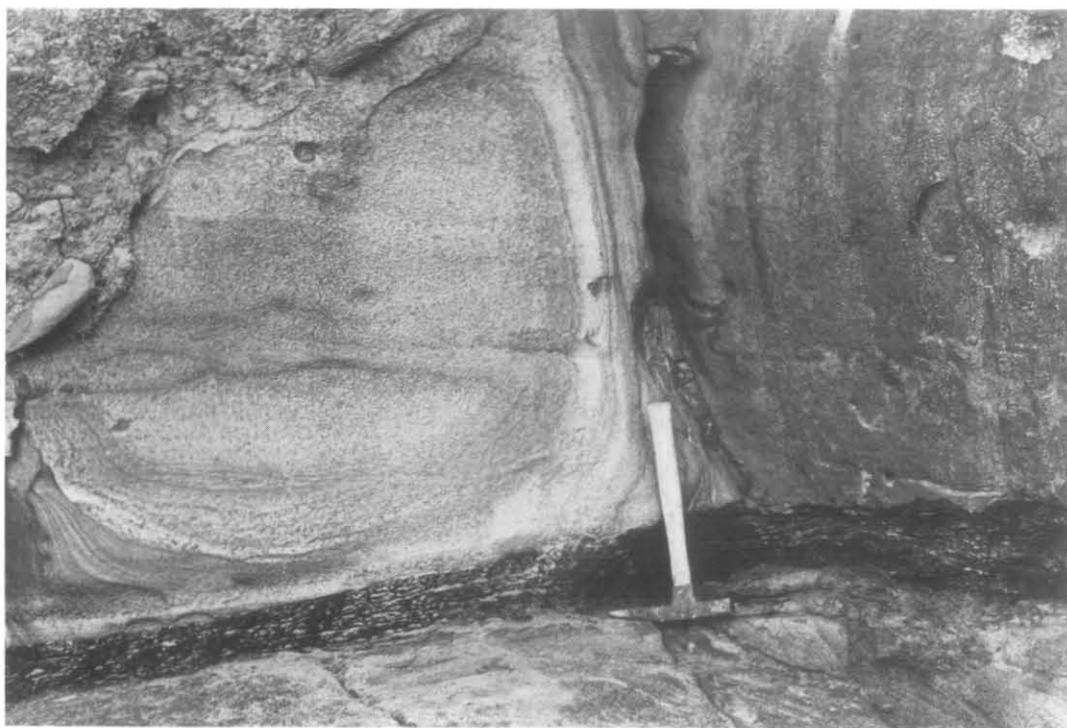
Plate 17. *Coal seam in mottled feldspathic sandstone, Cygnet Coal Measures, Sandrock Bay.*

Plate 18. *Liesegang rings in feldspathic sandstone, Cygnet Coal Measures, Sandrock Bay.*

upper coal seam at Mt Cygnet. Subsequently Johnston's record of *G. spathulata* was revised to *Glossopteris* sp. (Lewis, 1940). Palynomorphs from coal have been described from the Cradoc area (Dulhunty and Dulhunty, 1949) and listed with binomial nomenclature by Banks and Naqvi (1967). The palynomorphs indicate a Permian age in general, with *Didecitriletes ericianus* indicative of an age no older than Lower Stage 5b. *Dulhuntyispora* is exceptionally rare in Tasmania, but specimens have been recorded from similar stratigraphical horizons elsewhere in the State (B. E. Balme pers. comm.).

DOMINANTLY MEDIUM- TO COARSE-GRAINED, QUARTZ SANDSTONE WITH SUBORDINATE MUDSTONE AND MINOR CLAY PELLET AND QUARTZ PEBBLE BEDS (Rs)

This sequence (Rs) overlies the feldspathic sandstone with subordinate mudstone sequence (Pf) or the Cygnet Coal Measures (Pfc). Where these units have not been recognised, it overlies the Abels Bay Formation. It is not known whether this is due to facies change or disconformity. It is even possible that it is more apparent than real, a result of poor exposure caused by thick vegetation or a mantle of talus deposits which frequently obscures details of the bedrock geology on the steep slopes below the massive-bedded, cliff-forming quartz sandstone sequence (Rs).

Quartz sandstone predominates in this unit and frequently forms massive, cliff-forming outcrops. It is usually cross-bedded and often shows overturned cross-bedding. Less commonly the sandstone is laminated or structureless. In some developments the sandstone glistens because of crystal faces developed by overgrowth on quartz grains, and occasionally exhibits elephant skin jointing. When fresh the sandstone is grey or cream in colour but generally it weathers brown or, in some coarse-grained varieties, it leaches almost white. Humic matter may impart a dark chocolate colour. The grain-size ranges from fine to coarse. Coarse-grained sandstone is most common in the lower part of the sequence but is by no means confined to that part. Lutite beds and intervals of lutite interbedded with sandstone occur dispersed throughout the quartz sandstone sequence but are more common towards the top of the sequence where lutite may dominate over intervals as thick as 50 m. The quartz sandstone dominated sequence is about 220 m thick.

Although very minor mudstone and fine-grained sandstone occur within the basal 20 m of the quartz sandstone sequence (Rs), this interval consists primarily of medium- to coarse-grained, current-bedded sandstone. The succeeding 60 m interval is similar although some sandstone beds are laminated. The sandstone is usually white, cream or buff in colour. About 100 m above the base of the sequence (Rs) some sandstone beds are micaceous. Some examples of coarse-grained sandstone occurrences in the basal part of the sequence are:

Gordon [EN193116] — about 40 m above the top of the Cygnet Coal Measures

Snug Tiers [EN163311] — about 60 m above the top of the Cygnet Coal Measures

Cradoc Hill [EN051270] — directly above the top of the Cygnet Coal Measures

Woodstock [EN048311] — directly above feldspathic sandstone sequence (Pf)

Oyster Cove [EN208278] — 60–80 m above the Abels Bay Formation

Grey Mountain [EN078273] — about 60 m above the Abels Bay Formation

Snug Tiers [EN143278] — about 30–40 m above the Abels Bay Formation

The basal 13 m of the quartz sandstone sequence (Rs) is exposed on the foreshore at Sandrock Bay. Here the sandstone is medium- to coarse-grained and occurs usually as current-bedded units 450–680 mm thick with some beds alternating with 100 mm thick planar laminated beds. Some beds exhibit overturned current-bedding towards 160° (plate 19). The petrography of a thin section was described by Banks and Naqvi (1967) who noted that the sandstone was well sorted with quartz 80%, lithic fragments 10%, muscovite 5% and sericite 5%.

A notable occurrence of lutite occurs on North Bruny Island an estimated 90 m above the feldspathic sandstone and subordinate mudstone sequence (Pf). Beds of mudstone and alternating beds of mudstone and sandstone occur in coastal exposures between Bligh Point [EN262295] and near Woodcutters Point [EN257273]. Red mudstone is particularly prominent at Bligh Point. Here, on the southern side, 7 m of red mudstone is overlain by 6 metres of sandstone, whereas on the northern side 16 m of sandstone and siltstone overlies the red mudstone. Near the tip of Bligh Point the sandstone is coarse-grained, current-bedded and contains pebble beds. Pebbly sandstone also occurs at Langfords Point [EN261288] and west across the D'Entrecasteaux Channel a little over one kilometre north of Simmonds Point [EN235278].

Up to 220 m of dominantly quartz sandstone occurs at Heeneys Bluff [EN145197]. Outcrops

Plate 19. *Overturned current-bedding in quartz sandstone (Rs), Sandrock Bay.*

generally consist of medium-grained or medium- to coarse-grained, current-bedded sandstone which is pebbly in places. Some overturned current-bedding and elephant skin weathering is present but no shale developments were observed. Cliffs of massive- and cross-bedded sandstone up to 8 m high occur on the northern flanks of Mt Cygnet [EN141186], and more or less continuous exposures of sandstone up to 30 m thick occur at EN137185. Approximately 180 m of dominantly quartz sandstone occur on the northern side of Mt Cygnet between the Cygnet Coal Measures and the overlying dolerite sheet. Further south the base of the quartz sandstone sequence (Rs) is not exposed as it is truncated by a major dolerite dyke; however, at least 160 m of the quartz sandstone sequence (Rs) occur beneath the dolerite sheet in the headwaters of Deep Bay Creek [EN120155]. From north of Deep Bay Creek to Devils Royals [EN116147] the top 60 m of the sequence exposed beneath the dolerite sheet includes a variety of lutite lithologies, and in some places these occur in mixed float with soft sandstone. Rocks observed include purple, brown and grey, smooth mudstone which weather to a brownish chocolate colour and may contain plant impressions [EN116147]; soft brown laminated mudstone and silty mudstone, and some brown silty sandstone which weather to bluish and purple colours. Although not observed *in situ*, large boulders of very coarse-grained sandstone occur about 30 m below the highest mudstone outcrop.

The sandstone contains many pebbles of quartz 8–15 mm long and a few pebbles of slate or phyllite. It is not clear whether this lutite-rich interval is equivalent to part of the sequence at Heeneys Bluff or whether it overlies the Heeneys Bluff sequence. The presence of pebbly, very coarse-grained sandstone and lutite-rich intervals is similar to the upper beds of the dominantly quartz sandstone sequence (Rs) exposed at Dalys Hill (see later).

Lutite-rich intervals are also exposed beneath the dolerite sheet on the southern side of Devils Royals [EN114135], in road cuttings on the Channel Highway immediately east of the major dolerite dyke [EN110132], and on the east coast at EN106126. The coastal exposure consists of 13 m of mainly buff and brown coloured siltstone and is very similar to the Channel Highway exposures which consist of about 5 m of alternating beds of smooth, light brown mudstone with sandstone and siltstone. Some siltstone beds are red-purple in colour and subordinate grey carbonaceous siltstone also occurs. The sandstone beds are current-bedded and only a few hundreds of millimetres thick [EN110132]. The road cuttings extend eastwards to EN112130 and expose mudstone, some friable sandy siltstone and fine-grained sandstone. Further lutite developments occur towards Garden Island Creek [EN117125 and EN114128] and include red mudstone at EN118124. Close to one of these outcrops and some 6 m higher topographically,

coarse-grained sandstone with pebbles of quartz is exposed.

Within the valley of Garden Island Creek cliffs up to 25 m high composed of massive- and current-bedded quartz sandstone occur [EN145156], but additional outcrops of lutite are rare. For example, 13 m of quartz sandstone at EN130138 contains only a few shaley bands, and a few silty partings occur in sandstone cliffs at EN135139.

Significant exposures of the upper beds of the dominantly quartz sandstone sequence (Rs) occur at Dalys Hill [EN168127] where essentially the same sequence of lithologies is developed on both the eastern and western flanks. On Brittains Road at an elevation of about 80 m [EN144121] and again at 130 m [EN149121] micaceous, laminated silty sandstone occurs. At 130 m the silty sandstone passes up into red-purple, fine-grained micaceous siltstone. Brown and buff, micaceous siltstone and fine-grained sandstone occur along a branch road close to the 160 m contour. Several metres of tan coloured and red-purple siltstone beds with a thin bed of slightly bioturbated sandstone occur near the 180 m contour [EN154121]. The lutite-rich interval is succeeded at an elevation of about 205 m by a distinctive sandstone unit which is about 25 m thick and includes coarse- and very coarse-grained sandstone, pebbly sandstone and pebble conglomerate. Pebbles consist chiefly of white quartz and range up to 100 mm in length. Dolerite talus obscures most of the remaining interval below the overlying dolerite sheet but lithic sandstone is present just above an elevation of 300 m.

Fewer lutite outcrops occur on a track adjacent to Brittains Road, but include mudstone at EN149136 and siltstone at EN152132. Fine-grained sandstone predominates with subordinate micaceous sandstone in the intervening and surrounding areas between elevations of 80–180 m. Sandstone and mudstone float occur further north at EN156139 and EN159138.

It is possible that lithic sandstone continues through the saddle south of Dalys Hill, and lithic sandstone and mudstone is certainly present on the north-east side of Dalys Hill at an elevation of 290 m [EN172134]. At this locality the lithic sandstone similarly overlies coarse-grained, pebbly sandstone. The pebbly sandstone is identical to that occurring on the west side of Dalys Hill and includes pebbles of milky white quartz up to 60 mm long, and rarer quartz pebbles with a slight pink colouration. The pebbly sandstone forms a bench-like feature and is again well exposed at EN168139. Outcrops of coarse-grained sandstone [EN175121], pebbly, coarse-grained sandstone [EN175130], and pebbly sandstone [EN175139] may belong to this horizon.

The 100 m topographic interval beneath the pebbly sandstone outcrops on the east side of Dalys Hill shows both outcrop and float composed mainly of mudstone, siltstone and lesser fine-grained sandstone. The stratigraphic position of mudstone, siltstone and sandstone beds which extend up to an elevation of 350 m is uncertain [EN177145]. The stratigraphic position of pebbly, coarse-grained sandstone which occurs at a low elevation northwest of Dalys Hill [EN150142] is also uncertain.

The upper beds of the dominantly quartz sandstone sequence (Rs) may be exposed in the Pelverata [EN095338]–Kaoota [EN135366] area. Rodger (1957) noted an increase in the proportion of lutite beds in the upper part of the sequence here. At least 50 m of interbedded mudstone, siltstone and sandstone occur along and above Umfrevilles Road (between EN135370 and EN136360). The lutite beds range from massive to finely laminated and are commonly micaceous. Most lutite beds have weathered to yellow, tan and brown colours, but some carbonaceous beds are grey. The sandstone beds are current-bedded, rippled or laminated. Bioturbated and silicified sandstone 60 mm thick occurs at EN135369. Near the northernmost exposure float blocks of coarse-grained sandstone with granules and pebbles of white and pink quartz up to 10 mm long occur. These blocks may be derived from a correlate of the coarse-grained, pebbly sandstone at Dalys Hill. Further south the interbedded sandstone and lutite beds extend up slope topographically to within 10 m of the Kaoota Coal Measures without any indication of coarse-grained, pebbly sandstone; the contact may be faulted.

Blocks of thinly bedded, silicified and bioturbated, fine-grained sandstone, coarse-grained pebbly sandstone, and laminated quartz sandstone occur along the Pelverata Falls Track above an elevation of 220 m, and may similarly have been derived from the top beds of the quartz sandstone sequence (Rs). Nearby, siltstone crops out in Pelverata Creek at an elevation of 220 m, and a little lower, sandstone and mudstone occur. Some laminated quartz sandstone in this area resembles rocks present in the laminated quartz sandstone and lutite sequence (Rsq) mapped in the Oatlands area (Forsyth, 1984).

The upper beds of the quartz sandstone sequence (Rs) may also be present where purple mudstone and laminated mudstone crop out east of Pelverata [EN122340], and where interbedded sandstone, siltstone and mudstone is overlain by coarse-grained sandstone on the ridge top 1–2 km northeast of Pelverata.

The dominantly quartz sandstone sequence (Rs) is poorly exposed along much of the low-lying country

between Fleurtys Point [EN207180] and McKay Rivulet [EN195118] and deep weathering has occurred close to the mapped Tertiary rocks. In an excavation for a building 4 m of soft, deeply weathered, current-bedded, clayey sandstone occurs at EN208143. The sandstone is medium-grained, but some much coarser bands occur and the outcrop is interpreted as deeply weathered, feldspathic sandstone within the Upper Parmeener Super-Group. A little to the west on the Channel Highway coarse-grained, current-bedded and poorly-cemented feldspathic sandstone overlies light grey mudstone which in turn overlies current-bedded sandstone [EN207142]. A further 6 m of feldspathic sandstone and mudstone occur on a nearby secondary road [EN204141, EN206138]. The rocks at the above three localities resemble the Cygnet Coal Measures but insufficient supporting evidence was found to extend the outcrop northwards of the area indicated on the map.

North of Flowerpot some lutite outcrops occur including 3 m of purple and brown mudstone exposed on the Channel Highway [EN199178], mudstone at EN197187, 9 m of soft, brown weathering, blocky, banded and laminated mudstone and silty mudstone [EN196171], and flaggy and fissile siltstone and sandy siltstone [EN198167]. These occurrences are demonstrably in the dominantly quartz sandstone sequence (ᖇs).

South of Flowerpot Rock lutite-rich exposures dip westerly at 19–25° towards an elongate mass of dolerite [EN208167 to EN208162]. The nature of the lutite suggests perhaps that this may be a downfaulted section of the upper beds of the quartz sandstone sequence (ᖇs) overlain by a dolerite sheet. Such a model could be produced by an extension of the fault at Yellow Point [EN197190] southwards and would explain the absence of the Cygnet Coal Measures in the coastal sections south of Yellow Point. The lutite-rich exposures on the foreshore consist predominantly of banded, red, reddish-purple and purple siltstone and mudstone with beds and ribs of sandstone 100–150 mm thick. The sandstone varies from medium- to coarse-grained. At one exposure [EN208162] the sequence is 15 m thick and includes buff-coloured rocks. Eight metres of grey and brown weathering siltstone and sandy siltstone with more sandy beds and ribs possess a green (?ferrous) tinge at EN208167. Banded and laminated, brown, purple and chocolate coloured siltstone, and 100 mm thick sandstone ribs show ripple-marks on their upper surfaces [EN206167–EN207164].

Dark grey mudstone and sandstone occur at Tinderbox [EN263323]. Sequences up to 3 m thick of siltstone and mudstone interbedded fine-grained, ripple-marked sandstone occur at several localities

about Howden. including laminated grey mudstone and siltstone [EN232372] and purple siltstone and mudstone [EN248363]. Mud pellet conglomerate occurs at EN232374 and EN244340.

Outcrops 9–16 m high of current-bedded sandstone occur in coastal exposures from Oyster Cove through Coningham (plate 20) to Electrona [EN225270–EN215325]. Some thin (70 mm) mudstone beds occur interbedded with sandstone at Oyster Cove, but thicker (4 m) laminated grey-brown coloured siltstone occurs at Coningham where the overlying 6 m thick massive sandstone contains 300 mm of mud pellet conglomerate at the base. Interbedded sandstone, siltstone and laminated siltstone occur at Electrona [EN216328]. As vertebrate fossils are most commonly found in mud pellet conglomerate, the occurrence of this lithology near Flowerpot [EN195164] and on Bruny Island [EN236232] is also recorded.

Little palaeocurrent information is available. Current-bedding at Sandrock Bay is overturned towards 160°, and near Flowerpot [EN152203] towards 165°, 165°, 180°, 190° and 194°. Current-bedding near Heeneys Bluff [EN152203] indicates currents towards 110°.

Palaeontology

No identifiable plant fossils are known from the dominantly quartz sandstone sequence (ᖇs) but the occurrence of vertebrates at Tinderbox and Coningham is of particular significance. Cosgriff (1974) noted than an actinopterygian fish reported from Tinderbox Bay by Johnston and Morton (1891) closely resembles species of *Pteronisculus* from Early Triassic deposits of Madagascar and Spitzbergen. The fauna recorded by Cosgriff from Coningham includes *Blinasaurus townrowi* Cosgriff, *Chomatobatrachus halei* Cosgriff, *Deltasauras kimberleyensis* Cosgriff, *Ceratodus*, *Cleithrolepis* and *Saurichthys* and indicates an Early Triassic age intermediate between the *Lystrosaurus* Zone and the *Cynognathus* Zone (Cosgriff, 1974). The conchostracans *Cyzicus (Lioestheria)* sp. and *Palaeolimnadopsis tasmanii* Tasch occur at Tinderbox Bay [EN266325] and further support an Early Triassic age (Tasch, 1975).

KAOOTA COAL MEASURES (ᖇk)

The Kaoota Coal Measures consist dominantly of feldspathic and lithic sandstone with subordinate mudstone and thin, workable sub-bituminous coals. Fossil plants and silicified wood occur.

The sandstone generally contains less than 30% quartz (Rodger, 1957) and ranges from fine- to coarse-grained. Some sandstone beds contain mud
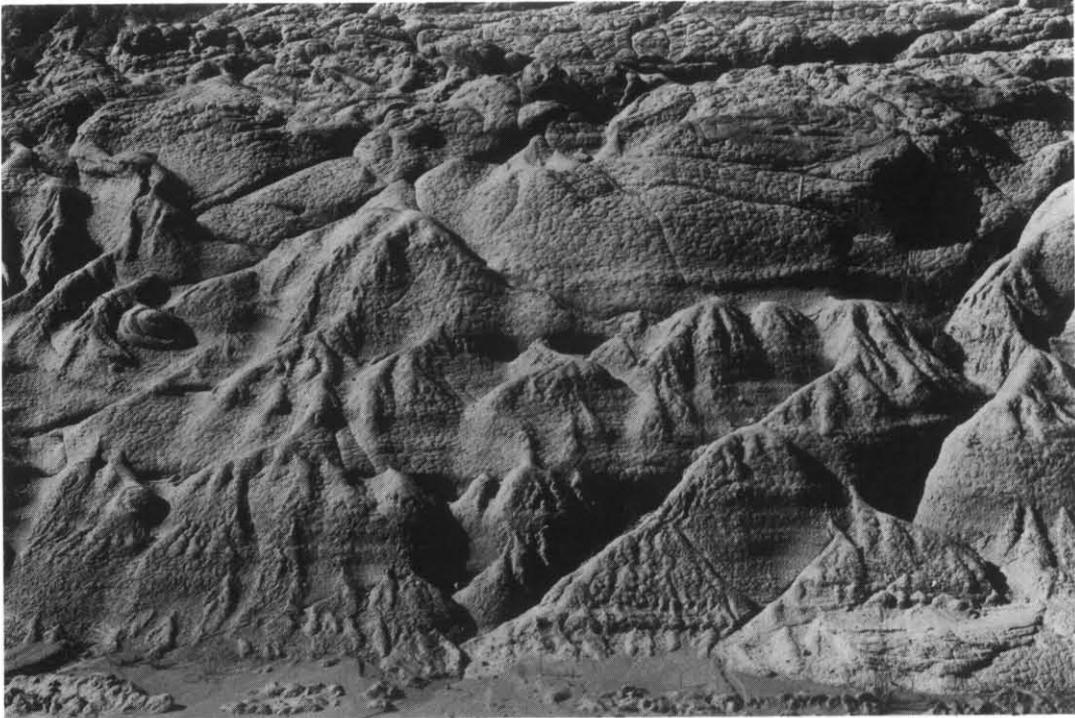
Plate 20. *Deeply-gullied mudstone and siltstone (ℛs) with elephant-skin weathering, Coningham.*

pellet conglomerate lenses and concretionary structures [EN138346]. Drilling carried out near the turn of the century proved 192 m of these beds above an intrusive dolerite body (Reid, *in* Hills *et al.*, 1922). A further sequence of 60–100 m occurs above the collar of the drill hole and is terminated above by another dolerite sheet.

The lower dolerite sheet intersected by the drill hole may have a surface expression [EN120358] where it appears to dip towards the north-west. The surface exposure is overlain by dark grey shale which is associated with white quartz sandstone [EN158358], and is overlain about 30 m higher topographically above the dolerite by massive cliffs of lithic sandstone. Although quartz sandstone blocks occur possibly beneath the dolerite in the bed of Slide Creek [EN114356], in general the contact between the Kaoota Coal Measures and the underlying dominantly quartz sandstone sequence (ℛs) appears to be faulted both south-west and south of Kaoota hamlet. Some of the intervening strata may be exposed [EN135364–EN133365]. At the last locality quartz sandstone dips steeply to the north-west away from a narrow dolerite dyke, and is faulted against or passes beneath massive lithic sandstone and shale.

The average composition of the Kaoota Coal Measures (calculated as an average for each borehole) from the logs presented by Reid (*in* Hills *et al.*, 1922) and Threader (1973) is: sandstone 79%, lutite 18% and coal 3%. Coal as a percentage of non sandstone is 14%.

Rodger (1957) considered the presence of mica to be signifcant stratigraphically in the Kaoota Coal Measures as mica appears to be present only in the shale bands of the basal 46 m of the feldspathic sandstone sequence.

The leaves *Heidiphyllum elongatum* and *Cladophlebis australis* are present (Rodger, 1957) and indicate a Middle to Late Triassic (Norian) age. In addition Johnston (1888a) listed *Thinnfeldia obtusifolia* and *Sphenopteris lobifolia*.

The Kaoota Coal Measures may be more widespread than indicated on the map but exposure is always poor. Lithic sandstone may occur continuously from EN138346 to EN137365 beneath the dolerite talus, and possibly extends a little way east of the saddle [EN143353]. The Kaoota Coal Measures may extend west of the coal workings, and may occur beneath the dolerite sheet which forms Herringback to the valley of Flynns Creek. Lithic sandstone and shale crop out at EN102367 and another small outcrop of feldspathic sandstone occurs at EN098369, but for most part of the area is covered with a thick mantle of talus. By reference to the land title maps an adit on a coal seam described by Thureau (1881) was probably located

in Flynns Creek near EN097363. Baked ?lithic sandstone may underlie the Herringback dolerite near Parsons Creek [EN106375]. Among the Department of Mines coal collection held in 1945 were coal samples labelled Parsons, Huon which may have been collected from Parsons Creek.

Similar lithic sandstone to that which occurs in the Kaoota Coal Measures, also occurs near Dalys Hill, but there is no evidence of coal and the rocks have not been included in the Kaoota Coal Measures on the map.

A more detailed account of the coal workings and coal types is given under economic geology.

[S.M.F.]

TERTIARY

At the close of Mesozoic times or very early in the Tertiary Period Tasmania underwent a period of pronounced faulting which resulted in the formation of a series of NW-trending horst and graben structures. A low angle unconformity separates the Tertiary rocks from the underlying older rock sequences. Considerable thicknesses of non-marine conglomerate, sandstone and claystone are known to have accumulated in elongate basins formed in these grabens. The Derwent Valley follows the course of one such graben, and geophysical evidence indicates the presence of considerable thicknesses of Tertiary sedimentary rocks at various localities which include the northern end of the D'Entrecasteaux Channel, immediately offshore at Middleton [EN210130], and underlying the isthmus between North and South Bruny Island.

The major developments of Tertiary rocks on land within the Kingborough map sheet represent erosional remnants of infill of the pre-Tertiary landscape peripheral to the main graben. The principal areas of outcrop within this marginal region include the Coffee Creek–Margate–Electrona area [EN220330], Oyster Cove [EN210265], Trial Bay [EN200240], Peppermint Bay [EN192210] and the coastal strip between Fleurtys Point [EN204178] and Middleton [EN200117]. Substantial developments occur about Huonville [EN004380] with smaller outcrops at South Arm [EN405380], north of Deep Bay Point [EN084163] and at Elizabeth Point [EN086152]. Much of North Bruny Island was also probably once deeply covered by several hundreds of metres of Tertiary rocks. Most of these rocks have long since been removed by erosion and now only scattered remnants of the original cover are preserved.

The climate throughout much of the Tertiary period appears to have been hot, wet and subtropical to tropical. This is reflected in the weathering patterns of the rocks and the development of ferricrete and lateritic bauxite. Where older rocks are exhumed from below Tertiary cover by later erosion they almost always show the deep chemical weathering so typical of tropical climates.

Basalt and associated pyroclastic rocks (and greybilly) are often present within the sedimentary sequence. The principal areas of outcrop are Coffee Creek–Margate [EN220330], Tinderbox [EN260325], South Arm [EN405380], Kaoota [EN140365], Huonville [EN045387] and North Bruny Island [EN302205].

SANDSTONE, SILTSTONE AND CLAYSTONE (Ts)

Characteristically the Tertiary freshwater sequences consist of poorly-consolidated, ill-sorted and usually deeply weathered conglomerate, sandstone, siltstone and claystone. Regional dips are very low but large-scale cross-bedded units exposed in the Kingborough Municipal Tip south of Margate [EN114343] dip to the west at 15–18°. Much of the Tertiary detritus appears to have been derived from Triassic sandstone, and where intersected (as for example in boreholes NF50 and NF51 at the head of North West Bay) the underlying Triassic rocks are deeply weathered.

On the Huon river south of Ranelagh [EN026376] about 5 m of boulder beds rest on an uneven surface of the Deep Bay Formation and are overlain by basalt. Nearby, at EN026375, the boulder beds rest on fairly well-consolidated sandstone. The boulder beds are predominantly composed of well-rounded dolerite clasts but other rock types also occur.

Near Woodbridge [EN192210] the dolerite is deeply weathered to a mottled reddish pink and white lateritic clay and is associated with subordinate poorly consolidated sandstone and siltstone and a small area of silicastone lag.

At the Oyster Cove crossroads [EN197272] a substantial claypit is being worked in white and pale grey, poorly-consolidated siltstone and claystone (plate 21).

A geophysical survey near Middleton (Leaman, pers.comm.) indicates that the Tertiary sequence there is at least 75 m thick.

On North Bruny Island only a few small areas of a once much more extensive Tertiary cover remain. Outcrops of poorly-bedded, ill-sorted sandstone and conglomerate can be seen in a small, disused quarry on the eastern side of the road a little to the

north of D'Arcys Lagoon [EN298123], and also on a small point about half a kilometre south of Smootheys Point [EN310164]. There are silt- and clay-grade rocks at high-water mark in Great Bay [EN313177], and somewhat better siltstone outcrops occur in roadside cuttings at the northern end of Nebraska Beach near Dennes Point [EN282308] where occasional small carbonaceous fragments are partly coalified.

At the northern end of Harts Hill [EN205345] near Margate a random jumble of very highly weathered and rotten blocks of limestone with subordinate bedded marl and *terra rossa* may represent a sink hole or spelean deposits possibly formed as a result of Tertiary weathering (plate 22).

BASALT AND ASSOCIATED PYROCLASTIC ROCKS (Tb)

Basalt and associated pyroclastic rocks are well developed in the Kingborough area although areally they are very limited in their distribution. The principal occurrences are at Coffee Creek–Margate [EN210366], Tinderbox [EN260325], Kaoota [EN140365], South Arm [EN405380] and in the Huon and Mountain Rivers near Huonville [EN045387] Each occurrence represents a discrete eruptive centre (see later).

Immediately south of where the Channel Highway crosses the North West Bay River at Margate [EN214366] the eroded flank of the Margate volcanic centre is well exposed. The rounded hillock known locally as the 'Margate Meteorite' is an erosional residual of volcanic ejectamenta shaped by the North West Bay River as it cut down through the volcanic centre. It is composed of pyroclastic ejectamenta or tephra. The tephra piled up around the vent as continued explosions ejected molten lava high into the air. Some of the larger pieces, which are more than one metre across, show flowage tails formed by streamlining as they were airborne before they came to rest and solidified. Excellent examples of twisted volcanic bombs lying in place where they fell amongst the tephra were abundant but many of the best have since been removed. Some of the volcanic bombs enclose a kernel of country rock torn from the side of the vent and wrapped in lava as it was erupted skywards. The rapid cooling during flight chilled much of the tephra into dark glassy basalt fragments. These are now weathered to rusty coloured rock, pigmented by oxidised iron minerals.

The exact site of the original vent is obscured by superficial deposits but it was probably a few hundred metres north of the present course of the North West Bay River.

At the Longley Road junction [EN210365] outcrops of massive basalt within the tephra indicate that a more substantial lava flow broke out that way. In line to the south-east, a small remnant of basalt fills an old valley side and has baked and silicified underlying sands into greybilly. This may mark the old course of the flow as it made its way out through Dru Point [EN227360]. Inland, upstream along the North West Bay River and the Margate Rivulet, a capping of massive thick basalt forms the higher ground above the tephra. It formed as a strong out-pouring of lava spread out over the older tephra and filled up the pre-existing valley to a depth of more than 50 m. This lava cooled more slowly to a dense crystalline basalt, and in places developed cooling joints and columns.

On the northern margin of the sheet at EN223391 an old Tertiary valley filled with basalt and associated pyroclastics is well exposed in road cuts. The southern wall of the valley slopes at 50–60°. These developments originated from the Doctors Hill centre on the Hobart sheet (Moore, 1979) and continued southwards in the region of Coffee Creek to flow into North West Bay where coalescence with the flows from the Margate vent may have occurred east of Dru Point. In a borehole (NF50) near Coffee Creek [EN229379] the basalt was proved to rest on 23 m of greybilly, sand and clay which in turn rest on deeply weathered Triassic sandstone. In a detailed drilling programme associated with the Whitewater Creek dam sites Moore (1979) has demonstrated the presence of a valley cut into basalt which was then refilled with further basalt, pyroclastics and sediments. The history is therefore complex in detail but at least two periods of erosion and deposition are implied.

A third centre occurs at Tinderbox [EN260325]. Here the basalt is not associated with any sediments. In cuttings in the Howden–Tinderbox road a substantial flow, fed from a vent north of the road, is well exposed.

Basalt and basalt lag cover a substantial but localised area near Kaoota [EN140365] but exposure is poor.

In the Huon River [EN027378] massive basalt rests on several metres of dolerite boulder beds, and a little further north basalt crops out in Mountain River [EN035377, EN045386]. These occurrences are probably related to an eruptive centre southwest of Grove on the Hobart map sheet.

On North Bruny Island only a small area of volcanic rocks has survived erosion. This is located to the west of the Main Road about half a kilometre south of its junction with Trumpeter Road [EN303206]. The rocks are mainly pyroclastic and consist of basaltic blocks, ash and ejected
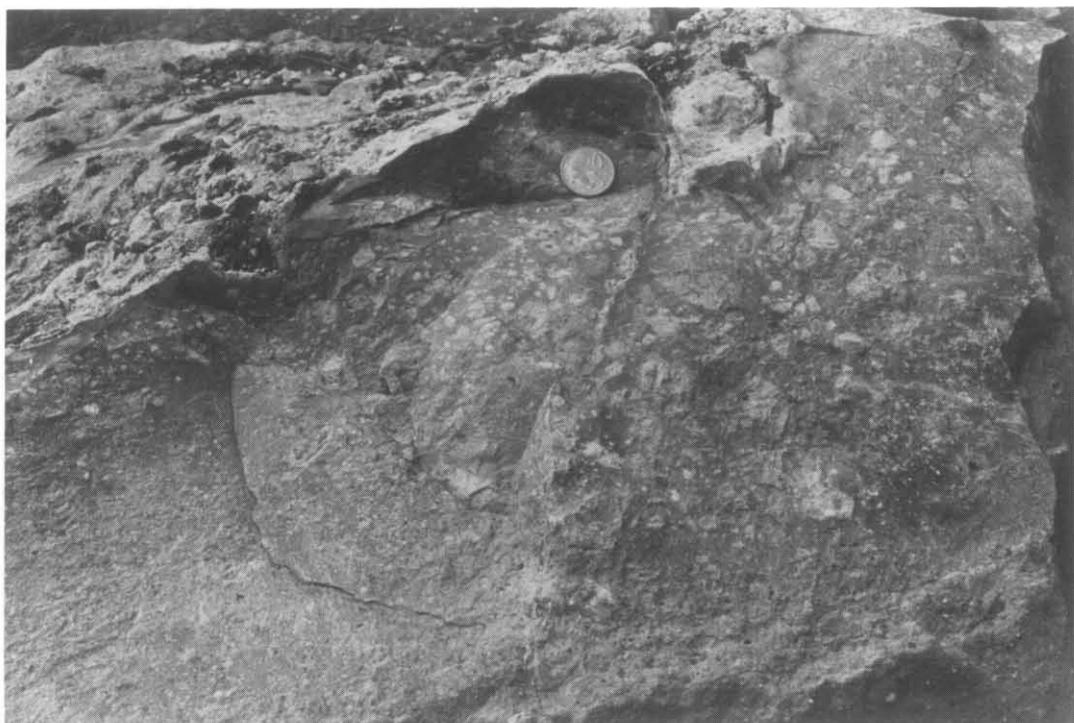
Plate 21. *Tertiary silicastone, Elizabeth Point, Deep Bay.*

Plate 22. *Brickpit in deeply weathered Tertiary claystone, Oyster Cove.*

debris. At the time of mapping they appeared to overlie substantial developments of greybilly and ferricrete. Relationships have since been obscured by the dumping of large amounts of granophyric dolerite in recent road improvements.

SILICASTONE (GREYBILLY AND SILCRETE?) (Tq)

These rocks consist of quartz-rich sand, granule conglomerate and pebble conglomerate cemented together into a very hard mass by secondary amorphous silica. They are usually white or pale grey in colour and are characterised by their extreme hardness, conchoidal fracture and glassy appearance. The non genetic term silicastone is used in the first instance since greybilly is thought to have been formed by the passage of molten basaltic lava over superficial deposits of water-logged sand and gravel, whereas silcrete is believed to result from the formation of a duricrust in a hot, humid climate; and both modes of formation are possible for particular developments on the Kingborough map sheet.

Although individual outcrops of silicastone are often small and discontinuous, they are both widespread and numerous. In the Coffee Creek–Margate–Electrona, South Arm and Huonville areas the silicastones are intimately associated with the basalt and may be reasonably inferred to be greybilly. Elsewhere, as for example at Oyster Cove, Kettering, Deep Bay Point, Elizabeth Point and much of North Bruny Island, there is no evidence of basalt. If these developments are greybilly then inferentially it follows that the basalt must have once had a more widespread distribution. Substantial areas of basalt may not have survived the intense chemical weathering of the tropical climate in Tertiary times.

Silicastone is excellently exposed in cliff and shore platform sections at Deep Bay Point [EN084162], Elizabeth Point [EN086152] (plate 23), Electrona [EN217340], and Oyster Cove [EN213265]. In all instances the silicastone consists of very hard sandstone with pebbly patches. Silicification is not uniform throughout and some parts are only partly silicified and have the texture of a normal medium- to fine-grained sandstone. The most silicified parts have the texture of chert, a glassy appearance and a conchoidal fracture. They are frequently nodular or irregularly pillow-shaped in form and sometimes individual pillows may coalesce to produce an irregular sheet-like form. In the coarser conglom-eratic developments the clasts are less readily discernible within the areas of intense silicification than they are in the surrounding less affected areas. At Deep Bay Point at least 15 m of silicastone occupies a valley in the Abels Bay Formation and

Jurassic dolerite. The south-west wall in the Abels Bay Formation is well exposed and slopes steeply at 45–60°.

On North Bruny Island outcrops of silicastone are well exposed at various points around Great Bay [EN300170] and also at the northern end of Barnes Bay [EN275256].

FERRICRETE (Tf)

On North Bruny Island ferricrete has been mapped marginal to basalt. The ferricrete is highly variable. It is generally deep red or reddish brown in colour but ochreous developments also occur. Some ferri-crete is probably lateritised sandstone whereas pisolitic varieties usually contain detrital quartz and other rock fragments up to granule size. In some instances the ferricrete occurs as concentric layered shells of ochreous material which range in colour from red to orange, yellow and brown. Occasionally some of the spheroids are hollow. The distribution of the ferricrete on North Bruny Island suggests that it is older than the basalt but this has not been confirmed by direct observation of the stratigraphic relationship.

Ferricrete is formed at or near the surface of sand, gravel and clay deposits by heavy cementation by iron oxide derived by oxidation of percolating iron-rich solutions. Rocks of this type usually occur in tropical areas where the climate is characterised by hot, dry winters and hot, wet summers.

Excellent outcrops of ferricrete can be seen on the foreshore at the extreme northern end of Great Bay [EN300193] and paddocks on both sides of the Main Road immediately north of the bay are liberally littered with large blocks of similar material. Ferricrete also forms red sheet-like cappings on a number of small hills between the Main Road and Trumpeter Bay [EN315210]. Road metal derived from several shallow scrapes in the area gives the road a deep red colour.

Ferricrete derived from dolerite boulder beds (Tfd) is well developed in the Robinsons Hill area [EN270203] north of Missionary Bay, and is inferred to be of Tertiary age.

[M.J.C.]

QUATERNARY

The Quaternary deposits of the region include fluviatile, aeolian, slope, and possibly marine sediments. There are also Quaternary lag deposits after Tertiary basalt, silicastone and ferricrete.
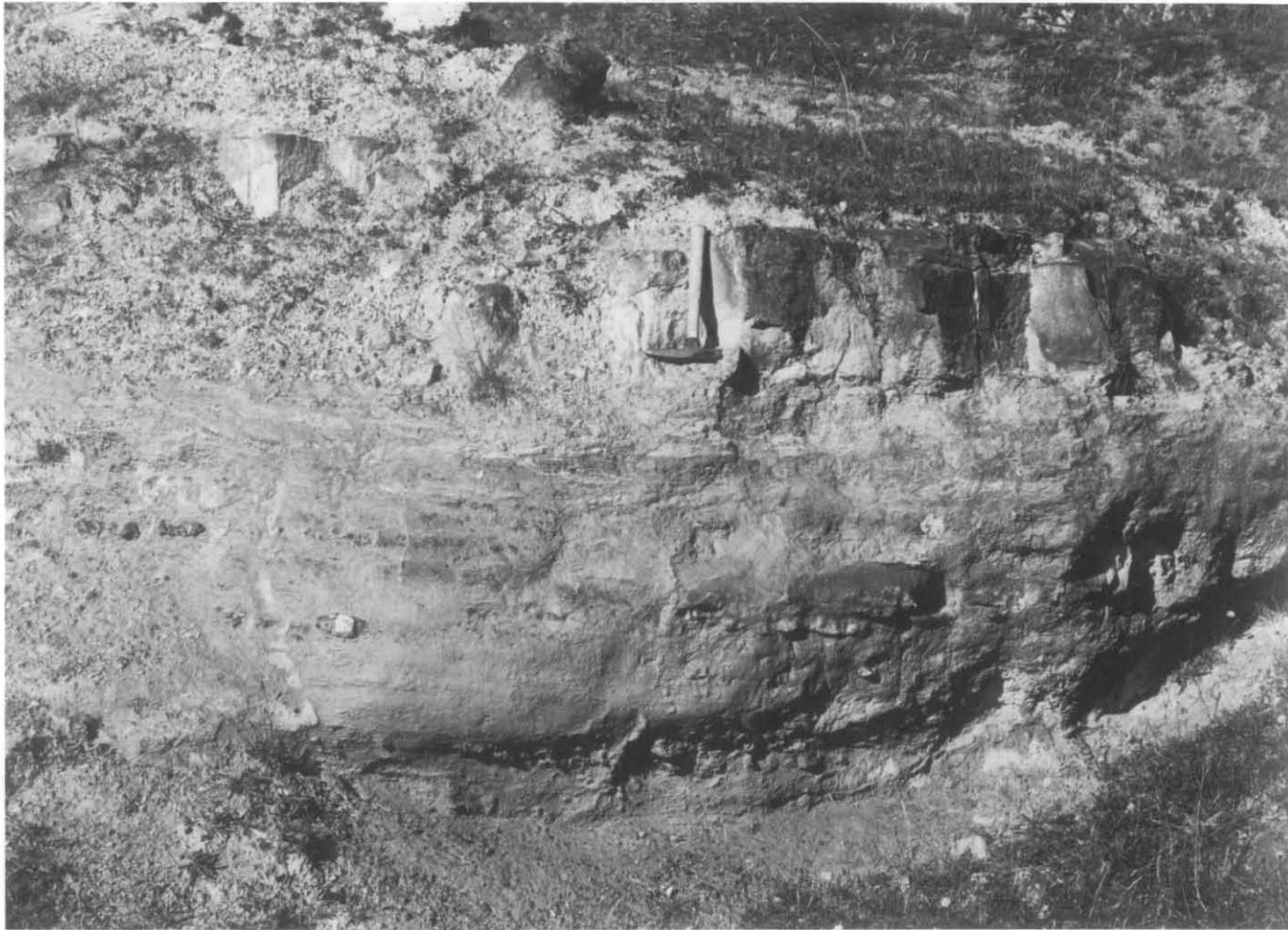
Plate 23. *A jumble of blocks of Harts Hill Limestone, marl and* terra rossa. *A possible spelean deposit or sink-hole formed as a result of Tertiary weathering. Northern end of Harts Hill, Margate.*

Although a strong palaeosol occurs at a few localities, the overall lack of good sections through the Quaternary deposits precludes the confident determination of a precise stratigraphic framework for the region.

GRAVEL AND BOULDER BEDS (Qg)

Deposits grouped in this subdivision were mapped along the Huon River near the western margin of the map sheet; as localised deposits on the Cygnet peninsula (plate 24), in particular near Poverty Point [EN040150]; in the Randalls Bay area [EN090120]; and along the lower reaches of the North West Bay River, and at Margate [EN225360]. A primary distinction has been made between deposits composed predominantly of siliceous clasts (Qgs), and those composed predominantly of dolerite clasts (Qgd).

Along the Huon River siliceous and doleritic gravels occur up to heights of more than 40 m, and occur above a prominent river terrace which reaches a height of about 10 m above the present river level. The gravels are moderately well-sorted and contain rounded clasts generally less than 150 mm in diameter. The deposits are weathered and contain significant amounts of secondary iron oxides. Where present, dolerite clasts are usually decomposed. These deposits represent the dissected remnants of old terraced gravels which formerly choked the Huon River and are similar to deposits in the Derwent River which are probably of pre-Last Interglacial age (Colhoun, in Leaman, 1977).

More problematical are deposits in the Randalls Bay area where semi-consolidated siliceous gravels are moderately well-sorted and contain clasts less than 100 mm in diameter. Sandy lenses occur within the gravels, and where observed, dip in a landward direction. These deposits contain incipient joints and may represent early Pleistocene river deposits.

At Poverty Point siliceous gravels are well sorted and contain clasts less than 80 mm in diameter. Imbrication of the long axes of individual cobbles dips gently towards the sea, which suggests that the deposit is possibly of marine origin. The deposit occurs up to a maximum height of a little over 20 m which is consistent with known deposits of Last Interglacial age in other parts of south-east Tasmania (Van de Geer et al., 1979).

Deposits composed almost entirely of dolerite clasts occur in the lower reaches of the North West Bay River. Clasts may reach 500 mm in diameter. The clasts are often completely decomposed, and the deposits occur up to heights of about 30 m, which suggests a correlation with the predominantly siliceous gravels of the Huon River near Huonville.

SCREE AND TALUS (Qt)

A distinction based on rock types (dolerite, syenite, Lower Parmeener Super-Group and Triassic rocks) has been used to differentiate the slope deposits of the map sheet. All are essentially of local derivation. It should be noted that slope deposits are more extensive than has been indicated on the map as priority has been given to bedrock geology.

Significant deposits of dolerite talus occur in the rugged country to the east of Snug Tiers, as for example north of the Falls Hill [EN120330] and south-east of Chicks Perch [EN100360]. Angular blocks of dolerite up to 4 m in diameter occur in these deposits. The dolerite blocks have very thin weathering skins which suggests that the deposits were produced during the Last Glacial stage.

Slope deposits are found associated with intrusive Cretaceous syenite in the Mt Mary [EN047194] and Mt Windsor [EN025188] areas south-west of Cygnet. The deposits consist of angular blocks of syenite usually less than 250 mm in diameter, and often supported by a clay matrix. The topography of the area has a distinct, but subtle, hummocky appearance, and probably preserves the old solifluction flow surfaces. Although the area has a maximum height of less than 400 m it is considered that the highly jointed nature, and the abundance of intrusive bodies, made them highly susceptible to the action of mobilisation by freezing and thawing of percolating waters, probably during the Last Glacial stage. It is possible, however, that similar deposits may have formed during other glacial episodes earlier in the Pleistocene.

West of Ranelagh [EN020380] slope deposits composed of Lower Parmeener Super-Group rock fragments less than 750 mm in diameter, apparently overlie siliceous gravels (Qgs). Although the stratigraphic relationship cannot be proved, it is considered that the talus is younger than the gravels in this area. There is no evidence of undercutting of the talus by the gravels which would be expected if the gravels were younger than the talus.

BLOWN SHEET SAND DEPOSITS (Qs)

Aeolian coversands are extensive on Bruny Island (e.g. Wilson Hill area [EN302137]) and in the South Arm area [EN340350]. Two broad subdivisions are recognised by the degree of soil development. On Bruny Island and to the east of Collins Springs Hill [EN395365] on the South Arm peninsula, the sands are essentially featureless and no distinct dune morphology is present. The sands are well sorted and fine- to medium-grained. Occasionaly high-angle cross-bedding is present. In all cases a podzol soil type has developed on the

Plate 24. *Quaternary gravels, Drip Beach area.*

sand, and consists of a dark humic-rich A1 horizon, a bleached A2 horizon, and an iron-rich B2 horizon. In areas with poor internal drainage a groundwater podzol may form. This has a thicker A1 horizon than the normal podzol, a thinner A2 horizon and a very thick B2 horizon ('coffee rock'). It is considered that the coversands were deflated from the exposed bed of the Derwent River and D'Entrecasteaux Channel during colder glacial climatic phases of the Pleistocene, but it is impossible to allocate a more precise age.

A younger series of aeolian sands occur in the South Arm area to the east of Half Moon Bay [EN340370] and extend through the settlement at South Arm to immediately east of Fort Hill [EN343345]. Dune topography is preserved in this area and the sands display little, if any, soil development; a Holocene age is indicated. Broken shells are sometimes present within the sand bodies and were presumably blown into their present location. In a dam situated one kilometre north of South Arm [EN340364] unleached dune sand is seen to overlie an older, strongly-podzolised coarse sand.

STABLE AND MOBILE DUNE DEPOSITS (Qd)

Dune sands occur associated with present beaches in the South Arm area (*e.g.* Half Moon Bay [EN337370]) and on Bruny Island (*e.g.* Dennes Point [EN276300]). The sands show little, if any, soil development. Carbonate rhizomorphs are common in recently deflated areas.

RAISED BEACH DEPOSITS (Qr)

Deposits classified as raised beaches were mapped in the South Arm area [EN355355], on Bruny Island (*e.g.* Great Bay at [EN307194]) and locally, on the western side of D'Entrecasteaux Channel (*e.g.* Trial Bay at [EN203240]).

These deposits have formed in areas marginal to present beaches and consist of a series of low beach ridges that may contain broken shells, and which display minimal soil development. Maximum soil development observed was leaching of the topmost 300 mm.

The degree of soil development and proximity to present beaches indicates that the deposits are Holocene in age and that they must have formed

since sea level reached its present height about 6 000 years ago.

In an excavation in a disused sand pit 2 km south-west of Calverts Lagoon [EN385359], beach ridges are seen to overlie havily podzolised beach sands which are probably of late Pleistocene age.

BEACH AND TIDAL FLAT DEPOSITS (Qb)

South-east Tasmania is a microtidal area with an average tidal range of 1.2m. Beaches have formed in response to this environment and are well developed on Bruny Island [EN305185] and in the South Arm area (*e.g.* Half Moon Bay at [EN336370]). Extensive tidal flats are present in Ralphs Bay [EN360360] where they are over one kilometre in width at low tide. Similar but less extensive deposits are present in North West Bay, and in many of the smaller bays along the western coast of the D'Entrecasteaux Channel and Port Cygnet.

ALLUVIUM, RIVER TERRACE AND LAGOON DEPOSITS (Qa)

Several different types of deposit have been grouped under this subdivision of the Quaternary deposits. The deposits have been mapped mainly on the basis of morphology and are relatively level areas which are generally adjacent to watercourses. The boundaries shown on the map correspond with breaks of slope at the edges of such areas.

Extensive deposits of alluvium are present along the Huon River. Upstream from Huonville [EN030360] the river is a misfit and is currently cutting into older gravel deposits which form a prominent terrace which reaches a maximum height of about 10 m above present river level. islands at the mouth of the Huon River [*e.g.* EN010280] are the delta of the present river and have formed since sea level reached its present height about 6 000 years ago.

In the Cradoc area [EN025280] an area of sand of unknown origin and a thickness of at least 3.5 m as determined by drilling, was mapped as a separate body (Qas).

Infilled lagoons which originally formed in swales between dunes or by damming by frontal dunes occur on Bruny Island [EN299138] and in the South Arm area [EN350348].

[P.W.B.]

IGNEOUS ROCKS

Jurassic Dolerite (Jdl)

Dolerite is the most common igneous rock present and it occurs both as major and minor intrusions in the Parmeener Super-Group over much of the map sheet. Major intrusions generally have the form of slightly transgressive sheets hundreds of metres thick which become steeply transgressive in places, or give rise to dyke-like segments which intrude at different stratigraphic horizons.

A dyke-like body over 2 km wide extends through Red Hill [EN185220]. Much thinner sills and narrow dykes (such as that which extends some 15 km in a NNE direction from Randalls Bay) also occur. Potassium-argon ages on the Red Hill dyke are in the range 143–174 Ma (McDougall, 1962; Schmidt and McDougall, 1977). Schmidt and McDougall suggest that the best estimate of the age of emplacement of the Red Hill dyke and other Tasmanian dolerites is 170±5 Ma. This age is consistent with the field evidence of dolerite intrusion into the Middle or Late Triassic Kaoota Coal Measures, and intrusions in dolerite by the radiometrically dated mid-Cretaceous syenite.

The dolerite of major intrusions is medium- to coarse-grained, less commonly pegmatitic or granophyric. Minor intrusions and the margins of major intrusions are fine-grained and may become glassy near the contacts with host rocks, which are usually sharp. In contrast to the broad metamorphic aureoles about the later syenite intrusions, the metamorphic effects due to dolerite are usually confined to within a few metres of the intrusive margin. This may be explained by the relative lack of catalytic fluids emanating from the dry dolerite magma. Although some bronzite microphenocrysts occur in the fine-grained dolerite near chilled margins, the bronzite is gradually replaced by pigeonite, so that the basic mineralogy at distances greater than 15 m from the margins consists of labradorite, pigeonite, augite and some quartz and potassic feldspar mesostasis (McDougall, 1962). In the Red Hill dyke a complete gradation from normal dolerite through fayalite granophyre to silicic granophyre has resulted from fractional crystallisation of the initial magma and probable transport of the residuum (McDougall, 1962). Dolerite near Robleys Point [EN065194] and a relatively thin dyke-like body south of Copper Alley Bay [EN060165] is described by Edwards (1947).

The physical apperance of dolerite outcrops varies considerably and depends on the degree of differentiation, grain size, the intensity of cooling joints, later fractures and the degree of weathering (plates 25, 26). Not infrequently surface outcrops are deeply weathered and friable, but spheroidal weathering with kernels of fresher rock is most common. Greenish weathering along joints in deeply weathered, fine-grained dolerite occurs north of Little Oyster Cove [EN206256]. Pinkish, deeply weathered, very coarse-grained dolerite occurs south-east of Cygnet [EN094178].

Veins of pegmatitic dolerite in medium- to fine-grained dolerite, and a dyke of fine-grained dolerite intruding fayalite granophyre have been noted previously (McDougall, 1962). Veins of pegmatite 25 mm wide occur at Shorts Hill [EN061330]. Further pegmatite occurs at Mundys Hill [EN093276, EN090281]. At Kettering Point [EN209243] a leucocratic dyke-like body of dolerite some 0·6 m wide has indefinite margins with coarse-grained dolerite. The dyke-like body is nearly vertical and strikes at 025°. The dolerite is also rather leucocratic in the Red Hill dyke south of Oyster Cove [EN192266, EN192268]. At Simpsons Point [EN236122] a one metre wide dyke of chilled dolerite trends approximately at 310°, and veins of similar material intrude medium- to coarse-grained dolerite. Zig-zag veins of dolerite 12 mm wide follow joints in fine-grained dolerite or highly-baked sedimentary rock at Bones Hill [EN116253] 3 m below a very fine-grained dolerite outcrop near the top of a major sheet. A few blocks of an unusual amygdaloidal variety of fine-grained ?dolerite occur west of Flynns Creek [EN099369].

A major sheet-like body of dolerite nearly 400 m thick (with later minor Cretaceous syenite intrusives) was encountered in the Woodbridge Borehole (Farmer and Clarke, 1985). The contacts are glassy to very fine-grained. The upper one third of the body consists of layered coarse- and very coarse-grained dolerite. Grain size gradually decreases through the middle and lower parts of the sheet, but layering is still present 260 m below the top. All layering is flat-lying. Similar features were observed in another major sheet-like body of dolerite in a borehole at the Quoin, south-east of Ross (Clarke and Farmer, 1983).

[S.M.F.]

Cretaceous Alkaline Intrusives (Cs)

Alkaline intrusive rocks of very variable composition crop out about Cygnet, Oyster Cove and Woodbridge. Recorded as a series of NE-trending bodies from Port Cygnet to Oyster Cove on the geological map of Tasmania (Johnston, 1888a), they have subsequently occasioned much debate. The first systematic descriptions and detailed classifications are those by Twelvetrees and Petterd (1899), Twelvetrees (1901; 1903a; 1903b; 1907) and Paul (1906). Johnston (1888b, p70) stated that in the Gardners Creek area the alkaline rocks were

Plate 25. *Roadstone quarry in semi-rotten dolerite, Lower Wattle Grove.*

Plate 26. *Deeply-weathered granophyric dolerite, Red Hill.*

overlain unconformably by Late Palaeozoic rocks, but more generally they were considered to be of Permo-Carboniferous age following Twelvetrees and Petterd (1899), until Skeats (1917) showed that they also intruded Jurassic dolerite near Kettering. Similar examples of this relationship were further reported at Port Cygnet (Hills *et al.*, 1922). The map produced by A.M. Reid (*in* Hills *et al.*, 1922) portrayed a large body of alkaline rocks centred on the Mt Windsor–Mt Mary area west of Cygnet, associated with almost N–S dykes to the north, and NE–SW dykes through the Oyster Cove–Kettering area to the north-east, a factor which appears to have influenced most later workers. Edwards (1947) gave a detailed petrological account of the various rock types and considered that the rocks in the Regatta Point area were formed by the reaction of a potash rich alkaline magma, of syenitic composition, with pre-existing dolerite. Edwards further considered the main intrusion to be a stock of syenite porphyry (banatite) with later stage intrusions of numerous porphyritic dykes of varying compositions. Rodger (1957) interpreted the occurrence of alkaline rocks at Oyster Cove as three major dyke-like intrusions although he noted on his map that the southernmost body is 'a syenite dyke swarm and not a continuous mass'. Carey (1958) suggested that the alkaline rocks and dolerite were essentially contemporaneous with the former being produced by the assimilation of limestone by differentiated dolerite. Leaman and Naqvi (1968) pointed out that radiometric age determinations (Evernden and Richards, 1962; McDougall and Leggo, 1965) proved a Jurassic age for the dolerite and a Cretaceous age for the alkaline rocks. They interpreted the major alkaline centre (as mapped by them) as an asymmetrical laccolith with a substantial hybrid zone in the vicinity of Regatta Point produced by thermal metamorphism and reaction of potassic fluids from the alkaline rocks, and a sheet-like body of underlying tholeiitic dolerite. The following account is essentially concerned with the occurrence and field relationships of the alkaline intrusive rocks as mapped by Dr Farmer. A more detailed account of their petrography, petrology and chemical composition will be the subject of a separate Bulletin by Dr R. J. Ford, University of Tasmania.

The present detailed survey indicates that the alkaline intrusive rock suite consists of a complex of numerous small dykes and sills associated with a number of more substantial sheet-like bodies in the vicinity of Black Jack Ridge [EN045163], Mt Mary–Mt Windsor [EN040190], Silver Hill [EN020223], the coastal region north-west and south-west of Wheatleys Bay [EN018167] (plate 27), Regatta Point, Farewell Hill [EN155240], immediately west of Underwoods Hill [EN155260], and at Helliwells Point [EN198222]. The mapping

clearly demonstrates that the stratigraphy is continuous throughout the main intrusive occurrences. The dykes are highly variable whereas the larger sheet-like bodies are usually composed of more uniform, drab grey and buff-coloured, porphyritic syenite (banatite).

The alkaline rocks are principally intruded into rocks of the Lower Parmeener Super-Group (where they are most abundant within the lower stratigraphic units of the sequence), but they also intrude Jurassic dolerite at Kettering and nearby areas [EN205245], south of Green Point [EN075181], Lower Wattle Grove [DN995195], Constance Rivulet [EN075247], west of Devereux Hill [EN105197], Tobys Hill [EN100228], Lymington [EN063164], and Beaupré Point [EN051145]. Whereas no alkaline intrusives are known to occur wholly within rocks of the Upper Parmeener Super-Group, at Oyster Cove Point [EN220257], a NE-trending dyke occupies a pre-existing or concomitant faulted boundary between Triassic sandstone and the Abels Bay Formation.

Contrary to previous accounts, the effects of thermal metamorphism in the surrounding sedimentary country rocks are severe, the more so considering the small size of most of the intrusive bodies. Intensely baked, dark flinty hornfels with substantial pyrrhotite nodules extends for several metres on either side of contacts of small intrusive bodies at many localities, as for example Green Point [EN075181] (plate 28) and Petcheys Bay [EN012172]; and as already noted, all, samples processed for palynological purposes from throughout the Cygnet–Oyster Cove–Woodbridge districts have yielded abundant but totally carbonised organic material. This indicates a substantial background heat flow throughout the area over and above the more localised contact zones of both the alkaline intrusives and Jurassic dolerite.

Individual contacts are usually sharp, often irregular, with narrow chilled margins both in the dykes and the thicker sheet-like bodies. Others are more diffuse with occasional stringers and schlieren. Some bodies wedge out and disappear very rapidly. Excellent examples are exposed in the large quarry at Kings Hill [EN036204] (plate 29) and in cuttings behind a large water tank north of Nicholls Rivulet [EN083212]. The top of a vertical dyke 2 m wide is well exposed on the shore platform and cliff northwest of Poverty Point [EN039148]. Elsewhere, as for example on the shore platform at Deep Bay [EN083152], irregularly stepped dyke dilations are well developed. A thin sill of syenite porphyry within the Abels Bay Formation is well exposed at Deadmans Point [EN205236].

The contacts of intrusions of alkaline rocks in Jurassic dolerite at Kettering, Lower Wattle Grove

Plate 27. *Syenite dyke in Truro Tillite, Kings Hill.*
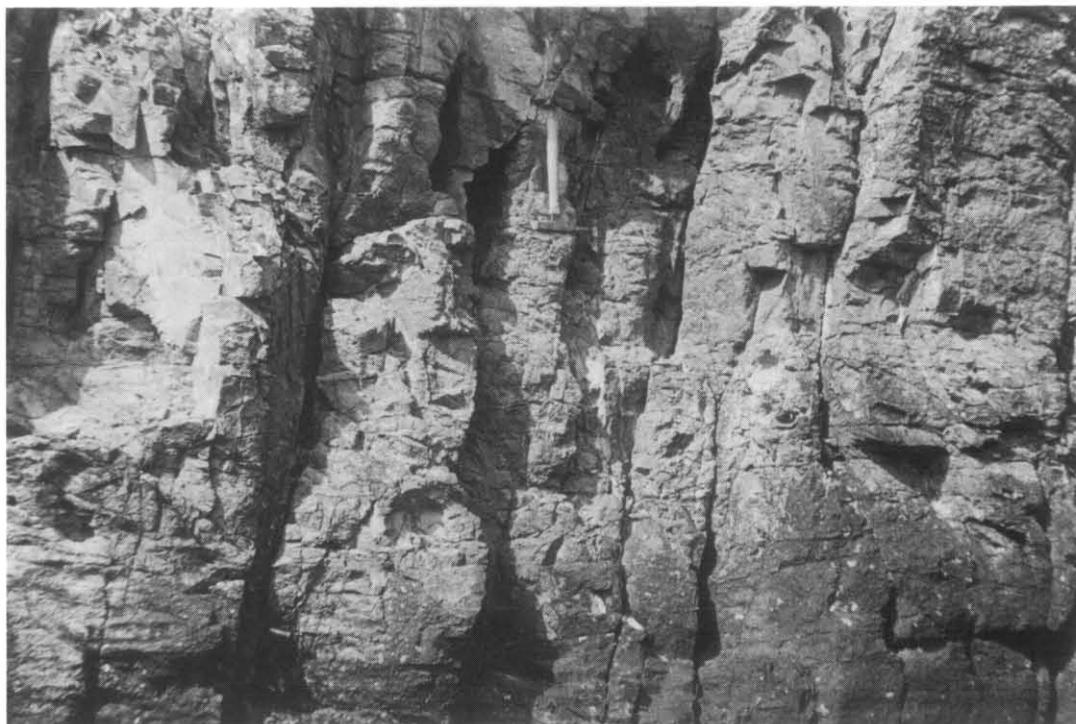
Plate 28. *Massive sheet-like syenite, coastal section south of Wheatleys Bay.*

and elsewhere are similarly sharp, sometimes irregular, and have very thin chilled margins, but otherwise show little or no interaction with the dolerite.

Over thirty intersections of alkaline rocks were encountered in the Woodbridge Bore (Farmer and Clarke, 1985). Thicknesses range from 400 mm to 37 m, but most intersections fall within the range of 5–20 m. Both sheet-like bodies and dykes are present. The thicker bodies are sheet-like and some are composite with sub-parallel internal and external contacts. Chilled margins are very thin and abrupt. They mostly consist of drab grey and buff-coloured, uniformly porphyritic banatite. Many of the thinner bodies have steeply inclined and irregular margins and are clearly discordant. Most contacts are sharp with very thin chilled margins, but a few are more diffuse. These dyke-like bodies are extraordinarily variable. Normally they are coarsely and irregularly porphyritic, but some are more finely and uniformly porphyritic. Colours range from orange-red to red, pink, green, greenish yellow, khaki and dark grey. Within the one thousand metre bore the distribution of the alkaline rocks is uneven. Two substantial sheet-like bodies (12 m and 22 m thick respectively) occur within tillite above dolerite. Within the very thick dolerite body, sheet-like alkaline intrusives 14 m, 18 m and 17 m thick respectively, occur near the top, the middle and the base of the dolerite. The two lower occurrences are associated with several thin, steeply inclined dyke intrusions. No significant interaction between the alkaline intrusives and the dolerite was observed in any instance. Below the dolerite, alkaline intrusives occur with an ever increasing frequency towards the base of the Truro Tillite. Most are substantial sheet-like bodies, several are clearly composite, but some are thin and steeply inclined dykes. The alkaline rocks become markedly more xenolithic towards the base of the tillite. No alkaline rocks were encountered in a 26 m intersection of Precambrian phyllite basement.

A large area of so-called 'hybrid' rocks has previously been mapped inland from the coastal region near Regatta Point (plate 30) where syenite is faulted against dolerite, and interpreted as resulting from the contact and interaction of a single large syenite sheet or laccolith and an underlying dolerite sheet or sill (Leaman and Naqvi, 1968). Dr Farmer's notes indicate that 'the field evidence shows, however, that:

(1) The laccolith is not a large single body but consists of several essentially sheet-like bodies generally with a banatitic texture, associated with a highly variable suite of thin, steeply inclined dykes.

(2) Much of the so-called 'hybrid zone' consists of highly baked tillite with ghosted pebbles, and fossiliferous Bundella Mudstone. Therefore much of the 'hybrid zone' must be removed from the area previously included within it, or, the 'hybrid zone' must be recognised as syenite contaminated by sedimentary rocks rather than dolerite.

(3) Much of the 'hybrid zone' consists of coarse-grained, porphyritic syenite with large feldspar phenocrysts. These rocks are widely and irregularly scattered throughout the 'hybrid zone', and their irregular distribution and often coarsely porphyritic nature suggest dyke intrusions rather than sill-like bodies.

(4) The true 'hybrid' rocks (that is, those rocks which cannot be assigned to either syenite or baked sedimentary rocks or dolerite with any confidence) are also very irregular in their distribution. This suggests that the 'hybrid zone' rocks are associated with irregularly distributed bodies of syenite, and not an even, widespread zone as would be expected from a sill or sheet-like body.

(5) Where 'hybrid' rocks and syenite are seen in good exposures, contacts between porphyritic syenite and 'hybrid' rocks are steeply inclined.

(6) Banding and veining is usually steeply inclined.

(7) The general trend of evidence therefore suggests that any true 'hybrid zone' between syenite and dolerite (if developed at all) is much smaller than previously supposed, and that any 'hybridisation' between syenite and dolerite is brought about by a nexus of steeply inclined dyke-like bodies rather than the contact between a syenite laccolith and an underlying dolerite sheet or sill. The widely disparate radiometric dates for the dolerite and syenite certainly preclude hydridisation (or the mixing of two distinct magmas) as defined by Harker (1904).'

Analysis of the trends of the syenite dykes (fig. 4) based on 107 determinations indicates a pronounced preferred orientation a little west of north, with a subsidiary orientation a little north of east.

The main rocks types include:

Plate 29. *Tinguaite porphyry dyke immediately north of Langdons Point.*

Plate 30. *Tinguaite porphyry dyke immediately north of Langdons Point. Close-up showing feldspar swirls.*

BANATITE (SYENITE PORPHYRY)

This is the predominant rock type within the alkaline intrusives and forms the major sheet-like bodies as well as many of the dykes. The un-weathered rock is typically rather uniform and drab grey or buff-coloured. It is hard, dense and porphyritic with abundant large phenocrysts of feldspar up to 20 mm in length embedded in a groundmass containing small crystals of ferro-magnesian minerals. Many occurrences are deeply weathered to the characteristic 'biscuit rock' in which the large tabular feldspar phenocrysts are embedded in a soft kaolinised groundmass. Examples are widespread as in the large quarry at Kings Hill [EN036204]. A specimen from the Mt Windsor area contains zoned plagioclase (andesine), zoned sanidine and hornblende. Accessory minerals include sphene, apatite, zircon and magnetite. The groundmass consists of very small grains of feld-spar, quartz and magnetite.

GARNET TRACHYTE

Garnet trachytes described previously by Rosen-busch (in Twelvetrees, 1901, p. 3) and analysed by Paul (1906) are not precisely localised and the following description by G. B. Everard refers to a dyke intruded into the Bundella Mudstone at Langdons Point [EN069176]. 'The hand specimen is a fine-grained, grey rock with phenocrysts of honey-coloured garnet and colourless, transparent feldspar up to 4 mm long. A little pyrite is widely disseminated in small crystalline aggregates often associated with the garnet. Crystals of epidote up to 3 mm long also occur. In thin section the rock has a trachytic texture consisting of a mass of sanidine laths averaging 0·3 mm long and showing flow, together with minute ragged flakes of biotite and granular epidote. There are occasional irregu-lar, scattered masses of magnetite, partly altered to haematite. Minute aggregates of pyrite also occur. The garnet phenocrysts are almost colourless, irregular in outline, incompletely isotropic and zoned. They have inclusions of epidote, feldspar, magnetite and green biotite. The feldspar pheno-crysts show zoning and are euhedral and lath-like; their edges are slightly rounded and irregular showing resorption or alteration. There are also larger, irregular plates of biotite'.

SANIDINE-GARNET PORPHYRY

This is a rather rare but striking rock which occurs as dykes near Harleys Jetty [EN023157] and at Brabazon Point [DN987181], the former in Bun-della Mudstone and the latter in dolerite. Large melanite garnet and sanidine crystals are embedded in a fine-grained, dark green groundmass. Some aegirine, hornblende and oligoclase also occur. Accessory minerals include sphene and apatite.

SANIDINE TINGUAITE (TINGUAITE PORPHYRY)

Immediately north of the jetty at the northern headland of Copper Alley [EN060068] two coarsely porphyritic dykes crop out on the shore platform (plates 31–32). These dykes have distinctly chilled margins and one contains pronounced swirls of large sanidine phenocrysts. The tinguaite consists essentially of large phenocrysts of sanidine in a dense, fine-grained, green groundmass. Also pre-sent, particularly as inclusions in the feldspar, are aegirine, melanite garnet and apatite.

SYENITE APLITE AND SYENITE PEGMATITE

Dykes, veins and schlieren of aplite and pegmatite are common at Regatta Point and Petcheys Bay [EN012172]. The aplitic rocks are variable in composition and contain various types of feldspar, a little biotite and some quartz. The pegmatites contain coarse tablets of sanidine in a groundmass of orthoclase, magnetite and some pyroxene with interstitial muscovite and sphene.

GARNET ORTHOCLASITE

This rock type closely resembles the syenite aplite but differs in the presence of much brown melanite garnet. Examples occur south of Regatta Point.

[M.J.C.]
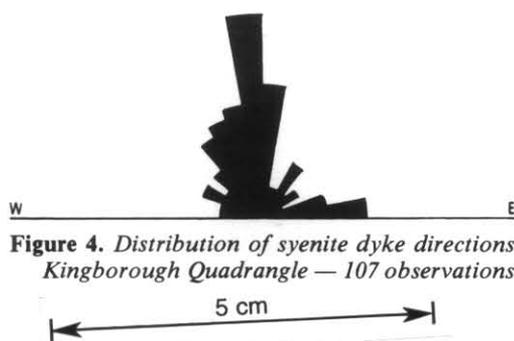
Figure 4. *Distribution of syenite dyke directions, Kingborough Quadrangle — 107 observations.*

Cainozoic Volcanic Rocks (Tb)

VOLCANIC CENTRES

Basaltic lavas and pyroclastic rocks in the King-borough Sheet are found around seven eruptive centres. Remnants of valley-filling flows also extend down Mountain River to reach the Huon River at Ranelagh.

Plate 31. *Contact of porphyritic syenite dyke and Bundella Formation, Green Point.*
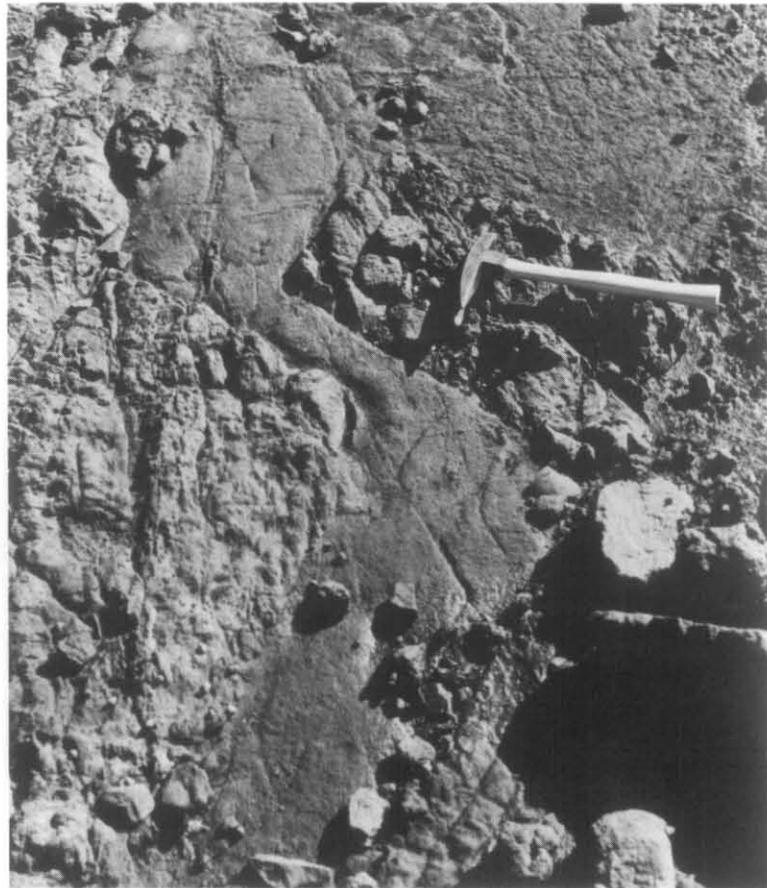
Plate 32. *Dyke dilations, syenite in syenite, south of Robleys Point.*

The best exposed volcanic sections are seen on the Channel Highway at Margate and Doctors Hill. Both these centres were observed during the French expedition of 1802 by Peron (1807). A Margate tephra outcrop was designated a geological feature and officially opened by the Minister for Tourism in February 1973. It is marked by a plaque, and a brochure describing the main features of the Margate volcanic centre was issued by the University of Tasmania (Sutherland, 1973).

MARGATE CENTRE

Basaltic tephra (plate 33) is here associated with lava flows and small dykes. At the Longley Road junction in Margate, 2·5 m of massive basalt with fissile weathered top is irregularly overlain by one metre of rubbly lava below the pyroclastics (plate 34). Similar basal basalt underlies the tephra on the Channel Highway on the north side of North West Bay River and at Dru Point.

The tephra probably came from a vent near the mouth of North West Bay River. The coarse agglomerate contains basalt blocks reaching over a metre across and numerous spindle-shaped bombs up to 0·6 m across with scoriaceous outer zones. Interbedded flows up to 1·5 m thick, warped slabs and oval blocks of basalt up to 2 m across, and numerous dykes are seen around the Highway bridge. The lava fragments range from dense to scoriaceous basalt and contain inclusions of Jurassic dolerite, quartz and sedimentary rocks up to 0·5 m across. The fine matrix in the tephra contains fragments of country rock and reddish weathered basalt.

Massive, dense basalt overlies the tephra to the WNW and SSW filling old valleys of North West Bay River and Margate Rivulet. It exceeds 45 m in thickness, shows prominent cooling columns and passes up into laminated jointing in the river section below Hillcroft Farm. It contains numerous inclusions of Jurassic dolerite and sporadic baked Permian sediments up to 100 mm across. There are sparse, mineralised vesicles and radiating zeolite lining joint planes

This lava possibly issued from the dolerite-Permian contact west of the Margate tephra, or from the Hickmans Hill neck intruding dolerite 4 km to the north west.

Scattered silicastone is associated with Tertiary sediments filling a channel extending from Margate to Electrona. This may mark the original southward extension of the basalt flow now eroded back to Margate. The occurrence of silicastone below basalt flows and its use as markers for former flow paths is discussed by Rawlings (1967), Taylor and

Smith (1975), Sutherland (1977) and Langford-Smith (1978).

DOCTORS HILL CENTRE

The main vent and its eruptives lie in the Hobart Sheet to the north (Sutherland, 1976), but lavas and pyroclastics extend into the Kingborough Sheet as far as North West Bay. Here, they fill an old valley of Coffee Creek and overlie Tertiary sands and clays in Borehole NF 50 [EN229379].

A separate valley contact is exposed in the Channel Highway south of Doctors Hill near Borehole NF 83. The contact dips 40–50° N over a deposit of angular fragments of Permian rocks (fossil scree?). This is overlain by one metre of lapilli tuff, then 1·5 m of agglomerate containing blocks of scoriaceous to dense basalt up to 0·5 m across, Permian rocks and rare weathered Jurassic dolerite up to 0·2 m across. Massive basalt overlaps the pyroclastics and shows platy jointing and a chilled base up to 50 mm thick. This becomes rubbly and scoriaceous where it rests on the Permian bedrock.

Silicastone forms residual exposures overlying Tertiary sediments and Triassic sandstone to elevations above 60 m near these two valley fills. These could mark former extensions of the flows.

HICKMANS HILL CENTRE

In this centre, 3 m of poorly-bedded agglomerate and tuffaceous agglomerate are exposed below massive basalt on the hill south of the Longley-Kaoota Road junction. The agglomerate contains blocks of scoriaceous basalt, mostly less than 50 mm across, and sparse volcanic bombs in a patchy, and in some parts, abundant baked tuffaceous matrix. The overlying basalt shows platy jointing and extends downslope to the Longley Road, becoming highly vesicular and rubbly in places. Possible exposures of the volcanics were mapped by Rodger (1957).

On this lower slope, further agglomerate may mark another small vent. It is associated with petrified wood and contains numerous fragments of Jurassic dolerite up to 70 mm across.

TINDERBOX CENTRE

A massive dyke-like plug forms the summit of a flow descending west down to North West Bay. The plug shows near-vertical NW trending platy jointing and intrudes minor agglomerate on its north side. The agglomerate weathers reddish and contains scoriaceous basalt fragments, mostly 10–50 mm across, spindle-shaped bombs up to 0·3 m across, and sparse indurated Triassic sandstone.
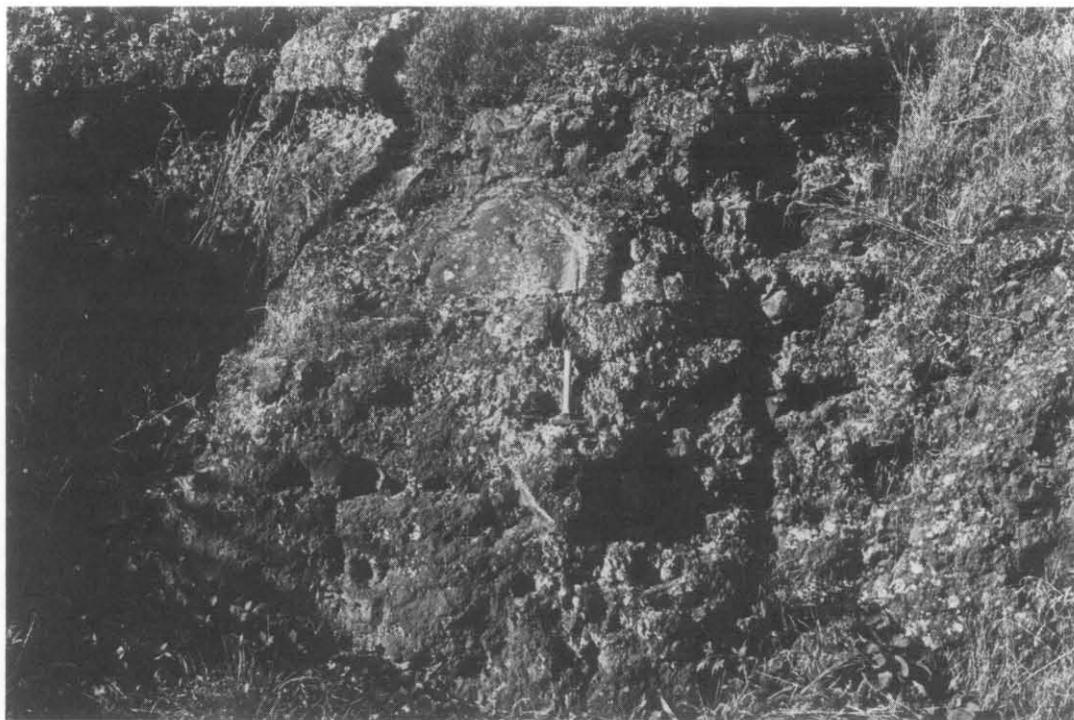
Plate 33. *Basaltic tephra, Channel Highway, Margate.*

Plate 34. *Massive basalt flow, Longley turn-off, Channel Highway, Margate.*

The flow is commonly scoriaceous along its sides and at its base, and many of its vesicles are elongated in the direction of the flow.

KAOOTA CENTRE

Basalt caps the hill 0·7 km east of Kaoota township. The summit is coarse-grained basalt jointed into blocky east-west strips. The basalt contains peridotite nodules (lherzolite), Triassic sandstone fragments up to 100 mm across, and sparse pyroxene and opaque oxide megacrysts.

North and east around the summit, irregular to elongate patches of pegmatoidal rock, up to 2 m across, may mark the position of an underlying feeder for the flow.

CAPE CONTRARIETY CENTRE

This lies to the east in the Tasman Sheet, but an overlying flow remnant is mapped in the north east corner of the Kingborough Sheet. A detailed section through this centre was described by Green (1961) where it is breached by the sea.

NORTH BRUNY CENTRE

A small occurrence of ejectamenta, viz. basaltic blocks, ash and other debris was located 1·5 km north of Great Bay (N. Farmer notes for Bruny Island School). The occurrence is now largely obscured by earth works (M. J. Clarke, pers. comm.).

RANELAGH FLOWS

Massive basalt flows are exposed at several points along Mountain River and above the Huon River at Ranelagh. The northernmost outcrop, in the Hobart Sheet one kilometre north-east of Ranelagh, was described by Sutherland (1976).

In Huon River, 4–5 m of basalt overlies 6 m of dolerite boulder beds, which in turn rest on Permian rocks. Nearby [EN026375] the dolerite boulder beds overlie fairly well-consolidated ?Tertiary sands. The basalt here is relatively uniform and lacks the xenoliths described in the most north-eastern basalt.

No source is identified for these basalts, but they probably flowed down Mountain River.

MISCELLANEOUS BASALTS

Sporadic basalt boulders are found on the shore south of Margate around Snug and Kettering.

These are olivine basalts of a type not found in local outcrop, but which resemble rocks described from the Younger Volcanics of Victoria. They are probably ballast thrown out from boats plying Bass Strait to Victorian shores.

AGE OF VOLCANISM

No radiometric dating is available on the basalts in the Kingborough map sheet and palaeontological control is scanty. By analogy with centres dated in the Hobart Sheet (23–30 Ma; Sutherland, 1976, and unpublished data), the basalts are probably mostly Oligocene-Miocene in age. Such ages are compatible with the degree of dissection shown by the occurrences.

STRUCTURAL CONTROL

The two largest centres, Margate and Doctors Hill, lie near major faults juxtaposing Triassic and Permian beds and the Cape Contrariety Centre is fault bounded. The other centres show no obvious structural control.

PETROLOGY

The volcanics include alkali olivine basalt and more alkaline fractionated rocks of alkali basalt and basanite lineages.

RANELAGH BASALTS

There are two types. One has small olivine phenocrysts and sparse feldspar and pyroxene microphenocrysts in a sub-fluidal intergranular groundmass with some brownish glass (Huon River and 2 km north-east of Ranelagh).

The other includes xenocrysts and xenoliths of lherzolite and ophitic dolerite mineralogy (one kilometre east of Ranelagh). The dolerite forms irregular fragments and shows considerable corrosion sieving and replacement of pyroxenes which are rimmed by the groundmass pyroxene. The interstitial mesostasis in the dolerite is largely altered to chalcedony-opal and in some cases encloses a central cavity. These xenoliths are interpreted as partially fused, devolatilised Jurassic dolerite.

A major element analysis of the basalt from its northern end (Sutherland, 1976) is quoted here with additional trace element data (analysis 1, tables 1 and 2).

Table 1
MAJOR ELEMENTS, CIPW NORMS, KINGBOROUGH BASALT SUITE

Analysis	1	2	3	4
SiO_2	44·94	43·73	46·93	48·85
TiO_2	2·42	2·74	1·97	2·45
Al_2O_3	12·90	11·02	14·07	14·39
Fe_2O_3	2·56	3·45	3·26	2·28
FeO	10·27	9·11	8·02	9·58
MnO	0·19	0·18	0·16	0·17
MgO	10·21	13·91	6·64	6·30
CaO	9·67	8·26	6·35	6·92
Na_2O	2·82	2·45	4·68	4·88
K_2O	1·14	1·29	2·75	1·85
P_2O_5	0·56	0·72	1·09	0·68
Loss	2·11	2·29	3·08	1·90+
Total	99·15	99·15	99·01	100·25
Or*	6·91	7·86	17·07	11·12
Ab	18·57	17·52	24·20	30·48
Ne	3·18	2·10	9·39	6·23
An	19·59	15·77	9·73	12·10
Di	20·85	17·38	12·95	15·03
Hy	—	—	—	—
Ol	20·47	27·95	17·96	15·80
Mt	4·41	4·34	2·12	2·91
Il	4·71	5·37	3·93	4·73
Ap	1·32	1·71	2·66	1·64

1. Alkali olivine basalt, flow, Mountain River, 3km north-east of Ranelagh [EN052397].

2. Transitional picrite, plug, Smugglers Cove, 0·5 km north of Cape Contrariety [EN423371].

3. K-rich, transitional nepheline mugearite, flow, 0·7 km ESE of Kaoota [EN140365].

4. Mugearite, 1·8 km north-west of Margate Tephra site [EN201377].

Analyses 1–3 by P. Beasley and E. Kiss, Australian National University; analysis 4 by Launceston Laboratories, Tasmania Department of Mines.

* Anhydrous mass% norms. Analyses 1·2 calculated at $Fe_2O_3/FeO = 0·3$, Analysis 3 calculated at $Fe_2O_3/FeO = 0·15$, Analysis 4 calculated at $Fe_2O_3/FeO = 0·2$ (R. E. Pogson, Australian Museum).

+ Loss includes H_2O^+ 1·69, CO_2 0·08 and SO_3 0·13 mass%.

Analysis	1	2	3	4
Ti	13746	15732	9722	—
Mn	1219	1194	1023	—
Ni	199	438	196	145
Cr	257	611	177	—
Zn	101	115	158	165
Cu	63	42	36	39
V	171	151	66	—
Ba	259	248	604	500
Sr	539	640	1286	840
Rb	24	24	52	33
Y	25	35	38	30
Zr	114	211	548	320
Th	22	21	27	—
U	1	1	3	—
Pb	16	9	15	—
Ga	19	19	29	—
La	—	43	78	—
Ce	—	87	15	—
Nd	—	49	79	—

1. Alkali olivine basalt, flow, Mountain River, 3km north-east of Ranelagh [EN052397].

2. Transitional picrite, plug, Smugglers Cove, 0·5 km north of Cape Contrariety [EN423371].

3. K-rich, transitional nepheline mugearite, flow, 0·7 km ESE of Kaoota [EN140365].

4. Mugearite, 1·8 km north-west of Margate Tephra site [EN201377].

Analyses 1–3 by F. L. Sutherland, with La, Ce and Nd determined by J. Bedford, School of Earth Sciences Laboratory, Macquarie University. Analysis 4 determinations by Launceston Laboratories, Tasmania Department of Mines. Values in ppm.

Table 3
PROPOSED FRACTIONATION LINEAGE FOR NEPHELINE MUGEARITE

Analysis	Parental basanite	Bow Hill Ne-Hawaiite	Antill Ponds Ne-Hawaiite	Kaoota Ne-Mugearite
SiO_2	43·7	45·2	46·0	49·0
TiO_2	2·1	2·5	2·5	2·1
Al_2O_3	12·5	12·9	13·5	14·7
Fe_2O_3	1·7	1·7	1·7	1·5
FeO	11·1	11·1	11·2	10·2
MnO	0·2	0·2	0·2	0·2
MgO	13·2	9·4	8·7	6·9
CaO	8·6	8·5	8·6	6·6
Na_2O	3·7	4·5	4·0	4·9
K_2O	2·1	2·6	2·3	2·9
P_2O_5	1·1	1·4	1·4	1·1
Mg No.	68	61	58	56
Crystallising phases	$Ol(Fo_{81})$ Cpx, Spl	$Ol(Fo_{80})$, Cpx Spl, Ulvspl	(ol, Cpx) (Ulvspl, Ilm)	? ?

Recalculated anhydrous 100% analyses, parental basanite from Sutherland *et.al.* (1984).

CAPE CONTRARIETY BASALT

This includes larger crystals of olivine, pyroxene and calcic-sodic plagioclase in a groundmass of more sodic plagioclase (Green, 1961).

Basalt from a small plug intruding the breccias of the centre and from the capping flow was examined here. A thin section of the plug rock contains large, fresh, both strained and unstrained olivines, strongly resorbed clinopyroxene and rare composites of olivine and orthopyroxene, suggesting largely disaggregated lherzolite minerals. There are smaller olivine phenocrysts and sparse, zoned clinopyroxenes rimmed by the groundmass augite, set in a fine-grained groundmass of zoned labradorite-andesine and disseminated grains of opaque oxides.

The capping basalt contains less olivine, which is altered on the margins to 'iddingsite', but includes prominent clinopyroxene and orthopyroxene xenocrysts, which show marked reaction coronas of olivine crystallised from the host basalt.

The evidence suggests greater settling of olivine xenocrysts in the plug basalt than the capping flow. The high olivine content (c. 30%) gives the rock a picritic composition (analysis 2, table 1) and high $Mg/Mg + Fe^{2+}$ (0·72). However, the normative andesine of the analysis (An/An + Ab 0·47) suggests a rock fractionated towards a transitional hawaiite, if the xenocrystal olivine is disregarded.

Megacrysts of Al-augite in the capping basalt (c. Mg_{51-56} Ca_{30-36} Fe_{13-14}, Al_2O_3 4–7%) suggests moderately high pressure crystallisation. The evidence suggests that the rock formed following some fractionation of the host magma by olivine and clinopyroxene crystallisation at mantle depths.

MARGATE–DOCTORS HILL– HICKMANS HILL– TINDERBOX BASALTS

These are moderately fractionated rocks of the hawaiite-mugearite series, described as the Rokeby Type (Edwards, 1950). Olivine phenocrysts are fresh to 'iddingsitised', sometimes being altered in zoned stages reflecting the escape and alteration by volatiles. 'Iddingsite' alteration is most extensive in more scoriaceous rocks. The groundmass is dominated by zoned andesine-oligoclase and textures are commonly fluidal. Olivine is generally the main phenocryst, but the Tinderbox rock develops some microphenocrysts of clinopyroxene.

Staining tests indicate little potash-feldspar is present in the groundmass. Chemically (analysis 4) they match the sodic hawaiites and mugearites

analysed in the Hobart Sheet (Ne <10%, Or <11%, $Mg/Mg + Fe^{2+}$ 0·49–0·52: analyses 14–15A; Sutherland, 1976). No mantle inclusions were found in the rocks in the Kingborough Sheet and the final fractionation of the magmas probably took place within the crust.

KAOOTA BASALT

This is the most undersaturated, alkaline rock found in the Kingborough Sheet. A K-rich nepheline mugearite (Ne 9%, Or 17%, $Mg/Mg + Fe^{2+}$ 0·56), it contains common xenoliths of lherzolite with typical mantle mineralogy (Varne, 1977).

The host rock exhibits microphenocrysts of olivine (Mg_{58} Fe_{41} Ca_1) in a groundmass containing feldspar zoned from K-oligoclase to anorthoclase (Na_{68} K_{20} Ca_4). There is interstitial Na-sanidine (Na_{47-56} K_{39-49} Ca_{4-5}) and zeolite as well as prismatic clinopyroxene (titan-salite, Mg_{39} Ca_{47} Fe_{14}, TiO_2 1·5%) and opaque oxides, partly altered to biotite. Nepheline is not obvious, but may be occluded in the interstitial material.

The coarser pegmatoidal rock is dominated by stout tablets of anorthoclase (Na_{62} K_{31} Ca_6) containing cores of finely twinned sodic plagioclase. These contrast with slender, partly curved laths of sanidine (Na_{44} K_{56} Ca_1). Prismatic titan-salite (Mg_{38} Ca_{47} Fe_{16}; TiO_2 1·2%, Na_2O 0·5%) is zoned to greenish sodic salite (Mg_{30} Ca_{46} Fe_{24}, Na_2O 3·1%) and some of the pyroxenes are altered on the margins to green-brown sodic amphibole. The remainder of the rock contains some partly altered olivine, grains of ulvospinel (Fe_{73} Ti_{25} Mg_2, Usp 76), squarish grains of nepheline and an interstitial mesostasis containing infillings of radiating zeolite.

PETROGENESIS

For a greater understanding of their petrogenesis the Kingborough basalts need to be considered with similar basalts in the Hobart Sheet (Sutherland, 1976). The Kingborough basalts are dominated by members of the fractionated alkaline association and flanked by members of the less fractionated alkali basalt association (Ranelagh, Cape Contrariety).

SODIC ALKALI BASALT LINEAGE

The Ranelagh alkali basalt is depleted in compatible elements (Ni 199, Cr 257 ppm) compared to primitive south-eastern Australian basalts of similar Ne-normative affinities (Ni 364, Cr 328 ppm; Mt Fraser basalt, Victoria; Frey et al., 1978). The relatively high CaO (9·7%) suggests its fractionation was dominated by olivine ±Mg-orthopyroxene

crystallisation, without Ca-pyroxene, at mantle pressures. Continued fractionation of this type would eventually lead to transitional hawaiite of the Cape Contrariety composition, with increased contents of incompatible elements such as K, P, Sr, Zr, Y (cf. analyses 1 and 2, tables 1 and 2).

As olivine is joined by Ca-pyroxene (e.g. Al-augite megacryst composition in the Cape Contrariety basalt) further high pressure fractionation would give the decreased CaO and MgO found in the Whitewater Creek lherzolite-bearing mugearitic hawaiite (MgO 5·3%, CaO 7·0%; analysis 15A, Sutherland, 1976). With introduction of such magmas into the crust, some lower pressure modification would give the Rokeby-Kingston hawaiite-mugearite range (MgO 5·4-7·8%, CaO, 7·3-8·3%; analyses 13-15, Sutherland, 1976). This is the stage at which the Kingborough hawaiite-mugearites were erupted, giving lavas showing relatively low compatible element (Ni 145 ppm) and some relatively high incompatible element values (K, Sr, Zr; cf. analyses 2 and 4, tables 1 and 2).

K-RICH BASANITE LINEAGE

The Kaoota K-rich nepheline hawaiite is similar in Si, Al, Mg and Ca contents to the hawaiite-mugearites, but has higher alkalis, in particular K_2O. The compatible elements (Ni 196, Cr 177 ppm) are depleted and the incompatible elements (Sr 1286, Y 38, Zr 548 ppm) are increased relative to primitive values. This again suggests considerable crystallisation of olivine and Ca-pyroxene, but from more undersaturated magma.

It marks a more extreme fractionation in the mantle along the trend shown by Tasmanian K-rich nepheline hawaiites (Bow Hill Flow; Sutherland, 1984, Sutherland et al., 1984). The Bow Hill magma represents about 10% olivine, 10% Al-augite and 2·5% spinel crystallisation (wehrlite composites) from a primitive basanite. A slightly more fractionated rock contains ?cognate megacrysts of olivine, Al-augite, spinel and ulvospinel (Antill Ponds plug, F. L. Sutherland, unpublished data). Fractionation of these phases, dominated by Ca-pyroxene and Fe-Ti oxides, would lead to lower CaO, MgO and higher SiO_2, Al_2O_3 of the Kaoota rock. The suggested magmatic lineage to the Kaoota stage is shown in Table 3.

PETROLOGIC ASSOCIATIONS

The dominant, fractionated alkaline type in the Kingborough basalts forms part of an extended ENE-WSW belt of such rocks (D'Entrecasteaux Channel-southern Derwent Estuary-north-eastern Tasman Peninsula-eastern Sorell-Runnymede).

This alkaline association (fig. 5) is fringed by the alkali basalt association (olivine nephelinite, basanite, alkali basalt) which in turn may pass into the tholeiitic association (transitional basalts, olivine tholeiite, quartz tholeiite).

These three associations reflect different degrees of partial melting in the underlying mantle. The alkaline association probably marks the least melting below the volcanic regions. The parental magmas were generated by 6-11% melting, based on the Ne-normative character of the rocks (Frey et al., 1978). The generally small volumes of lava and absence of thick flow sequences away from vents is compatible with relatively restricted melting. The fractionated nature of the lavas probably reflects stagnation of melts within the mantle, without widespread rise of the magmas into crustal chambers.

The relationship of the more undersaturated K-rich series (Kaoota) to the sodic fractionated series (North West Bay) is not known. In sequences of such rocks elsewhere in Tasmania, the K-rich series underlies the sodic series (Kingston, E. Sorell, Oatlands). This suggests evolution in localised eruptive cycles of increasing partial melting. K-rich initial melts would indicate melting with incorporation of metasomatic K-rich phases such as phlogopite or biotite in the mantle source peridotite (Wass, 1980). This enrichment in K could be accomplished either by generating very small amounts of melt or by greater melting of more strongly metasomatised mantle.

Recent work suggests that the degree of metasomatism in the mantle may be reflected in basalt generation by the initial $^{87}Sr/^{86}Sr$ isotope signature shown by relatively primitive basalts (O'Reilly and Griffin, 1984). The more the mantle is metasomatised, the greater is the radiogenic contribution to the initial $^{87}Sr/^{86}Sr$ ratio. In southern Tasmania, both sodic and K-rich undersaturated rocks show low intital $^{87}Sr/^{86}Sr$ ratios (0·7026-0·7033; Compston et al., 1968; McDonough and McCulloch, 1984), in contrast to Tasmanian tholeiitic rocks which show mugh higher initial $^{87}Sr/^{86}Sr$ (0·7039-0·7078).

Sutherland (1980) suggested that the Tasmanian mantle, with an asthenosphere depleted in initial $^{87}Sr/^{86}Sr$ relative to a LILE enriched mesosphere, was anomalous compared to the mantle of mainland eastern Australia. He based this on the low initial $^{87}Sr/^{86}Sr$ in Tasmanian alkali basalts compared to known mainland values (0·7035-0·7046). This is confirmed by more extensive recent data from Victoria and New South Wales (McDonough and McCulloch, 1984; O'Reilly and Griffin, 1984). Thus, the present isotopic evidence supports the
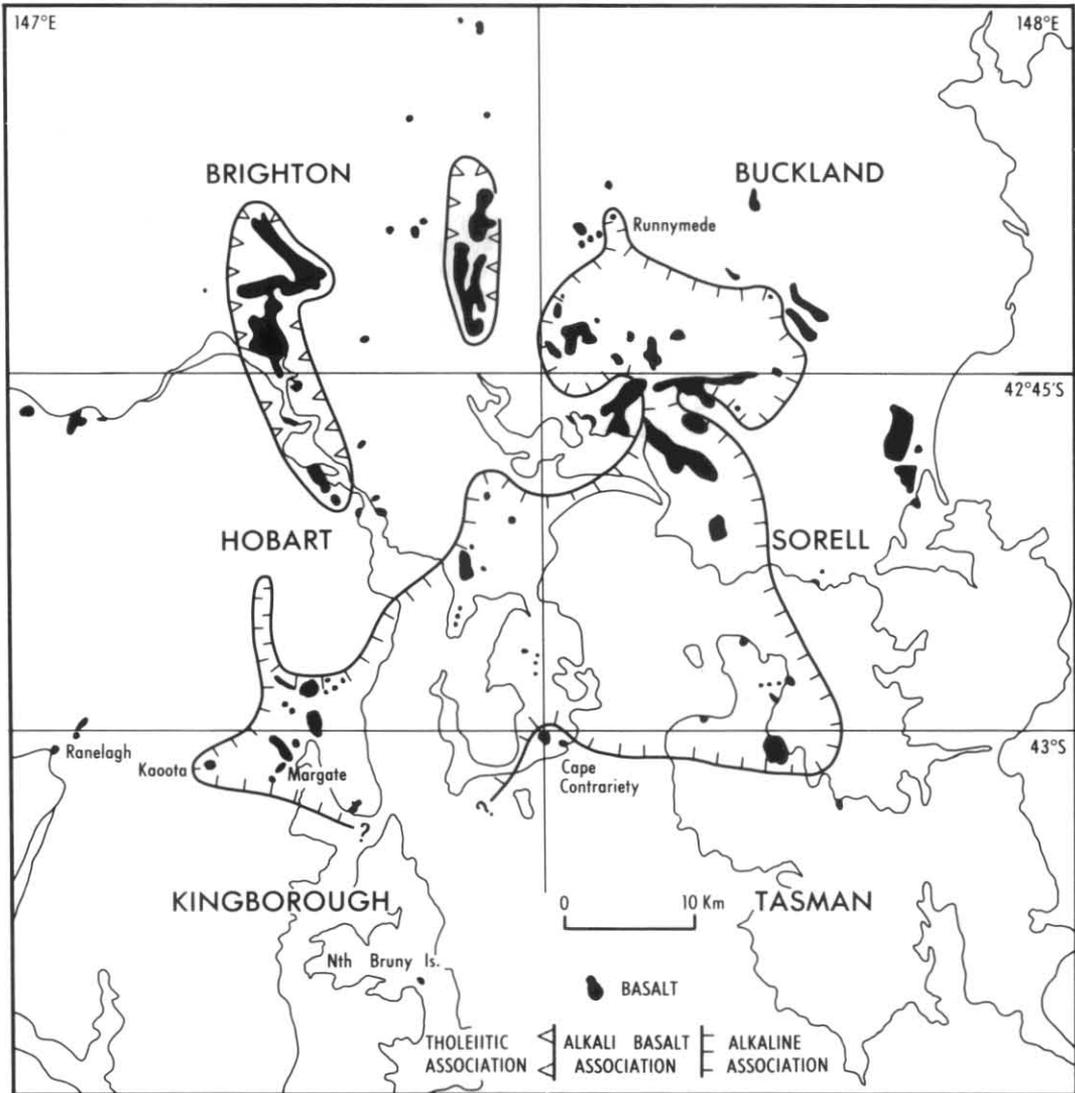
Figure 5. *Distribution of Cainozoic basalts and associated rocks, south-eastern Tasmania.*

concept that alkaline association basalts as in the Kingborough Sheet, formed from restricted partial melting in a mantle relatively impoverished in metasomatic components, particularly amphibole.

[F.L.S.]

STRUCTURAL GEOLOGY

Dolerite form and structure

Several factors contribute to the difficulty of resolving the form and structure of dolerite bodies. Firstly, the often subtle effects of metamorphism due to dolerite intrusion are masked by the more intense thermal metamorphism caused by the Cretaceous alkaline intrusives. As a consequence evidence for the occurrence of steeply dipping intrusive margins in many areas is restricted to exposures of the actual contact or chilling of the dolerite margin. Secondly, although the degree of physiographic dissection is sufficient to reveal the structure of individual portions of sheets, the dissection is usually insufficient to reveal the relationship between intrusions at different stratigraphic horizons. Thirdly, talus, deep weathering or soil or vegetation cover usually obscure dolerite boundaries, so that it is often impossible to determine whether adjacent dolerite bodies merge, are in faulted contact, or intrude one another. Similarly at other boundaries concealment hampers the recognition of pre-, syn- or post-dolerite faulting. Finally, several complicating features contribute to gravity anomalies, so that the structural interpretation of dolerite based on the gravity field is often ambiguous.

THE FORM OF SPECIFIC INTRUSIONS

A major dyke extends 15 km across the map sheet from Randalls Bay trending somewhat east of north [EN104115–EN137259]. The dyke may extend further north through dolerite terrain but there is no clear cut evidence. Further north outcrops of dolerite (possibly a dyke) occur along a marked airphoto linear, which is probably a fault between the predominantly quartz sandstone sequence (Rs) and the Kaoota Coal Measures [EN137351–EN137353]. The linear extends north to the boundary of the map sheet. Along the well-defined portions of the dyke, strata on the eastern side are relatively displaced downwards by almost 300 m. The western side exhibits near vertical contacts with flat-lying strata [EN127196, EN112143]. The dyke is about 60 m wide in the south [EN128204] to less than 30 m wide in the north [EN136253]. At its southern end the dyke exhibits step joints forming horizontal columns, and a few kilometres to the north it reaches medium- to coarse-grained size. In its northern, narrower section, it is fine-grained.

EAST CYGNET SHEET

West of the major dyke a broadly crescentic area of dolerite crops out east of Cygnet. For most part this body is a sheet which shows sill-like contacts generally with the Deep Bay Formation. The contact of the fine-grained sheet base and the underlying highly-baked Deep Bay Formation is exposed north of Cygnet [EN071241]. The base of the sheet can be followed several kilometres in a south-easterly direction and it gradually descends into the Bundella Formation. Through this region the sheet appears to be 200–300 m thick. The upper contact dips north-easterly at a lower angle than the overlying strata and the sheet ascends progressively through the Deep Bay, Minnie Point, Risdon and part of the Abels Bay Formations. South-east from Cygnet the upper surface of the sheet remains within and more or less concordant with the Deep Bay Formation descending in only one area to intrude the Bundella Formation [EN115186]. Through this region the base of the sheet is not exposed, and it is not clear whether the linear boundaries with the Bundella Formation on the north-western side of the outcrop area represent up-faulting and removal by erosion, or whether the linear boundaries represent steep intrusive contacts. The latter possibility may be supported by the occurrence of fine-grained dolerite at [EN102202]. Chilled dolerite near the boundary in Nicholls Rivulet is probably close to a near-horizontal intrusive margin as the dolerite remains fine-grained for several hundreds of metres to the east and for about one kilometre upstream in the rivulet.

In the southern area the sheet may extend as far east as the major dyke, and it is not unreasonable to postulate that the stratal displacement across the dyke may be due to sheet termination at the dyke. Further north, however, an elongate block of Lower Parmeener Super-Group rocks occurs between the sheet exposures and the dyke, and it is uncertain whether the dolerite sheet has been up-faulted and eroded, or whether the sheet abruptly descends to a lower horizon, which in some areas, would be below the Bundella Formation. This latter possibility is preferred as, at Sunny Banks, a steep-sided, transverse dolerite body terminates the uplifted Lower Parmeener Super-Group block and the dolerite is overlain near its southern edge by highly-baked Bundella Mudstone [EN126243]. In its central part the transverse dolerite body is coarse-grained, but on its northern side a quarry shows fine-grained dolerite which appears to overlie Abels Bay Formation [EN128245]. Fairly fine-grained dolerite and baked Woody Island Siltstone suggest that the southern edge of the body is also intrusive [EN133241], but this is confused by coarse-grained dolerite near the boundary further

west [EN127242]. The significance of very fine-grained dolerite between the dolerite-Woody Island Siltstone boundary and the highly-baked Bundella Mudstone which overlies the dolerite is uncertain [EN126242]. The occurrence of medium-grained dolerite with no obvious signs of chilling only 1·5 metres beneath an outcrop of the Bundella Mudstone indicates rapid grain-size changes, that perhaps the Bundella Mudstone occurrence is a xenolith, or, that faulting may be present.

The transverse dolerite body at Sunny Banks may give rise to sheet split which over-rode the Abels Bay Formation to intrude the dominantly quartz sandstone sequence (Ɍs) as a sheet at Morrisons Hill [EN133280]. A definite connection between the two sheets occurs via a dyke-like body east of Nicholls Rivulet [EN127265]. It seems likely that the dolerite intrudes the sequence at two stratigraphic horizons in the vicinity of Mundys Hills [EN100275] unless the sheet in the Abels Bay Formation wedges out northwards, or the overlying sheet is abruptly terminated to the south.

The East Cygnet Sheet may terminate westwards against the NW-trending fault on the northern side of Deep Bay [EN086162]. If the sheet extends westwards beyond Deep Bay it must descend to at least 100 m below the top of the Bundella Formation as no dolerite or signs of metamorphism were encountered in the Deep Bay Bore (NF75 [EN077149]).

The absence of dolerite in the Deep Bay, Minnie Point, Risdon and Abels Bay Formations north of Cygnet indicates a NNE-trending dolerite boundary, marks a westwards truncation of the sheet, or an abrupt rise of the sheet to a higher stratigraphical horizon [EN071241–EN073249]. Dolerite which intrudes the Deep Bay Formation about 2 km to the south-west may be an outlier of the sheet or a faulted plug [EN058235]. The ?upper surface of the sheet also appears to transgress the strata northeast of Gaylors Sugarloaf [EN058260] and rises through the Risdon Sandstone and Abels Bay Formation and possibly merges with the dolerite which intrudes the dominantly quartz sandstone sequence (Ɍs). The structure is complex because dolerite contacts with the Minnie Point Formation occur at similar elevations both east and west of Gaylors Sugarloaf; but no intrusions are known in the section immediately further west, yet intrusive contacts with the dominantly quartz sandstone sequence (Ɍs) are found in the intervening country at Gaylors Sugarloaf. The dolerite body forming Gaylors Sugarloaf is probably downfaulted with respect to the Abels Bay Formation on its southern side.

GREY MOUNTAIN–PELVERATA–KAOOTA

North of the East Cygnet Sheet outcrop, at least two dolerite sheets which intrude the Upper Parmeener Super-Group crop out. West of Pelverata a 60–140 m thick layer of the dominantly quartz sandstone sequence (Ɍs) occurs between two major dolerite sheets [EN065320–EN088350]. Sandstone outcrops on either side of Victoria Creek may represent a southern extension of the sandstone layer west of Pelverata [EN070290–EN070298]. A small outlier of dolerite north of Pelverata Creek probably represents the basal portion of the two sheets west of Pelverata [EN098333].

Two dolerite sheets occur near Kaoota. The lower sheet which crops out east of Slide Creek [EN115357] was intersected in a nearby borehole (NF64). This sheet intrudes near the base of the Kaoota Coal Measures. The upper sheet caps the Kaoota Coal Measures of Herringback and forms a nearby outlier [EN120383, EN125368]. The base of the upper sheet may occur in Parsons Creek as baked lithic sandstone occurs in this area [EN106375]. The upper sheet may be continuous through Chicks Perch [EN090370] and be the same intrusion as the upper of the two sheets west of Pelverata.

The western margin of the dolerite terrain extending from Kaoota to the Bluff is, for the main part, the base of one or more dolerite sheets intruding the Kaoota Coal Measures [EN135365–EN140335].

The intrusion forming the dolerite terrain about Grey Mountain extends eastward in its sill-like form almost as far as Snug Plains [EN150300]. It terminates its sill-like form along a steeply dipping discordant intrusive contact with Upper and Lower Parmeener Super-Group rocks. To the west the dolerite outcrop terminates along a N-trending linear passing through EN064290. This linear is probably a post-dolerite fault downthrown to the east, although where the linear trends NNE near Woodstock, metamorphosed host rocks indicate that this portion of the linear is probably an intrusive boundary [EN066307]. It is probable that erosion has removed the sheet from the Barretts Creek area and that remnants of the sheet are exposed on Woodstock Hill and Catos Hill where, on the southern slopes, a dolerite sheet intrudes the Upper Parmeener Super-Group 40 m above the Abels Bay Formation [EN042290–EN026287]. West of the Huon River contacts between dolerite and Abels Bay Formation [EN005288], and further north contacts between dolerite and the dominantly quartz sandstone sequence (Ɍs), suggest that the sheet may be continuous across the Huon River.

The continuity of the sheet is broken for a few kilometres north and south of Woodstock [EN033316] on the eastern side of the Huon River, where Lower Parmeener Super-Group rocks have been uplifted and are intruded by dolerite. In this region north-east of Catos Hill, a dolerite sheet ascends from in the Deep Bay Formation through to the Minnie Point Formation. Progressively north of Woodstock dolerite abuts against Deep Bay Formation through to Abels Bay Formation, but it is not known whether this boundary is intrusive or faulted. It seems likely that the Lower Parmeener Super-Group rocks in this area have been uplifted by increased dilation due to a dolerite sheet related, perhaps, to a feeder structure. North of Ironstone Creek [EN047359] to near Paradise Hill [EN066380], metamorphism of the host rocks and the fine-grained character of the dolerite indicate that this boundary is intrusive. This conclusion is further supported by the presence of a dyke with the same trend extending north of Paradise Hill. This boundary appears to mark a steep rise in the sheet from within or below the Abels Bay Formation to the dominantly quartz sandstone sequence (Rs) accompanied by negligible change in sheet thickness. North of Paradise Hill the riser follows a more north-easterly trend and a thin dolerite sheet is present west of the riser [EN072383]. An unusual feature of the main sheet east of the riser is the presence of xenoliths of Truro Tillite at the top of the sheet. The largest xenolith abuts against the quartz sandstone (Rs) roof rocks at EN076374.

WATTLE GROVE SHEET

The irregular upper surface of this sheet intrudes the Woody Island, Bundella and Deep Bay Formations between Petcheys Bay [EN002176] and north of Wattle Grove [EN002234]. Pre-intrusion faulting has resulted in intrusive contacts with the Truro Tillite. The sheet may have been intersected in boreholes 32 [EN015237], 42 [EN011253] and NF55 [EN035263], but the lack of nearby surface outcrops of dolerite make this unlikely. Dolerite was not intersected in NF82 [EN051217] where Truro Tillite was intersected to a depth of 219·5 m, but a possible eastern extension of the sheet may occur at Robleys Point [EN065195].

LYMINGTON AREA

The intrusion of Beaupre Point appears to be a slightly transgressive sheet, but the presence of a possible xenolith of Truro Tillite suggests the proximity of a feeder structure. Nearby, at Lymington, a dyke approximately 200 m wide trends towards the East Cygnet Sheet. If uplift of the

rocks on the south-eastern side of the dyke has been caused by dilation across the dyke, then the dyke probably dips to the south-east.

NIERINNA AREA AND SOUTHWARDS

Near Nierinna Creek a major sheet intrudes the Deep Bay Formation and, in some places, the top of the Bundella Formation [EN192355]. Near Hickmans Hill, a relatively broad, low dyke-like feature rises from the main sheet to intrude at least as high as the Abels Bay Formation. Steep intrusive contacts bound the outcrop area of the dolerite sheet on both the western and eastern margins. The presence of dolerite dykes arising from beneath the Deep Bay Formation west of the sheet outcrop, borehole intersections of subsurface dolerite east of the outcrop area (NF84, NF87, NF88) and the absence of significant differential sheet dilation effects along the boundaries, all indicate that the sheet extends subsurface at lower stratigraphic levels east and west of the main outcrop area. The sheet may again ascend to higher stratigraphic levels in the Deep Bay Formation through to the Abels Bay Formation east of Perrins Ridge and north-east of Sam Smiths Hill [EN160345–EN154386].

A similar feature to the broad dyke-like feature at Hickmans Hill extends from Margate Rivulet to south of Kettering [EN180330–EN180235]. This intrusion has metamorphosed host rocks and is very fine-grained near its western margin near the Snug Rivulet [EN181305]. The upper surface of the bordering dolerite sheet is exposed on the eastern side of the dyke-like feature in Snug Rivulet. There appears to be no significant break in the strata adjacent to the western edge of the dyke-like feature to suggest a termination of the subsurface dolerite sheet. More probably, the sheet thickens causing increased dilation uplift of roof rocks south of Oyster Cove Rivulet [EN170277]. However, to the east a fault from Margate to the dyke-like feature could mark a subsurface termination of the sheet, or could be a pre- or post-dolerite fault. On its eastern side the dyke-like feature is fine-grained at its boundary with the dominantly quartz sandstone sequence (Rs) some 300 m south of the fault. A further 2·5 km south, granophyric dolerite exhibits faulted and intrusive boundaries with the same sequence (Rs). Further east at Oyster Cove, a bordering dolerite body exhibits discordant intrusive boundaries with the Abels Bay Formation [EN214271]. These dolerite bodies which border the margin of the dyke-like intrusion may give rise to the sheet which caps The Sheppards Hill [EN225285].

At Kettering Point and north of Little Oyster Cove a dolerite sheet intrudes the Deep Bay Formation

[EN212246–EN203260]. A quarry adjacent to the dyke-like body exposes a discordant intrusive boundary between Bundella Mudstone and fine-grained dolerite. The contact dips at 35–40° to the east, whereas the Bundella Mudstone dips at 80° to the east. It is evident that at least a component of the Bundella Mudstone dip and that adjacent faulting had occurred prior to dolerite intrusion. Dolerite is also present offset from the dyke-like feature near Little Peppermint Bay where a sheet-like, 380 m thick, body with horizontal layering (and minor Cretaceous syenite) within the Truro Tillite was intersected in the Woodbridge Borehole [EN193227] (Farmer and Clarke, 1985). A dolerite dyke nearby may also indicate subsurface dolerite [EN185216].

South of Masons Creek the dyke-like feature appears to have given rise to a sheet which first intrudes the Abels Bay Formation, and then transgresses into the dominantly quartz sandstone sequence (ℝs) [EN175200]. This sheet may connect with a major dyke near Devils Royals and Echo Sugarloaf [EN113143–EN108123]. Fine-grained dolerite occurs near the base of the sheet. Linear boundaries between coarse-grained dolerite and quartz sandstone which cross Garden Island Creek [EN150159] and north of Magpie Hill [EN193150] may indicate post-dolerite faulting, but this could not be conclusively demonstrated during mapping.

The base of a dolerite sheet intruding the Abels Bay Formation is exposed at Peppermint Bay [EN195212]. Dolerite also occurs south of Fleurtys Point [EN203170]. Both these coastal occurrences of dolerite may represent down-faulted portions of the main sheet to the west, but the evidence is inconclusive.

The mass of dolerite exposed in the headwaters of Kruses Creek intrudes the dominantly quartz sandstone sequence (ℝs) on its western side, and relatively uplifted Lower Parmeener Super-Group rocks on its eastern side. Exposures indicate that the contact with the Upper Parmeener Super-Group varies from near vertical to dipping 30–40° towards the east [EN138249, EN138248]. Where the Oyster Cove road crosses the eastern boundary the dolerite is finer grained and the Bundella Mudstone is highly baked.

BLACKMANS BAY–TINDERBOX

Between Blackmans Bay [EN268378] and Tinderbox Bay [EN272326] a dolerite sheet intrudes the Deep Bay Formation. The sheet ascends in a general westerly direction, moderately to steeply discordant through the overlying Lower Parmeener Super-Group formations, to eventually intrude the dominantly quartz sandstone sequence (ℝs).

Metamorphism within rocks of the Lower Parmeener Super-Group is intense.

BRUNY ISLAND

Between Trumpeter Bay [EN323206] and Moorina Bay [EN338120] a dolerite sheet intrudes the Deep Bay Formation. Although broadly concordant, coastal exposures reveal local discordance as for example at Lookout Bay [EN329201]. The sheet appears to be the source of dykes near Variety Bay [EN340159], and the broad areas of dolerite which intrude the Abels Bay Formation south of Great Bay.

A dolerite sheet also intrudes the Deep Bay Formation near Bull Bay Point [EN302290], but other east coastal exposures a few kilometres to the south reveal discordant intrusive boundaries with the Abels Bay Formation and the Upper Parmeener Super-Group. North of Great Bay to the north end of Bruny Island the dolerite sheet appears to have an irregular upper surface, and also appears to be the source of several dykes. Intrusive boundaries occur with all stratigraphic units ranging from the Deep Bay Formation to the dominantly quartz sandstone sequence (ℝs). Boundaries between this sequence (ℝs) and dolerite between Woodcutters Point [EN250265] and Bull Bay [EN292292] may represent the base of a sheet. The dolerite is coarsely granophyric at the southern end of Dennes Hill.

[S.M.F.]

Faulting

The Parmeener Super-Group, which dips gently to the south-west, has been considerably disturbed by intrusions of Jurassic dolerite and Cretaceous syenite, and has been extensively faulted.

Faults trend in all directions (fig. 6) but they may be divided into four groups — NW, N, ENE and WNW strike. The faults are steep and displacements are vertical or down the dip of those with a hade.

Figure 6. *Distribution of fault directions, Kingborough Quadrangle — 96 observations, 10° intervals.*

5 cm

Bedding dips commonly increase towards the downward displacement along faults [*e.g.* EN076193]. No lateral components of movement have been noted even at the faulted, steeply-dipping boundaries of dolerite or syenite intrusions.

Most of the mapped faults are of north-westerly trend. The faults of this group are usually linear [*e.g.* EN020248] although there are examples of up to 7 km in length which are sinuous in plan [EN050260]. The sinuous faults consist of comparatively long straight sections of different trends connected by a short arcuate section, as, for example, at EN050253 where a member of the NW-trending group is continuous with a fault of westerly trend. Faults of the north-westerly group may be downthrown to the south-west or north-east. The maximum fault displacements noted are greater than 200 m to the south-west [EN053256] and greater than 55 m to the north-east [EN047160]. Members of the group displace the boundaries of Jurassic dolerite [*e.g.* EN027287] and terminate Cretaceous syenite intrusions [*e.g.* EN083198]. At a number of localities [*e.g.* EN178208] NW-trending faults abut dolerite boundaries and do not appear to continue into the dolerite body. However, due to the lack of marker horizons within dolerite required to determine the presence of absence of vertical movements, such mapped relationships cannot be accepted to show conclusively that the faults existed before Jurassic dolerite intrusion.

Northerly trending faults are similar in general morphology to those of north-westerly trend, in that they are usually linear although sinuous examples have been mapped [*e.g.* EN210330]. Most of the faults of this group are downthrown to the west, with the maximum displacement noted of some 60 m. However the greatest displacement displayed by any of the faults of the region is a downthrow of greater than 350 m to the east along the northerly trending faults bounding the western margin of D'Entrecasteaux Channel [EN210330]. A member of this group of faults displaces the Jurassic dolerite at EN064260, whereas a northerly trending fault does not appear to disturb the dolerite intrusion at EN287270.

Sinuous faults of the ENE-trending group are not uncommon [*e.g.* EN170277]. Most of the faults display a downthrow to the south with the maximum displacement noted of greater than 120 m [EN050182]. The maximum downthrow to the north for a member of this group is approximately 60 m [EN200259]. Faults of ENE trend appear to terminate Cretaceous syenite occurrences at EN017192 and displace Jurassic dolerite at EN200259, whereas the dolerite intrusion at EN185282 does not appear to be affected.

Faults of the WNW group are of similar morphology to those of the other groups, with some members continuous with the sinuous faults of other trends [*e.g.* EN050254]. Members of the WNW-trending group of faults display downthrow to a maximum of greater than 20 m to the south [EN100154] and approximately 90 m to the north [EN051228]. A WNW-trending fault does not appear to affect the Jurassic dolerite body at EN114150, whereas a fault of this trend appears to affect the Cretaceous syenite at EN008199.

SUMMARY AND CONCLUSIONS

Faults of all trends show similar morphological characteristics. They are usually steep and linear although markedly sinuous faults are not uncommon. The faults display vertical displacements and no horizontal components of movements along the faults have been noted, even where steep dolerite and syenite outcrop boundaries have been affected.

Faults of all trends have been mapped terminating at Jurassic dolerite boundaries, as well as similarly trending faults affecting the dolerite intrusions. Such relationships suggest that pre-dolerite faults of all trends may have existed with faults of similar trends developing later. However, features suitable for indicating vertical displacements within dolerite intrusions are rare and many of the faults mapped abutting dolerite intrusions may well continue into the igneous body, or indeed form the delimiting boundary to the dolerite masses, especially the linear ones of northerly trend.

Examples have been noted where Cretaceous syenite intrusions are terminated by faults of all but those of northerly trend, which are not well-developed in the main region of syenite occurrences around Cygnet [EN065210]. The Parmeener Super-Group forms a domal structure around the Cygnet intrusions and members of all the fault groups downthrow strata away from the domal centre, enhancing the domal structure. The Cretaceous syenite occurrences at Cygnet, with the accompanying domal structure, have evidently had an anisotropic effect on the development of faults of all trends, which appear to be of later age.

The steep dip and often sinuous nature of the faults, which display vertical displacements with no evidence of any component of horizontal movement, indicate the faults to be of normal type. Their steep nature is attributed to the surface boundary condition effect on stress fields during their development.

Tertiary deposits are unaffected by the faults but are preserved in areas of depositional basins bounded by pre-Tertiary faults of particularly northerly trend.

[E.W.]

ECONOMIC GEOLOGY

Gold

Prospecting for alluvial gold has been carried out sporadically for more than one hundred years. Thureau (1881) reported that it had first been found in the Agnes Rivulet, but was not overly impressed with the prospects in the alluvium of the Lymington area. Attempts at primary lode mining were started in 1898 and Smith (1899) reported fine specks of gold in samples from Mt Mary.

It is difficult to establish how much gold the district has produced but Twelvetrees (1902; 1907) estimated about 3 000 ounces then valued at $32 000. Most came from the Lymington flats which are surrounded by steep hills much intruded by syenite. Reef gold was mined in a shaft near Kings Hill road.

Much of the higher ground in the Petcheys Bay-Lymington region is composed of rocks of the Lower Parmeener Super-Group which are extensively intruded by Cretaceous alkaline syenite. Gold deposited at or near the contacts of syenite and country rock has been shed into either the Lymington basin or the shore flats of the Huon River. The Lymington valley has been eroded across the alkaline intrusives and would appear to offer an ideal basin for the alluvial concentration of gold at the mouth of Forsters Rivulet.

The Mt Mary mine was situated west of Cygnet township and consisted of several shafts which are now inaccessible. The country rock is Truro Tillite intruded by many small bodies of syenite. Scott (1927) reported disseminated pyrite mineralisation in both tillite and syenite. Brecciation of the contacts was reported by Twelvetrees (1907) and a reddish contact rock bears visible gold.

The Livingstone mine was situated on the slopes of Tobys Hill north-east of Cygnet. The mine worked a quartz reef in syenite porphyry near the contact with Bundella Mudstone. A shaft was sunk to a depth of 20 m following the parallel bands of quartz rock. Initial assays were promising (Smith, 1899) but later results were disappointing. The lode also contained small amounts of arsenopyrite, pyrite, chalcopyrite and galena. This lode has been thought to be the most promising in the district and it is the only one found to date entirely within the alkaline intrusives.

An old shaft at EN057205 shows finely porphyritic syenite dipping at 40–45° within tillite. The contact zone has a very slaggy appearance but no mineralisation was observed.

Pyrite is the predominant mineral associated with thermal metamorphism by all types of alkaline rocks and dolerite. Galena and chalcopyrite occur at the Livingstone mine and the quarry near Copper Alley bridge at Lymington [EN061170]. Pyrrhotite is found in nodules in tillite and Woody Island Siltstone near Wilsons Yard and Crooked Tree Point [EN072193]. It has been produced by the thermal metamorphism of pyrite nodules by dolerite and/or alkaline syenite. Extensive pyrite and magnetite occurs at Regatta Point.

Coal

Coal seams are developed within the Upper Parmeener Super-Group at two levels. At the base the Cygnet Coal Measures are of Late Permian age, and near the top the Kaoota Coal Measures are of Late Triassic age.

The Cygnet coalfield is situated on the western flanks of Mt Cygnet [EN133173] and Heeneys Bluff [EN147197] about 8 km east of the township of Cygnet. The coal was mined intermittently from 1880 until 1940 (Bacon, 1983a), 1945 (Noldart, 1975) or the immediate post-Second World War years (Farmer, 1979h). Two separate departmental production records variously show operations ceasing in 1931–1932 and 1939–1940. All adits and workings have deteriorated badly and present exposure is very poor. Accounts of the workings indicate that the coal seams are thin (usually <1 m thick), are not laterally extensive and are much faulted. The inferred reserves are very small (less than one million tonnes) and the potential for future exploration and development is considered to be negligible (Bacon, 1983a).

At the time of Thureau's visit in 1881 only minor mining activity had taken place on the slopes of Mt Cygnet. Twelvetrees (1902) reported that a dip tunnel had advanced 270 m. By 1922 a number of operators had developed the area and a large number of trenches, adits and shafts had been excavated at points spaced along the outcrop for a distance of about 5 km.

The Mt Cygnet mine [EN125184] was opened in 1881 and was worked intermittently until 1897 when Robert Harvey took over the running of the mine. Three thousand tonnes of coal were produced in 1901. Two coal seams were reported at the mine. The main worked seam was one metre thick with a lower 0·3 m thick seam 8·3 m below the main seam. Two main dip tunnels or pits were in use by 1923, the dip tunnel or Pit No. 2 being referred to as Gordon's Workings. Pillars had been pulled from Pit No. 1 by 1922 (Hills et al., 1922) and most of the coal was produced from Pit No. 2. Roof rolls were reported to be common.

Two strike tunnels were reported to have been driven into coal in the early 1900s on the western

slopes of Heeneys Bluff [EN141195]. The first adit (Heaney's No. 1) worked a seam 0·9 m thick and was separated by a fault from Heaney's No. 2 workings about 300 m to the north-east (Hills *et al.*, 1922).

Approximately 1·3 km north-east of Heaney's No. 2 adit a seam 0·3 m thick was exploited in small-scale operations at Berry's Workings. Mining had ceased some years before the 1922 inspection (Hills *et al.*, 1922).

A new adit close to the old Gordon's Workings and given the same name was opened in 1939. A small tonnage of coal was mined, reportedly for metallurgical purposes. The mine closed in 1940.

A borehole (NF85 [EN126183]) proved the Cygnet Coal Measures to be at least 35·2 m thick (Farmer, 1979h). Four coals were intersected in the bore. Only the upper 0·9 m thick seam appears to have been mined and the old workings were encountered in the borehole. A second coal 0·2 m thick occurs 4 m below the main seam, and two thin (50 mm) leaves of coal lie between the two thicker ones. The interseam thickness of strata indicates rapid lensing of units compared with the Mt Cygnet mine workings.

The coal is sub-anthracitic doubtless due to the proximity of Jurassic dolerite. Sulphur content is low (0·41–0·57%) but ash content is high (17·6–23·2%). Steamships used a mixture of the coal and wood to reduce the ash problem (Hills *et al.*, 1922).

Due to the small area of potential reserves, the much faulted terrain and the thin coal seams, the potential for further exploitation of the field is poor. There may be enough coal for limited local consumption, but not for any larger scale mining venture. The *in situ* reserves are inferred to be very small and less than one million tonnes.

A thin (20 mm) coal seam within the Cygnet Coal Measures is exposed on the shore platform at Middleton [EN210136].

The Kaoota (or Sandfly) Coal Measures are of Late Triassic age and contain a number of seams up to 2 m in thickness. The coal was mined from 1881 until 1971 with two mines, the Wallsend and the Sandfly, producing most of the coal (Bacon, 1983b).

The Kaoota coalfield is situated close to the township of Kaoota [EN135366] about 5 km south of Sandfly. The Kaoota Coal Measures are the uppermost unit of the Upper Parmeener Super-Group and consist essentially of feldspathic and lithic sandstone with subordinate mudstone and thin workable coals. Jurassic dolerite has intruded the coal measures sequence as transgressive sheets.

Dolerite caps the hill [EN125367], around which mining was first established, and probably underlies the block of country which comprises the coalfield, since boreholes drilled in the area have encountered dolerite at depth. Dolerite talus thickly blankets many slopes. The area of potential coal reserves is likely to be much faulted, as both major mines (the Sandfly and the Wallsend) had their workings interrupted by faulting.

The Kaoota coalfield has been periodically mined since 1881. Whereas there were only two named mines in the coalfield, these were served by a large number of adits. New adits were dug as the older adits were abandoned and often given the same name. The Sandfly mine had no less than eleven adits.

Much of the history of the coalfield is documented by Hills *et al.* (1922) and Whitham (1973). Thureau (1881) noted a ten metre shaft and a number of adits being worked at the Sandfly mine, but due to poor access little mining was done until the construction of a tramway in 1906. Montgomery (1893) reported that the mine owners were more concerned with finding a suitable route for the tramway in preference to working the mine. Twelvetrees (1903a) inspected adits and trenches on eight outcrops of coal. The longest tunnel was 20 m long and exposed a split seam with the top ply 1·54 thick separated by a fireclay 1·22 m thick from the lower ply 1·23 m thick. Twelvetrees noted that the fireclay was 'charged with the imprints of Mesozoic ferns' (*Dicroidium*). Most of these workings were in the vicinity of the Sandfly No. 3 workings [EN126366].

In 1904 the Sandfly Colliery Company mined 200 tonnes of coal for steaming trials in a warship (Whitham, 1973). Work on the tramway to Margate started in 1905 and required the construction of ten substantial bridges. The tramway was completed in 1906, but in 1907 the company collapsed after producing only 8 500 tonnes of coal. The Tasmanian Wallsend Colliery company then acquired the tramway and produced 16 000 tonnes of coal, mostly from the Wallsend workings [EN119364] before the mine was closed in 1910 after striking major problems with faults.

A local syndicate took over the Sandfly leases in 1917, but produced only 1 600 tonnes of coal from the No. 3 workings before closing in 1919. In 1920 fire destroyed one of the major tramway bridges and in 1922 the tramway was dismantled. Some of the rails and one locomotive were acquired by the Catamaran Coal Company (Whitham, 1973).

From 1937 until 1957 ground to the east of the old Sandfly mine was worked by the Fogarty family,

then by the Roberts family until 1971. Mining activity was stopped by the existence of faults which severely disrupted the workings (Threader, 1973).

Threader (1974) noted that the Sandfly mine and most other workings mined the Sandfly seam, whereas the Wallsend mine worked the Wallsend seam. The two seams are about 120 m apart with the Sandfly seam occupying the lower stratigraphic position.

Total production from the area was less than 80 000 tonnes. A typical analysis of Sandfly coal from the 1948 (Fogarty) workings at EN132368 had a low sulphur content (0·45%) but high ash content (22·1%). Other analyses listed in Bacon (1983b) have sulphur contents between 0·32–0·47% and ash contents between 20·2–24·14%.

As the main seam worked (the Sandfly seam) was only 0·75 m thick on average and the small areal extent of the coalfield is highly faulted, the prospects for future mining development in the Kaoota area are not great. The *in situ* reserves are inferred to be very small, and probably less than two million tonnes (Bacon, 1983b).

Limestone

Thin developments of limestone occur at Harts Hill, near Margate [EN205345] and at Silver Hill near Glaziers Bay, Cygnet [EN021233]. The deposit at Harts Hill is very deeply rotted possibly as a result of Tertiary weathering. The calcium carbonate content ranges between 72% and 82% and small quantities have been used for agricultural lime (Hughes, 1957). The deposit at Silver Hill is even more limited and consists of a small lens within the Deep Bay Formation. Several trial pits were dug (Everard, *in* Hughes, 1957) but no production occurred. The limestone is very impure with acid insoluble fractions as high as 46%.

Sand and construction materials

Jurassic dolerite, Cretaceous syenite, Parmeener Super-Group rocks thermally metamorphosed by dolerite, and to a lesser extent particular horizons within the Parmeener Super-Group and younger rocks, provide potential sources for road making materials. Weathering, jointing, the degree of metamorphism, mineralogy, topography, location and accessibility determine the suitability of the various rock types.

Fresh dolerite of fine- to coarse-grain size yields material suitable for crushing when a uniform clean aggregate is required. Dolerite with a granophyric texture, where sufficiently weathered to be easily crushed but not clayey, forms a material which is easily worked and often used to top dress gravel roads as well as the base for sealed roads. The quarries on the Channel Highway near Red Hill [EN199277] and North Bruny Island [EN290286] are examples of this type of material. The rock quarried often exfoliates from around boulder-sized kernels of fresher dolerite.

Old river terrace gravels have been worked around Huonville [EN040363], Beaupré Point [EN050140], Randalls Bay [EN095124] and Howden [EN242362]. The finer fractions have been worked for sand around Huonville. Sandpits are extensively worked in Quaternary sands in the South Arm area [EN340358]. There are several pits in deeply weathered Triassic sandstone at Blackmans Bay. Gravel and sand horizons have been worked in the Tertiary developments near Huonville and Coffee Creek, Margate [EN234386, EN214339]. Immediately south of the Oyster Cove crossroads [EN197272] Tertiary clay, although a little sandy, is currently worked for brick clay. Tertiary ferricrete is used as a top dressing on gravel roads on North Bruny Island.

The sizing analyses and Atterburg limits of all deposits of sand and construction materials in the Kingborough Quadrangle are listed in Tables 4 and 5.

Groundwater

Details of the underground water resources of the Cygnet area in the south-east of the quadrangle have been published elsewhere (Leaman, 1967). The general comments made in the above publication apply to the whole quadrangle and it is reasonable to assume that the information on yields and water quality is valid overall.

[M.J.C.]

Table 4
SIZING ANALYSIS OF SAND DEPOSITS, KINGBOROUGH QUADRANGLE

No.	AMG Ref. (EN)	Locality (see fig. 8)	Sizing analysis % passing (mm)														
			37·5	28·5	19	9·53	4·76	2·36	1·18	0·6	0·425	0·3	0·25	0·212	0·15	0·075	0·038
S1	398364	Calverts Beach	—	—	—	—	—	—	tr	100	—	93	60	27	8	4	3
			—	—	—	100	98	98	98	98	—	60	—	—	2	0	—
			—	—	—	—	—	—	—	tr	—	80	48	26	5	1	1
S2	394380	Sandville Ranch	—	—	—	—	—	78	71	67	—	60	—	—	37	11	4
			—	—	—	—	—	—	—	0	—	12	—	—	—	—	96
S3	384356	South Arm	—	—	—	—	—	—	—	100	—	98	—	—	21	3	0
S4	396364	South Arm	—	—	—	—	—	tr	100	100	—	96	—	72	22	0	—
			—	—	—	—	—	—	100	100	—	96	—	73	25	4	2
S5	365352	South Arm Neck	—	—	—	—	—	—	100	99	—	58	—	—	2	1	—
			—	—	—	—	—	—	100	—	96	—	—	—	—	5	—
S6	062290	Upper Woodstock	—	—	—	—	—	100	—	—	90	—	—	—	—	1	—
S7	061293	Upper Woodstock	—	—	—	—	—	100	—	—	—	—	—	—	—	—	—
S8	344343	Hope Beach	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S9	214339	Baretta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S10a	254385	Blackmans Bay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S10b	253384	Blackmans Bay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S11	244382	Bluetts Hill	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S12	234382	Coffee Creek	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S13	241363	Howden	—	—	—	—	—	—	—	—	44	—	—	—	—	18	—
S14	043375	Huonville	100	99	97	88	81	77	—	—	59	—	—	—	—	9	—
S15	040366	Huonville	—	—	100	96	75	64	—	—	—	—	25	—	—	8	—
S16	042367	Huonville	—	—	—	—	—	100	—	—	86	—	—	—	—	—	—
S17	043369	Huonville	—	—	100	99	98	97	—	—	—	—	—	—	—	—	—
S18	094122	Randalls Bay Road	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S19	213302	Lower Snug	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 5
SIZING ANALYSES OF CONSTRUCTION MATERIALS, KINGBOROUGH QUADRANGLE

No.	AMG Ref. (EN)	Locality (see fig. 7)	Sizing analysis % passing (mm)															Atterberg limits		
			75	53	37·5	28·5	19	9·53	4·76	2·36	1·18	0·6	0·425	0·3	0·15	0·075	0·038	LL	PI	LS
1a	196376	Blue Gate Creek	—	—	—	100	94	81	61	44	25	15	—	8	4	2	—	—	—	—
* 1b	197377	Blue Gate Creek	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
* 2	168366	Allens Rivulet	—	—	—	100	95	89	70	52	31	18	—	10	5	2	—	—	—	—
* 3	276340	Tinderbox	—	—	—	100	87	73	54	35	—	—	11	7	3	1	—	—	—	—
			—	100	97	94	88	62	43	29	—	—	11	—	—	5	—	38	20	9
* 4	197285	Lower Snug	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
* 5	127196	Gardners Bay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	177213	Woodbridge	89	70	60	45	43	36	32	28	27	22	15	9	5	4	3	—	—	—
7	190255	Kettering	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
* 8	045344	Ironstone Creek	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
* 9	190126	Middleton	—	—	—	—	100	98	82	56	—	—	15	—	9	—	—	37	20	8
*10	054152	Drip Beach	—	—	—	100	98	77	64	45	39	21	—	19	13	10	—	—	—	—
11a	096122	Randalls Bay	—	—	—	100	97	79	62	52	45	37	—	25	15	11	—	—	—	—
			—	—	—	100	90	62	52	47	45	42	—	35	20	14	—	—	—	—
11b	091117	Randalls Bay	—	—	—	100	91	70	54	44	—	—	30	—	—	12	—	28	10	17
*11c	084118	Randalls Bay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11d	095124	Randalls Bay	—	—	100	97	88	71	56	54	—	—	42	—	—	20	—	35	20	9
*12	023385	Ranelagh	—	—	—	—	100	90	68	52	—	—	29	—	—	9	—	24	3	3
13	030354	Huonville	—	—	100	98	95	84	58	31	—	—	12	—	—	8	—	39	19	8
*14	032351	Huonville	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15	032351	Huonville	—	—	—	100	92	72	57	41	—	—	18	—	—	9	—	44	21	10
*16	072315	Upper Woodstock	—	—	100	99	92	73	56	43	—	—	28	—	—	15	—	48	27	13
17	069300	Upper Woodstock	—	—	—	—	—	100	93	79	—	—	30	—	—	14	—	54	31	15
18	271340	Tinderbox Road	—	100	88	69	52	40	31	25	—	—	16	—	—	9	—	46	24	10
19	271340	Tinderbox Road	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	043375	Huonville	—	—	100	99	97	88	81	77	—	—	44	—	—	10	—	—	—	—
21	040366	Huonville	—	—	—	—	100	96	75	64	—	—	59	—	—	9	—	—	—	—
*22	042367	Huonville	—	—	—	—	—	—	—	100	—	—	25	—	—	8	—	23	8	4
*23	043369	Huonville	—	—	—	—	100	99	98	97	—	—	86	—	—	25	—	23	2	2
*24	270342	Tinderbox Road	100	76	56	—	38	24	17	14	11	9	—	7	5	4	—	—	—	—
25	189370	Blue Gate Road	—	—	—	—	100	95	74	48	34	24	—	18	14	11	—	—	—	—
26	184391	Allens Rivulet Rd	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*27	189334	Van Morey Road	—	100	89	—	81	72	58	40	27	20	—	15	11	8	—	—	—	—
*28	190306	Snug Falls Road	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*29	204243	Trial Bay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*30	200312	Snug Tiers Road	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*31	178202	Woodbridge	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* Disused

No.	AMG Ref. (EN)	Locality (see fig. 7)	75	53	37·5	28·5	19	9·53	4·76	2·36	1·18	0·6	0·425	0·3	0·15	0·075	0·038	LL	PI	LS
								Sizing analysis % passing (mm)										Atterberg limits		
32	180192	Woodbridge	—	—	—	—	100	93	85	58	—	—	12	—	—	5	—	36	14	9
33	254368	Howden	100	97	94	79	68	54	37	29	—	—	11	—	—	5	—	39	15	7
34	109133	Echo Hill	—	100	99	90	77	38	27	24	—	—	14	—	—	6	—	39	12	6
*35	062171	Copper Alley Road	—	100	98	97	97	74	57	47	—	—	36	—	—	29	—	39	16	8
36	052154	Drip Beach	—	—	100	99	94	81	71	64	—	—	56	—	—	18	—	14	0	0
*37	042150	Beaupré Farm	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*38	215356	Margate	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*39	291288	Dennes Hill	—	—	—	—	100	98	85	57	—	—	25	—	—	13	—	43	26	11
40	291287	Dennes Hill	—	—	—	—	100	99	81	53	—	—	26	—	—	16	—	49	28	14
41	302221	North Bruny	—	—	—	—	100	97	84	60	—	—	19	—	—	9	—	33	14	6
*42	042113	Granny Gibbons Bay	—	100	92	85	80	73	57	39	—	—	16	—	—	9	—	40	20	10
*43	073244	Cygnet	100	95	86	82	78	74	66	49	—	—	16	—	—	8	—	37	18	9
44	115188	Gardners Bay	—	—	100	97	92	81	63	44	—	—	19	—	—	11	—	40	24	11
45	139249	Nicolls Rivulet Rd	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
46	186330	Van Morey Road	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
47	199276	Red Hill	—	—	—	—	100	97	85	—	—	—	—	—	—	—	—	—	—	—
48	198278	Red Hill	—	—	—	—	100	85	65	46	—	—	17	—	—	7	—	38	23	11
*49	026202	Wattle Grove	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
50	173380	Allens Rivulet	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*51	189353	Nierinna Road	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*52	188333	Van Morey Road	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
53	214339	Barretta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*54	234386	Coffee Creek	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*55	078326	Pelverata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
56	023285	Cradoc	100	96	85	71	61	49	41	33	—	—	11	—	—	5	—	32	12	6
			94	83	75	69	63	57	48	32	—	—	9	—	—	5	—	32	13	7
57	144387	Sandfly	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*58	020367	Glen Huon Road	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*59	253364	Tinderbox Road	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*60	248363	Howden	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
61	242358	Wingara Road	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*62	136246	Nicholls Rivulet Road	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
*63	059260	Cradoc Hill	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
64	137383	Sandfly	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

* Disused

5 cm

12• ■Ranelagh
64• •57 26
Allens ■ •50
Kaoota■ Rivulet •25 1a•16
•2
S17• •S16
58• •S15 •S14
14• ■Huonville
13 15 •8

•55

■ •16
Woodstock

•17
S6• •S7
•56

■Cradoc

•63

•43

67• •45

•49

•5

35•

36•
37• •10

Beaupré
Point
•42

S18 11d 11a •34
•11b
11c• ■Randalls Bay

54•S10a• Blackmans
S12• S11 S10b•   Bay
Howden■ •33
Margate■ S13• •59
•38 61 •60

•53
27• S9
46•52

■Snug
30•
•28
•S19

•4
•48
•47
Oyster
Cove
•7
Kettering■
•29

Woodbridge■
6•

•31
•32

Middleton■
•9

24
18• •3
19

■Tinderbox

■Dennes Point
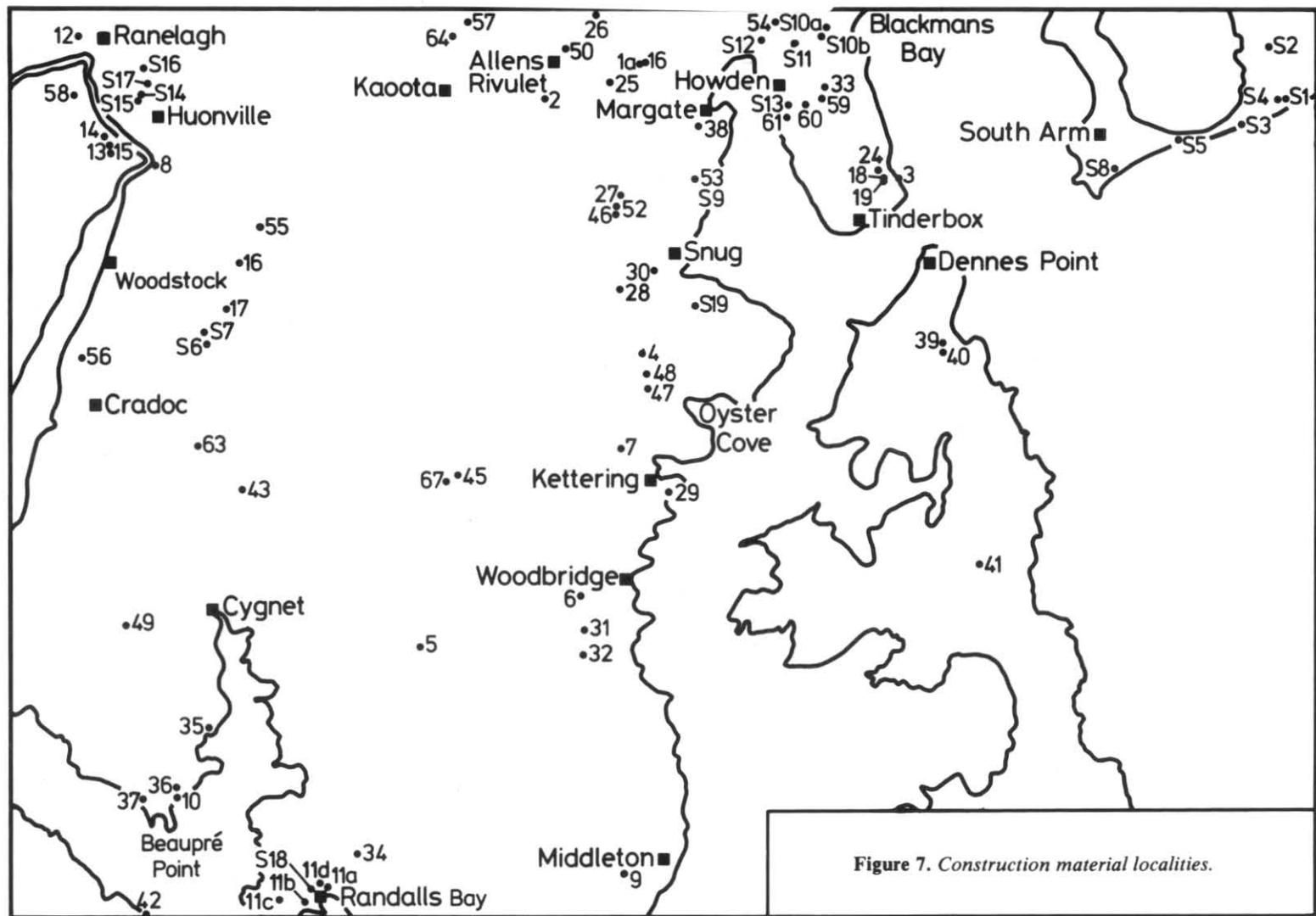
39• •40

•41

•S2

S4• ••S1
South Arm■ •S3
S8• •S5

Figure 7. *Construction material localities.*

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APPENDIX 1 DEEP BAY FORMATION

Section A. Upper part of exposed section from EN07351435 to EN07401425. Measured 7–8 April 1970, the section reads in correct stratigraphic order.

Unit

1A   1·05 m of orange weathering, grey fossiliferous siltstone with scattered pebbles, cobbles and small boulders up to 300 m long. Many large spiriferids.

2A   200 mm of hard, compact, fine-grained sandstone with small (up to 25 mm) pebbles towards base. Pebbles are not a conspicuous feature of the rock in general. Sparsely fossiliferous.

3A   250 mm of light grey weathering, fine- to medium-grained, richly fossiliferous, rubbly-looking, cavernous sandstone. Ribbed spiriferids and bryozoans are the main fossils. Pale buff colour when fresh, but weathers light grey. Many small quartz granules and pebbles up to 7 mm. Other clasts include dark mudstone, black slate and other low grade metamorphics.

4A   175 mm of light grey, compact sandstone with fossil layer 50 mm thick 50 mm above the base.

5A   110 mm of light brown siltstone with rounded pebbles up to 75 mm long. No fossils. Pebbles of granitoid composition.

6A   175 mm of light grey weathering, brown sandstone. Scattered shells and bryozoans throughout. Hard, compact, massive. Weathered to a deep red colour on upper surface in places.

7A   75 mm of buff coloured sandy siltstone.

8A   200 mm of light grey weathering, buff coloured sandstone. Upper surface reddened; fossiliferous throughout.

9A   325 mm of fine-grained, mottled, grey-red-brown sandstone. Rubbly appearance and more silty in top 150 mm. Fossiliferous throughout with spiriferids and bryozoans predominant.

10A   1·05 m of light grey to medium grey, brown weathering, sparsely fossiliferous siltstone. A few ribbed spiriferids and some worm burrows.

11A   500 mm of grey and brown, richly fossiliferous, fine-grained sandstone with a slightly rubbly appearance. Spiriferids and gastropods.

12A   300 mm of fine-grained and buff sandstone. Fossiliferous throughout with bryozoans, ribbed spiriferids and large martiniopsids. Patchy red staining or weathering on upper surface.

13A   125 mm of buff and grey, silty, very fine-grained sandstone with bryozoans.

14A   450 mm of fine-grained, fossiliferous sandstone. Ribbed spiriferids and bryozoans. Buff to light grey weathering.

15A   300 mm of brown weathering sandy siltstone with ribbed spiriferids and *Stenopora*.

16A   225 mm of hard, compact, very fine-grained grey sandstone with a few spiriferids and some fenestellids.

17A   125 mm of bryozoal siltstone with a few scattered shell fragments.

18A   275 mm of brown weathering, rubbly-looking, silty fine-grained sandstone. Bryozoans and some spiriferids.

19A   275 mm of brown weathering, rubbly-looking, silty fine-grained sandstone as below but with a 25 mm band of siltstone at the base.

20A   375 mm of cream weathering, grey, fine-grained sandstone with small pebbles of quartz and dark low grade metamorphic rocks up to 25 mm in length. Fossiliferous with coarsely ribbed spiriferids and bryozoans.

Gap (about 3·35 mm)

21A   150 mm of fine-grained, buff coloured, fossiliferous sandstone. Mainly stenoporids.

22A   150 mm of grey and buff, fossiliferous, pebbly siltstone. Highly weathered to a deep brown colour along joints.

23A   300 mm of buff and brown, medium- to fine-grained sandstone with quartz granules and pebbles of dark slaty material up to 12 mm in length. Coarsely ribbed spiriferids towards the base. Very closely jointed with the dominant direction of jointing 80° magnetic.

24A   200 mm of soft, brown weathering siltstone with many pebbles and cobbles (up to 200 mm). Clasts of quartzite and dark grey mudstone.

25A   475 mm of grey weathering brown and buff, fine-grained, fossiliferous sandstone with pebbles of quartzite up to 100 mm in length. Rubbly appearance.

26A   1·21 m of buff coloured, massive, compact siltstone. Apparently unfossiliferous.

27A   150 mm of hard, compact, fine-grained, buff coloured sandstone. No fossils observed.

28A   100 mm of buff coloured siltstone.

29A   250 mm of fine-grained, buff coloured sandstone with many small granules of quartz and rounded fragments of dark low grade metamorphic rocks. Some pebbles of granitoid (up to 100 mm) and one large cobble of granite (200 x 175 mm). Fossils not abundant, mainly small spiriferids and gastropods.

30A   50 mm of buff coloured, sparingly fossiliferous, pebbly siltstone.

31A   175 mm of light grey weathering, buff, fine-grained sandstone. Rounded clasts up to 75 mm. Ribbed spiriferids.

32A   150 mm of soft, brown siltstone with stenoporids and ribbed spiriferids.

33A   225 mm of grey and buff weathering, fine-grained sandstone. Sparsely fossiliferous, but some ribbed spiriferids and bryozoans.

34A   750 mm of soft, buff and yellow siltstone with silty sandstone bands and ribs. Pebbles up to 50 mm. Spiriferids and bryozoans.

35A 200 mm of hard, compact, fine-grained, buff coloured sandstone. Richly fossiliferous with large and small, ribbed spiriferids, fenestellid mats, large finely-ribbed pectenids (?*Etheripecten*) and stenoporids. Pebble band 12 mm thick with 6–12 mm pebbles about 25 mm above the base.

36A 450 mm of brown weathering, hard, compact, fine-grained sandstone. Fossiliferous with spiriferids and fenestellid mats.

37A 750 mm of alternating bands of cream coloured siltstone and harder, brown weathering sandstone in 150 mm beds. Sparingly fossiliferous with spiriferids, bryozoans and strophalosiids.

38A 850 mm of cream and buff coloured, pebbly siltstone with 100 mm fine-grained sandstone ribs. Quartzite and grey mudstone or siltstone clasts.

39A 250 mm of rubbly-lookingg, medium- to fine-grained, buff coloured sandstone.

40A 200 mm of cream to buff coloured, pebbly siltstone. Many pebbles up to 75 mm. A few spiriferids.

41A 350 mm of buff coloured sandstone with rubby appearance and cobbles up to 200 mm in length.

42A 900 mm of fine-grained, buff coloured, pebbly siltstone with some spiriferids.

43A 975 mm of buff and grey fossiliferous siltstone and sandy siltstone. Richly fossiliferous particularly in lower half with abundant strophalosiids, ribbed spiriferids and fenestellid mats. A few pebble-sized clasts.

44A 100 mm sandstone band; fine-grained, buff coloured. Pebbles up to 25 mm. Spiriferids.

45A 900 mm of fossiliferous grey siltstone with spiriferids, stenoporids, fenestellids. [The cliff section comes down to shore level at this point. Unit 46A begins at the base of the cliff section].

46A 825 mm of hard grey, buff weathering siltstone with a 100 mm sandy rib at the top. Contains a varied fauna with ribbed spiriferids, strophalosiids, fenestellid mats, gastropods, martiniopsids, terebratulids (?*Gilledia*) and large, finely-ribbed pectenids.

47A 2·28 m of medium grey to dark grey, laminated fenestellid siltstone. Friable when weathered. Some quartzite pebbles up to 75 mm long. A few poorly preserved ribbed spiriferids and a few branching stenoporids. Some low-spired coiled gastropods. Thin (12–25 mm) soft, sandy beds in places, and towards the top are thin (12–35 mm) somewhat irregular ribs of harder (?more siliceous) siltstone. Becomes flaggy in uppermost 450 mm, that is, beds are 50–75 mm thick rather than thin laminations.

48A 3·5 m of brown and buff siltstone and silty sandstone, with both laminations and blocky bedding. Becomes sandier towards the top. Fenestellids, spiriferids and small, low-spired, coiled gastropods throughout. Also lamellibranchs including finely-ribbed pectenids.

Section B. Lower part of exposed section from EN07351435 to EN07611488. Measured 21–22 April 1970, the section reads in reverse stratigraphic order.

[1A 1·05 m of orange weathering, grey fossiliferous siltstone with scattered pebbles, cobbles and small boulders up to 300 mm long. Many large spiriferids.]

1B 150 mm of soft, grey and brown siltstone; friable. Fossiliferous with abundant bryozoans and spiriferids.

2B 200 mm of hard, compact, grey (brown weathering) siltstone with shell debris and bryozoans throughout.

3B 50 mm of soft siltstone parting.

4B 475 mm of friable siltstone, grey and orange weathering. Has a slightly rubbly appearance when weathered. Bryozoans and spiriferids throughout.

5B 1·67 m of massive silty sandstone and sandy siltstone in beds 450–600 mm thick with softer, fissile and non-fissile, friable partings. Red staining or weathering in mottled patches.

6B 350 mm of soft, friable, ochreous-brown weathering siltstone with small ribbed spiriferids and bryozoans.

7B 800 mm of sandy siltstone with softer fissile siltstone partings. Rubbly appearance. Bryozoans and spiriferids throughout.

Gap (about 4 m)

8B 100 mm of light grey, very fine-grained, very compact, hard, non-fissile, flinty siltstone or fine-grained, well-cemented sandstone. Upper surface covered with fenestellid mats. Bryozoans highlight the bedding throughout.

9B 750 mm of hard, compact, grey and buff weathering siltstone with spiriferids and bryozoans. Quartzite pebbles up to 125 mm; rounded but not spherical.

10B 150 mm of light grey siltstone; crowded with bryozoans and some large spiriferids.

11B 175 mm of hard, sandy siltstone; grey when fresh, red and orange weathering.

12B 125 mm of soft, grey (buff weathering) siltstone with spiriferids, stenoporids and fenestellids.

13B 375 mm of light grey, fine-grained, silty sandstone. Compact and hard. Bryozoans.

14B 100 mm of soft, buff to yellow weathering fissile siltstone.

15B 175 mm of hard, sandy siltstone bed, grey in colour, buff weathering. Has a rubbly appearance where weathered.

16B 125 mm of hard, compact siltstone.

17B 525 mm of grey and buff, mottled weathered, soft, muddy siltstone with abundant strophalosiids, large and small ribbed spiriferids and bryozoans.

18B 250 mm of hard, compact, light grey, buff weathering siltstone with spiriferids and bryozoans.

19B 250 mm of siltstone, yellowish weathering, mottled in part, with martiniopsids and bryozoans.

20B 375 mm of light grey siltstone with large spiriferids and bryozoans.

21B 200 mm of silty sandstone with many ribbed spiriferids.

22B 325 mm of rubbly siltstone and sandy siltstone with bryozoans and spiriferids. Red weathering on top surface.

Gap (150–300 mm)

23B 225 mm of fine-grained, grey siltstone with abundant fenestellid mats.

Gap (7·5–9·5 m)

24B 200 mm of buff and cream coloured siltstone. Richly fossiliferous with fenestellids, small ribbed spiriferids and others.

25B 225 mm of light creamy grey, compact silty sandstone, with many pebbles of quartzite and dark slate and laminated mudstone. Has a very sandy appearance. Pebbles are much more numerous than in beds above. Richly fossiliferous with ribbed spiriferids, martiniopsids, stenoporids, fenestellids, strophalosiids, ostracods, low-coiled gastropods, lamellibranchs and small ?orthotetids.

26B 200 mm of soft, fissile, yellow and buff siltstone; friable when weathered. Stenoporids.

27B 250 mm of soft, grey and cream coloured, silty, fine-grained sandstone with abundant martiniopsids and large ribbed spiriferids.

28B 300 mm of soft, much weathered, deep ochreous siltstone with a more sandy rib at the top. Many clasts up to 40 mm of quartzite and slate. Large ribbed spiriferids and stenoporids.

29B 225 mm of light grey, very fine-grained silty sandstone with abundant fenestellid mats and ribbed spiriferids. Some clasts.

30B 75 mm of buff weathering siltstone. Poorly fossiliferous.

31B 175 mm of hard, grey, sandy siltstone with stenoporids and spiriferids. Some pebbles. Buff weathering. Large, ribbed spiriferids also present.

32B 125 mm of soft, buff weathering siltstone with dropped pebbles. Pebbles are predominantly dark slate or mudstone and ?low grade metamorphosed siltstone. A few large (75–150 mm) quartzite pebbles).

33B 50 mm of sandstone rib.

34B 100 mm of soft, buff weathering siltstone with pebbles up to 40 mm. Large spiriferids abundant.

35B 500 mm of very fine-grained silty sandstone.

36B 600 mm of alternating sandy siltstone bands (50–75 mm thick) and soft, yellow to brown weathering siltstone (50–100 mm thick). Many

dropped pebbles of various lithologies and up to 150 mm in length. Large spiriferids common throughout.

37B 150 mm of grey. silty, very fine-grained sandstone with pebbles. Poorly fossiliferous.

38B 450 mm of grey and buff mottled siltstone with pebbles. Richly fossiliferous with mainly stenoporids and spiriferids.

Section C. Lowest part of exposed section from EN07631504 to EN07611499. Measured 23 April 1970, the section reads in correct stratigraphic order.

1C 900 mm of dark grey-brown, hard, compact, massive, fine-grained sandstone [this is the lowest bed exposed in the coastal section at low tide]. Fossils are abundant and include coarsely- and finely-ribbed pectenids, ribbed spiriferids, terebratulids and common articulated lamellibranchs with a well-marked, close, concentric ornament (*Megadesmus*).

2C 1·67 m of compact, massive siltstone and fine-grained sandstone. Lowermost 300 mm is a very sandy siltstone with dropped pebbles of quartzite and slate, and ribbed spiriferids. Top 250 mm is medium grey to dark grey laminated bryozoal siltstone. Some pebbles. Fauna of main part of unit as below.

3C 1·07 m of hard, compact, grey weathering, very fine-grained sandstone with abundant spiriferids and other fossils. Lenses and stringers of coarse sand-grade material and granule conglomerate crowded with a small, high-spired gastropod.

4C 450 mm of grey, laminated bryozoal siltstone; bioturbated and with some pebbles.

5C 450 mm of medium-grained sandstone with clasts up to 200 mm in length. Many fossils particularly ribbed spiriferids.

6C 525 mm of dark grey, ochreous weathering, pebbly silty sandstone and sandy siltstone. Bioturbate. Many fossils, mainly spiriferids, in middle of unit.

7C 1·36 m of medium grey, laminated siltstone with many fenestellids and small, ribbed spiriferids. Scattered clasts; mainly pebbles and cobbles of quartzite, phyllite and slate. One small boulder (325 mm) of green, low grade metamorphic material.

8C 675 mm of fine-grained, silty sandstone, medium grey, cream and buff weathering with irregular pods and stringers of coarser sand and granule conglomerate crowded with a small, high-spired gastropod. Spiriferids, bryozoans and lamellibranchs.

9C 6·1 m of massive, unbedded, medium grey silty mudstone. The framework of the unit seems to be composed of numerous branching, massive stenoporid colonies which provided a sediment trap for the clastic detritus. The base of the bed is very uneven and gently undulates (?differential compaction). In places there are discontinuous laminated pods with abundant fenestellids. No

clasts were observed. The unit is deeply weathered in the cliff and little or no calcite remains of the original stenoporid framework. Fossils other than bryozoans are rare but small spiriferids and lamellibranchs also occur. *Eurydesma* and *Deltopecten* moulds occur at the base.

10C   4·26 m of blocky, fissile and non-fissile siltstone with thinner (300–450 mm) compact fine-grained sandstone bands. A few pebbles and some bioturbation in places. Fossils not abundant — spiriferids, lamellibranchs, productids and bryozoans.

Exposure ends in corner of the bay. Estimated gap to Unit 38B is 1·35 m.

Section D. Repetition of lowest part of the exposed section from EN07631504 to EN08631527. Measured 24 April 1970, the section reads in correct stratigraphic order. This is a repetition of Units 1C–10C in Section C, and Units 38B–8B in Section B. Some of the beds in this section are either very poorly exposed or not exposed in Section B. Even allowing for this factor there is clear evidence of significant lateral facies change between the two sections.

Units 1D–9D as for Units 1C–9C.

10D   250 mm of hard, compact, massive, very fine-grained sandstone with fenestellids, spiriferids.

11D   825 mm of alternating beds of fine-grained, cream weathering sandstone and soft, laminated, friable medium grey siltstone. Sandstone beds 100–150 mm thick. Siltstone beds are about the same order of thickness. Beds vary in thickness laterally. Fossils fairly abundant.

12D   300 mm of massive bed of hard, compact, grey weathering, fine-grained sandstone with abundant ribbed spiriferids. The bed varies in thickness laterally.

13D   1·21 m of pale grey, buff weathering siltstone. Friable when weathered. Richly fossiliferous. Very sandy in part. Beds vary in thickness and lithology very quickly laterally. Siltstone bands interdigitate with sandier beds in form of lenses.

14D   1·82 m of massive, though irregular beds of fine-grained silty sandstone with irregular thin bands and lenses of siltstone. Grades into siltstone above. Richly fossiliferous. Pale buff colour, pale grey weathering.

Units 10D–14D are the lateral equivalents of Unit 10C in Section C.

15D   1·52 m of medium grey, buff and orange weathering, soft siltstone with abundant fenestellids and a few ribbed spiriferids. A few pebbles of quartzite (up to 25 mm).

16D   975 mm of buff and cream weathering, soft, muddy siltstone with fenestellids and stenoporids. Some bioturbation.

17D   1·67 m of very soft, poorly cemented sandy siltstone with pebbles (75 mm). Richly fossiliferous with fenestellids, strophalosiids, spiriferids and lamellibranchs. Deeply weathered in cliff section.

18D   1·82 m of soft, sandy and pebbly dark and medium grey, mottled siltstone. Bioturbated and banded in places. Cream and buff weathering. Fenestellids, productids, spiriferids and lamellibranchs. Very poorly sorted and many rounded and angular pebbles (up to 100 mm) of quartzite and dark metamorphic rocks.

19D   1·82 m of hard, light grey, brown weathering, poorly cemented siltstone and sandy siltstone with medium- to coarse-grained sandstone and silty sandstone beds. Sandstone beds 100–250 mm thick; softer siltstone partings about 75–100 mm thick. The beds are not uniform in thickness or lithology and vary laterally quite rapidly. All transitions are gradational. Pebbles of grey siltstone and black slate. Richly fossiliferous. Large *Deltopecten*, ribbed spiriferids, strophalosiids and productids, fenestellids and small pectenids.

20D   2·28 m of soft, medium grey to dark grey, sandy siltstone. Poorly consolidated, brown and orange weathering. Irregularly laminated in places. Pebbles up to 75 mm in places. Richly fossiliferous with spiriferids and bryozoans.

21D   650 mm of soft, light grey, very sandy, poorly cemented sandy siltstone.

22D   600 mm of soft, light grey, sandy siltstone (like Unit 21D) with abundant fenestellids and spiriferids. Units 21D and 22D when fresh are dark grey, laminated mudstone and sandy siltstone.

23D   750 mm of hard, grey, buff and cream weathering siltstone. Well indurated, blocky appearance. Richly fossiliferous with strophalosiids, spiriferids, pectenids, fenestellids.

24D   300 mm of dark grey to almost black, heavily bioturbated, pebbly carbonaceous, silty mudstone. Buff weathering. Fenestellids and spiriferids.

25D   300 mm of dark grey, very pebbly sandy siltstone. Bioturbated. Many pebbles (up to 150 mm); mainly low grade metamorphic rocks. One dark siltstone or mudstone boulder 450 mm long. Strophalosiids, ribbed spiriferids, large martiniopsids.

26D   750 mm of sandy siltstone and silty sandstone, fine-grained, light grey. Bioturbated, pebbly; grades into sandstone laterally. Poorly consolidated. Medium grey when fresh, buff weathering.

27D   450 mm of hard, compact, light grey, fossiliferous sandstone. Small ribbed spiriferids abundant.

28D   450 mm of dark grey to medium grey, silty mudstone. Bioturbated. Spiriferids, small pectenids, fenestellids.

29D   150 mm of hard, compact, grey and brown weathering silty sandstone. Heavily bioturbated.

30D   900 mm of sandy siltstone, grey with deep red and ochreous areas centred on irregular coarser patches and pebbles. Runs up to syenite dyke.

Syenite dyke

31D 450 mm of medium grey, hard, compact, richly fossiliferous sandstone with abundant large martiniopsids and ribbed spiriferids.

32D 450 mm of mudstone, grey and friable. Passes laterally into more sandy beds.

33D 375 mm of hard, compact, fossiliferous sandstone. Pebbly and light grey in colour. Bioturbated. Several small faults (75–300 mm throw) orientated both parallel and at right angles to the syenite dyke.

Hereafter the section is disturbed by faulting and exposure ends before Elizabeth Point where beach sand and gravel, and Tertiary silicastone occur.

APPENDIX 2
MINNIE POINT FORMATION

This is the type section at Minnie Point between EN07401425 and EN07601400. Measured 8–9 April 1970 the section reads in correct stratigraphic order.

Unit
49 910 mm. The topmost bed of the Deep Bay Formation (Unit 48A) grades upwards into coarse-grained, poorly cemented, massive, pebbly, fossiliferous sandstone which is deeply eroded in the cliff side. Very soft with numerous pebbles. Fossils are small and are very poorly preserved.

50 100 mm of pebble bed with pebbles up to 125 mm but 50–60 mm on average. Very coarse with a variety of pebbles including ?granite, quartzite, dark slate and other low grade metamorphic rocks. Pebbles are nearly all rounded. This bed is probably only a lens in the major sandstone unit but is a good marker horizon.

51 3·04 m of very coarse-grained, poorly cemented, soft, buff and grey, massive sandstone with scattered pebbles (up to 25 mm) and many small pebbles (6 mm) throughout. Moulds of abraded fragments of thick-shelled spiriferids and lamellibranchs fairly common.

52 600 mm of soft, uncemented, creamy white sandstone — is really part of the unit below since it has the same lithology, but acts as a good marker by virtue of its colour. Pebbles up to 25 mm near the top.

53 2·25 m of coarse-grained, soft, cream and buff weathering sandstone. Pebble bands 75–150 mm thick towards the top. Massive, with moulds of fragments of thick shelled spiriferids.

54 2·13 m of massive, coarse-grained sandstone with numerous pebbles — similar to Units 52 and 53. Buff coloured and buff weathering. Ribbed spiriferids and martiniopsids, mostly abraded fragments but a few complete specimens.

55 300–450 mm of irregular, sub-lensoid, very pebbly sandstone. Pebbles well-rounded and average 50 mm in diameter. Abundant spiriferid fragments.

56 800 mm of compact, massive, grey, hard, well-cemented sandstone with subordinate very coarse-grained feldspathic sandstone and granule conglomerate. This unit is much more compact and well cemented than beds below. Some sub-rounded pebbles of quartzite and other low grade metamorphics. Fossils are abundant and surprisingly well preserved more particularly in the coarser intervals. They include pectenids, *Vacunella*, ribbed spiriferids, martiniopsids, strophalosiids, terebratulids and ?*Punctospirifer*.

57 1·82 m of soft, medium-grained, buff coloured, rubbly-looking sandstone with quartzite clasts up to 300 mm. Broken spiriferids and other fossils.

58 1·36 m of massive, medium-grained, brown sandstone with pebbles of rounded and angular quartzite.

59 450 mm of soft, brown, poorly cemented, medium-grained sandstone. Pebbly throughout, very porous. Fossil fragments uncommon.

60 825 mm of massive post of hard, well-cemented sandstone with many quartzite pebbles and quartz granules. Spiriferid fragments, *Deltopecten* and a few complete, large martiniopsids.

61 675 mm of light brown sandstone in beds 100–150 mm thick; medium-grained with many quartz granules (3–5 mm) and pebbles (up to 25 mm) scattered throughout. Upper and lower parts hard and well indurated, middle 200 mm deeply weathered and richly fossiliferous with complete ribbed spiriferids, martiniopsids, pectenids and other fossils.

62 1·44 massive post of medium- to fine-grained, pebbly sandstone. Brown, but grey weathering. Few fossils.

63 2·58 m of brown medium-grained sandstone in posts of 300–600 mm thickness. Few pebbles or fossils.

64 1·31 m of brown, silty, fine-grained sandstone with rubbly appearance. Quartz granules and quartzite pebbles (25 mm) common. Worm casts and other bioturbation moderately common in in places.

65 850 mm of soft, brown, fine-grained silty sandstone with very irregular pods and stringers of dark brown sandstone crowded with numerous small lamellibranchs and rarer large martiniopsids and other fossils. This interval looks to be very shallow water, sub-littoral deposition.

66 1·05 m of brown, medium-grained, massive sandstone with some pebbles (up to 100 mm) scattered throughout. Pebbles include quartzite, slate and other low grade metamorphic rocks.

67 750 mm of dark grey, hard, coarse, pebbly (up to 200 mm) siltstone; laminated, with a very marked change in lithology from beds below.

68 375 mm of hard, brown, pebbly (25 mm)

sandstone; medium- and fine-grained, well-indurated.

69 300 mm of dark grey, laminated siltstone with pebbles (similar to Unit 67).

70 150 mm of fine-grained, brown, grey weathering sandstone with few pebbles.

71 150 mm of dark grey, pebbly siltstone with pebbles of quartzite and slate.

72 75 mm rib of fine-grained, well-indurated sandstone.

73 200 mm of dark grey, buff weathering siltstone.

74 200 mm of fine-grained, well jointed sandstone with a rubbly appearance.

Gap (about 3·0 m)

75 1·67 m of grey, pebbly siltstone in beds 300–450 mm in thickness. Top 300 mm more compact, and stained red in places. Few fossils.

76 2·28 m of grey siltstone similar to Unit 75.

77 1·52 m of hard, grey siltstone. Very compact in top half. Pebbly and with a 25–75 mm rib of softer siltstone in middle.

78 Gap (600–900 mm) — probably soft, friable siltstone.

79 1·26 m of very hard, dark grey, pebbly siltstone. Massive, much the same as siltstone below. Reasonably fossiliferous near the base with reasonably preserved large, transverse spiriferids, lamellibranchs and ?bellerophontids.

80 3·04 m of hard, grey, pebbly siltstone similar to siltstone below but some bioturbation. Coarse pebble bands throughout. Rarer small boulders (up to 250 x 200 mm). Clasts mostly quartzite.

81 1·26 m of light grey and buff, fine-grained sandstone and silty sandstone. In beds separated from each other by thin, irregular siltstone bands. Moderately fossiliferous with large transverse spiriferids, large lamellibranchs and gastropods. Some quartzite pebbles. Topmost 300 mm has a rubbly appearance on the foreshore.

82 2·08 m of grey and buff, pebbly siltstone. Lenses of bioturbated material. Pebbles of quartzite and black mudstone and slate.

83 350–450 mm of fine- to medium-grained, buff weathering, grey sandstone. Hard and compact. Contact with siltstone below is very irregular. Very pebbly in places with elongate pebbles of black mudstone and low grade metamorphic rocks. Also pebbles of quartzite. Pebbles 75–100 mm at base of the unit but smaller upwards. Heavy bioturbation in places with carbonaceous wisps. Richly fossiliferous with productids, large transverse spiriferids, a variety of very large lamellibranchs and other fossils.

84 800 mm of dark grey, pebbly siltstone with abundant worm burrows and other biogenic structures. Carbonaceous pods and lenses. Shows rapid lateral variation. Irregular thickness due to variation of top Unit 83 which rises and falls very rapidly. Moderately fossiliferous as below.

85 1·21 m of dark grey siltstone, similar to siltstone below. In places there is a 200 mm hard, compact

sandstone at the base but when traced laterally it wedges out and disappears over a distance of 30 m.

[Risdon Sandstone]

APPENDIX 3
ABELS BAY FORMATION

This is the type section exposed at Abels Bay between EN07751400 and EN07801270. Measured 9–10 April 1970, the section reads in correct stratigraphic order.

Unit

[Risdon Sandstone]

Gap (1·11 m)

89 3·04 m of dark grey, pebbly siltstone with hard, fine-grained silty sandstone beds. Sandstone beds about 300 mm thick, the siltstone beds 600 mm thick.

90 4·26 m of hard, medium and dark grey, fine-grained sandstone and silty sandstone with siltstone partings. Beds of sandstone and silty sandstone 300–450 mm thick.

Gap (450 mm)

91 300 mm of hard, brown sandy siltstone.

Gap (1·82 m).

92 1·14 m of grey brown sandy siltstone in beds 300–450 mm thick. The top of this unit lies in the extreme corner of the bay.

93 3·04 m of grey siltstone and sandy siltstone in beds 200–300 mm thick. Abundant pebbles of dark mudstone and quartzite (100 mm).

94 350 mm of light grey cream coloured, fine- to medium-grained sandstone with numerous quartz granules and many cobbles of quartzite and other low grade metamorphic rocks.

95 350 mm of softer, medium grey, silty sandstone with many quartz and quartzite granules.

96 325 mm of light grey, fine- to medium-grained, compact, pebbly sandstone. Lithologically similar to Unit 94.

Gap (3·04–4·57 m)

97 1·11 m of medium and dark grey, pebbly siltstone.

98 300 mm of light grey to cream coloured siltstone with worm burrows and other biogenic structures.

99 300 mm of grey, pebbly siltstone.

100 350 mm of light grey and brown, silty, fine-grained sandstone with pebbles. Several small faults with throws of 150 mm.

101 910 mm of siltstone and sandy siltstone, pebbly, in 200–250 mm beds.

102 1·29 m of hard, sandy siltstone, pebbly, in 200–250 mm beds. Top 300 mm more sandy and much bioturbated.

103   910 mm of grey, very sandy siltstone and very silty sandstone with pebbles and bioturbation in places. Rare shell fragments.

104   1·26 m of silty sandstone and sandy siltstone in beds 200–450 mm thick. Pebbly. Woody fragments.

105   2·43 m of sandy siltstone and silty, fine-grained sandstone in beds 200–375 mm thick. Much bioturbation in sandier beds.

106   2·15 m of fine-grained, silty sandstone and fine-grained sandstone with pebbles. Bioturbated. Beds 350–600 mm thick. Silty partings are very thin. Topmost 750–910 mm is a single bed of sandstone.

107   3·70 m of sandy siltstone and fine-grained sandstone. Siltstone about 60% of unit, sandstone about 40%. Siltstone beds about 600 mm thick, sandstone beds 300–375 mm thick.

108   1·22 m of buff coloured, sandy siltstone.

109   910 mm of fine-grained sandstone with thin, sandy siltstone bands.

110   1·36 m of poor exposure; softer sandy siltstone.

111   1·21 m of fine-grained sandstone, light grey, buff weathering, with large pebbles and cobbles (225 mm maximum), and considerable bioturbation in places.

112   1·06 m of fine-grained grey and brown sandstone. Much bioturbation, pebbles and cobbles. A few shell fragments spiriferids.

113   2·79 m of fine-grained sandstone with thin siltstone beds and partings. Pebbly and cobbly. Clasts of low grade metamorphics. Bioturbated in places.

114   1·65 m of grey and buff, sandy siltstone with a 450 mm bed of sandstone in the middle. Pebbly.

115   775 mm of hard, compact fine-grained sandstone. Cream coloured, brown weathering. Pebbly.

116   1·52 m of fine- to medium-grained, brown weathering, light grey sandstone. Heavily bioturbated in lower part. Shell fragments.

Gap (4·57 m)

117   700 mm of dark grey, pebbly siltstone with pebbles and cobbles up to 100 mm.

118   2·66 m of dark grey, sandy siltstone. Massive, forms a single bed. Bioturbated.

119   2·66 m of massive, dark grey and light grey, pebbly siltstone. Heavily bioturbated. Rare spiriferids and ?lamellibranchs.

120   1·67 m of medium grey, pebbly siltstone. The top 300 mm are very sandy.

121   750 mm of hard, compact, medium grey, cream weathering, fine-grained sandstone broken into cuboidal blocks by jointing.

122   1·52 m of grey sandy siltstone and silty sandstone.

123   400 mm of hard, fine-grained sandstone.

124   3·35 m of dark grey, pebbly, bioturbated siltstone with hard sandy siltstone and fine-grained sandstone beds 200–350 mm thick. Siltstone predominates.

125   1·36 m of medium grey to dark grey, pebbly siltstone.

126   1·06 m of fine-grained, silty sandstone; hard and compact. Grades laterally into bioturbated sandy siltstone.

127   1·87 m of hard, compact, pebbly, silty sandstone. Fine-grained, grey. Forms a single post.

128   3·04 m of medium and dark grey, bioturbated siltstone with pebbles and cobbles up to 250 mm. Shell fragments.

129   1·15 m of medium grey, pebbly, much bioturbated siltstone.

130   500 mm of hard, compact, grey, fine-grained sandstone in a single bed. Bioturbated. Woody fragments.

131   1·52 m of medium grey siltstone with worm casts and pebbles.

132   1·52 m of hard, very fine-grained, bioturbated sandstone. Massive, but well-jointed. Light grey.

133   1·67 m of dark grey to medium grey (light grey weathering) silty, fine-grained sandstone with sandy siltstone partings. A few pebbles (75–100 mm). Much bioturbation. Sandstone forms 80% of unit.

Gap (3·04 m)

134   1·92 m of medium and dark grey, buff weathering siltstone with a few scattered pebbles.

135   1·21 m of fine-grained, silty sandstone; massive, hard, grey, cream weathering.

136   2·38 m of dark grey, brown weathering, sandy siltstone with pebbles, bioturbation and rare shell fragments.

137   700 mm of sandstone, fine-grained, creamy coloured. In a single post. Worm tubes and other bioturbation. Wood fragments.

138   1·01 m of medium grey, sandy siltstone and silty sandstone with alternating hard and soft bands. Beds about 150 mm in thickness.

139   750 mm of medium-grained, dark grey, brown weathering sandstone. Many worm burrows and other biogenic structures.

140   1·82 m of hard grey sandy siltstone with silty sandstone beds about 150–300 mm in thickness. Unit ends at stone pier.

Gap (1·21 m)

141   1·01 m of dark grey siltstone and fine-grained sandstone.

142   575 mm of hard, compact, grey, fine-grained sandstone. A single prominent post. A few pebbles, rare fossil fragments.

143   250 mm of dark grey siltstone.

144   375 mm of fine-grained, buff weathering, grey sandstone. A single post.

145   250 mm of grey siltstone.

146   400 mm of fine-grained, grey, pebbly sandstone.

147   600 mm of fine-grained sandstone. A single post.

148   575 mm of dark grey siltstone with a 200 mm sandstone rib in the middle.

149 300 mm of grey, fine-grained sandstone.

150 400 mm of grey, pebbly siltstone.

151 350 mm of grey, fine-grained sandstone.

152 200 mm of grey, pebbly siltstone.

153 750 mm of grey, fine-grained sandstone in a single post. Silty in the lowest 150 mm. Prominent.

154 5·56 m of essentially fine-grained, grey, buff weathering sandstone beds 200–450 mm in thickness with thin (25–75 mm) siltstone partings. Fossils moderately common.

155 1·67 m of fine-grained sandstone with siltstone partings. Beds 200–300 mm in thickness. Rare fossils, some wood.

156 1·29 m of siltstone and sandstone bands. Pebbly.

157 525 mm of grey, fine-grained, pebbly sandstone.

158 800 mm of grey siltstone with thin, fine-grained sandstone ribs.

159 375 mm of hard, compact, fine- to medium-grained sandstone in a single post.

160 1·52 m of alternating sandstone and siltstone in beds about 300 mm in thickness.

161 2·89 m of silty, fine-grained sandstone in beds about 300 mm in thickness, with siltstone partings of 100–150 mm.

162 1·06 m of grey, fine-grained sandstone in beds about 300 mm in thickness. A few pebbles, cobbles and small boulders up to 300 mm long. Wood fragments.

163 2·35 m of sandstone and silty sandstone in beds of 250–375 mm with slightly more silty partings.

164 5·15 m of grey, fine-grained silty sandstone with thin (75 mm) siltstone partings. Worm burrows and other bioturbation in places. Rare, more or less complete lamellibranchs and spiriferids.

165 600 mm of grey siltstone.

166 1·01 m of grey, fine-grained sandstone in 200 mm beds. A few pebbles and some bioturbation. Mottled.

167 300 mm of grey mottled sandstone as for Unit 166. Forms northern edge of Sandrock Bay.

Gap (200 m).

168 1·87 m of grey, fine-grained sandstone with siltstone partings. Siltstone partings becoming thicker upwards.

169 500 mm of siltstone with very thin (10–15 mm) ribs of sandstone.

170 1·11 m of siltstone with silty sandstone ribs. A few pebbles and moderate bioturbation.

171 2·89 m of dark grey siltstone with pebbles and some bioturbation. Beds 250–450 mm in thickness.

172 6·70 m of dark grey, carbonaceous mudstone with subordinate siltstone bands and lighter coloured arenaceous convolute laminae which have a nodular appearance. The nodular areas of convolute bedding are common and dimensions are typically 600 x 300 mm. A few scraps of woody, carbonaceous material. Becomes more silty in the top 1·52 m with beds of laminated sandy siltstone. The top 300 mm consists of soft, striped beds of sandstone and siltstone with laminae 3–6 mm in thickness.

APPENDIX 4
CYGNET COAL MEASURES

Section exposed at Sandrock Bay from EN07881265 to EN07641221.

Unit

1 1·0–1·2 m. The basal part consists of striped beds of sandstone and siltstone. The striped beds pass upwards, as far as can be seen, by gradation into a wedge of fine-grained sandstone, 0–100 mm thick, which in turn is overlain by a wedge of conglomerate which ranges from 0–200 mm thick over a distance of one metre. Then follow wedge-shaped sandstone beds between various gravelly and conglomeratic beds. The sandstone is fairly soft, grey in colour, weathering brown and somewhat mottled in appearance. The sandstone beds contain thin smears and threads of carbonaceous material arranged in an irregular and random manner. Lenses 70 mm thick and 3 m long of black carbonaceous and coaly material occur about one metre above the base of the unit. Fragments of coalified wood up to 300 mm long also occur. The pebbles in the conglomeratic beds are up to 35 mm long, poorly sorted, rounded but of low sphericity. The pebbles consist mainly of quartz and quartzite.

2 3·68 m of fine- to medium-grained, light grey and brown weathering, mottled, cross-bedded sandstone with some ferruginous concretions, coal threads and stringers.

3 1·8–2·5 m of light grey and brown weathering, laminated feldspathic sandstone. Mica and graphite on bedding planes.

4 1·8 m of fine-grained, grey and buff weathering, laminated and very micaceous sandstone. 25 mm thick siltstone bands occur in the lowest 300 mm of the unit.

5 7·4 m of fine-grained, grey, purplish or brownish, cross-bedded, micaceous and graphitic sandstone with ironstone concretions and clay pellets.

6 10·7 m of grey and buff weathering, cross-bedded sandstone with mudstone pellets.

7 1·5 m of grey and buff, laminated and finely cross-bedded, very micaceous sandstone. Some deep brown, ferruginous weathering.

8 >12·3 m of dominantly quartz sandstone sequence (Rs). Medium- to coarse-grained, massive, cross-bedded, quartz sandstone. Cross-bedded units very thick (up to 670 mm) compared with those in the Cygnet Coal Measures. Cross-bedding commonly overturned.