Papers and Proceedings of the Royal Society of Tasmania, Volume 101.

SOME FORMATIONS CLOSE TO THE PERMO-TRIASSIC BOUNDARY IN TASMANIA

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(With three text figures and one plate.)

ABSTRACT

The Cygnet Coal Measures is a unit of carbonaceous shale, coal and feldspathic sandstone in Tasmania of Upper Permian age. It is overlain gradationally or disconformably by the Springs Sandstone, the lower member of which, Barnetts Sandstone, is a thinly-bedded, fine-grained feldspathic to arkosic sandstone, and the upper, the Mountain Lodge Sandstone, a more thickly-bedded, medium-grained protoquartzite. The upper part of the Springs Sandstone is probably Otoceratan. The Permo-Triassic boundary lies within these gradational non-marine units and cannot yet be fixed accurately. The base of the Mountain Lodge Member is probably the most convenient boundary to use as the Permo-Triassic boundary in local field mapping.

INTRODUCTION

Milligan (1849 pp. 17-18) first described the coal measures at Southport subsequently correlated with the Cygnet Coal Measures. Thureau in 1881 mentioned the coal at Cygnet and his description of the section at the coal mines may still be the best. Subsequently Johnston (1887) described coal measures of similar age at Adventure Bay on Bruny Island and in 1888 described the section at Cygnet and correlated both successions with the Newcastle Coal Measures of New South Wales. Subsequently freshwater beds at this level have been recognised widely in Tasmania and sections measured in several places (eg. Mount La Perouse, Hobart, Zeehan, Lake St. Clair, Mole Creek). During 1965, a good succession near the nominal type area was established in detail by I. Naqvi and this led to a review of formations adjacent to the Permo-Triassic boundary.

Difficulty is experienced in many parts of Tasmania in delineating the Permo-Triassic boundary. There is a macrofloral change near the boundary from the *Glossopteris* to the *Dicroidium* flora but pinpointing this change in the field is very difficult because of the poorly fossiliferous character of the formations overlying the Cygnet Coal Measures and their correlates. The standard field convention has been to regard the base of the first thickly bedded quartz sandstone above carbonaceous shales (with or without a *Glossopteris* flora) of the Cygnet Coal Measures as a convenient place for the Permo-Triassic boundary with full recognition that this may not correspond exactly to the Permo-Triassic boundary elsewhere. Lewis (1940) recognised that the important palaeogeographic change occurred at the base not the top of the Cygnet Coal Measure but was not consistent (1946, pp. 22-3).

The difficulties are increased by lack of definition and reasonably precise knowledge of the so-called basal Triassic units. The Ross Sandstone of Bonwick (1870) and later authors is not properly defined in its type area and may be undefinable there. The outcrop is certainly not good in the Ross area. The Rhyndaston Sandstone (David 1932) is much better exposed at Rhyndaston than the Ross Sandstone at Ross, but its relationships to the Permian on the one hand and to younger units on the other are not yet clear. The Springs Sandstone (Lewis 1940) is moderately well-exposed in its basal portions and its relationship to underlying rocks in the type area determinable but not that to younger sedimentary rocks. No accurate section of this formation has been published. Recently the basal Triassic unit in the Lake St. Clair area has been called the Gould Formation (McLeod *et al.* 1961, p. 26), the relationships of which to underlying and overlying units are clear, if gradational, but of which no detailed section has been published. There are, in addition, innate difficulties in defining and correlating units such as the Springs, Ross, Rhyndaston and Gould Formations, because of their depositional environment, probably flood plains with braided channels.

In this paper, definitions and detailed sections of formations near the Permo-Triassic boundary in the Cygnet and Hobart Districts will be offered and the problem of the Permo-Triassic boundary discussed in some detail.

CYGNET COAL MEASURES

Stratigraphy

The nomenclature and synonomy of this formation have been dealt with by Smith (1959, pp. 47-8). The first significant report is that of Thureau (1881) who used the term "Mt. Cygnet measures" and recorded a sandstone floor, 3 ft. of coal, approximately 64 ft. of sandstone, a 5 ft. seam of coal within borders of carbonaceous clay, and a micaceous, laminated sandstone roof. His map and section clearly show two seams separated by sandstone but it is not quite certain that the thickness quoted for the inter-seam sandstone is not excessive due to faulting. Twelvetrees (1902) reported a slightly different section at the Mt.

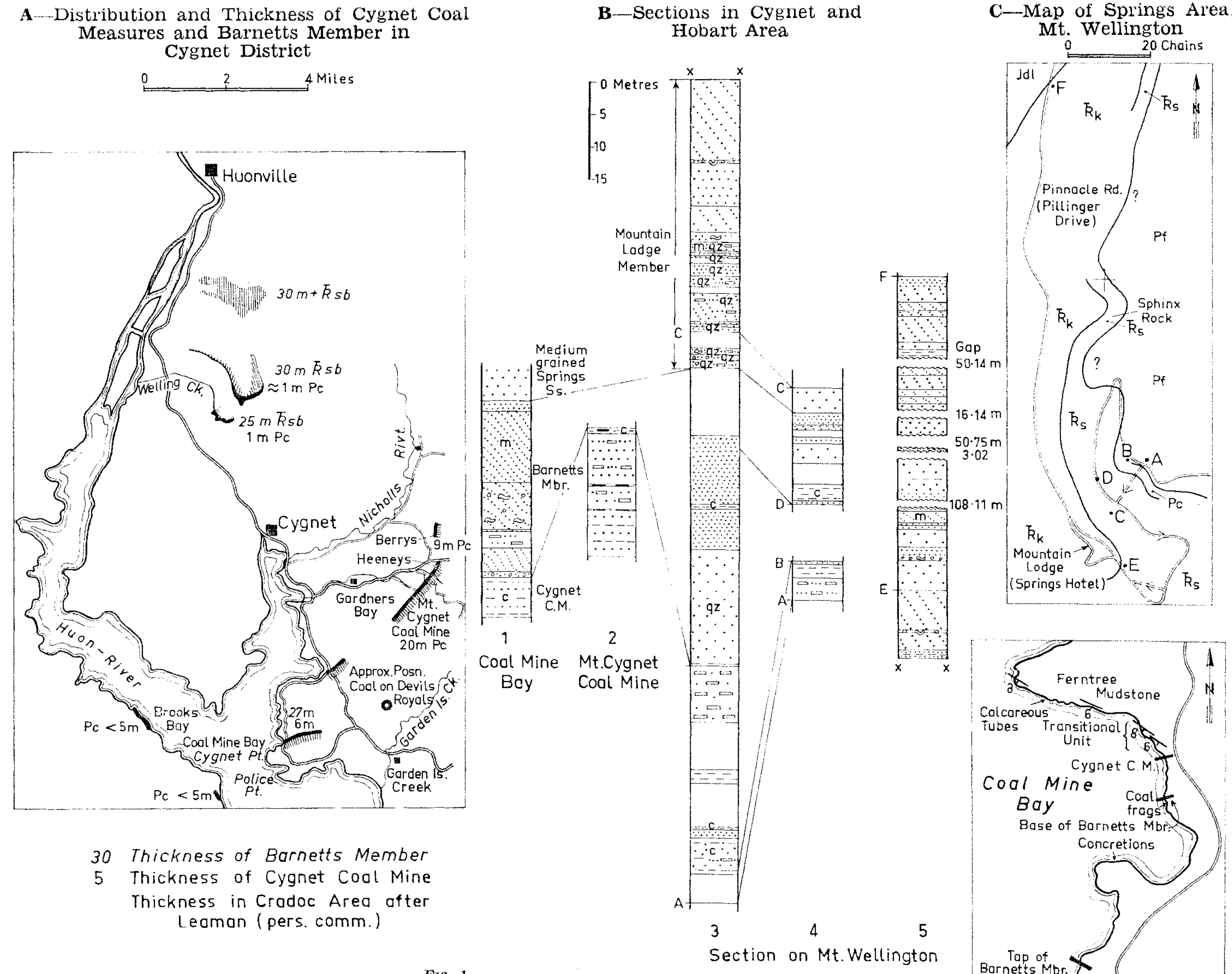

Fig. 1.

A. Map of the Cygnet area showing distribution and thickness of Cygnet Coal Measures and Barnetts Member.
B. Columnar sections of Cygnet Coal Measures and Springs Sandstone, Cygnet and Mt. Wellington.
1. Section at Coal Mine Bay. 2. Section at Mt. Cygnet Coal Mine. 3, 4, 5. Section on Mt. Wellington.
C. Sketch map of part of Mt. Wellington showing positions of sections.
D. Map of Coal Mine Bay area, Cygnet, showing position of type sections.

Cygnet Mines, a small 2 inch seam, another seam 1 ft. thick 12 feet above the first and the main seam 3 ft. thick, 25 ft. above the second. The main and two minor seams of which only one was aceous siltstone, the lower siltstone resting on dark sandstone and the upper with a roof of grey hard, glistening, quartzose sandstone with a conglomerate in places. Reid (in Hills *et al.* 1922) reported two main and two minor seams of which only one was being worked. At Berry's, north-west of the main working (fig. 1 A) a sandstone roof caps a seam 12"-14" thick resting on 12 inches of black shale. This shale rests on 8 feet of shale and 20 feet of sandstone which in turn overlies mudstone. Thus it would appear that in the nominal type area the coal measures are at least 6.8 m. thick and may be over 12 m. thick on Thureau's figures. Recent investigations by the authors show that detailed information in the type area is not available because of thick vegetation and deep soil cover. The Cygnet Coal Measures appear to overlie Ferntree Mudstone, to be between 12 and 18 m. thick and to be overlain by quartz sandstone and thinly-bedded (beds about 1 cm. thick) micaceous sandstones and siltstones.

The best section now available is that in shore platforms at Coal Mine Bay and immediately south (summarised as fig. 1 B, 1). The Ferntree Mudstone with rare erratics and some marine fossils is overlain gradationally by fine-grained carbonaceous siltstone with some sets up to 1.5 cm. thick of interbedded very-fine grained sandstone and carbonacous siltstone in beds up to 2 mm. thick but mostly less than 1 mm. in thickness. Such sets form less than 10% of the basal metre. From 0.9 m. to about 1.1 m. above the base the carbonaceous siltstone contains flow folds ("pseudo-nodules") from 4 cm. x 4 cm. to 6 cm. x 3 cm. and about 0.5 cm. thick consisting of beds less than 1 mm. thick of very fine-grained, white sandstone or coarse siltstone interbedded with carbonaceous siltstone.

A little higher in the section and especially about 1.5 m. above the base larger-scale but otherwise similar structures occur. These structures are up to about 15 cm. long. At about 1.9 m. above the base such structures tend to be the core of concretionary bodies up to 0.6 m. long with a tendency to an east-west orientation of the concretions.

Sandstone becomes more prominent upwards and becomes coarser-grained. A set of cross-bedded sandstone at least 10 cm. thick starts at about 4.8 m. above the base. There are other thinner, but otherwise similar units lower. The 10 cm. set consists of cross-bedded sets 2-3 cm. thick with beds of sandstone and carbonaceous sandstone less than 1 up to 2 mm. thick. Cross-bedding suggests currents mainly from the northerly quarter with rare ones from east or west.

The highest unit recognised is a thickness of at least 0.25 m. of interbedded sandstone (beds about 1-2 cm. thick) and graphitic sandstone and siltstone in beds about 0.5 to 1 mm. thick. There is no coal in this section but the overlying conglomerate contains fragments of coal. An outcrop was recorded and a shaft was sunk on a coal outcrop in the Devils Royals just east of this area (Hills *et al.* 1922, p. 145). At Coal Mine Bay the carbonaceous section is six metres thick and is overlain disconformably by conglomerate with a quartz rich matrix.

No macrofossils occur in this section and unfortunately specimens submitted to Dr. G. Playford, University of Queensland, for palynological study yielded no recognizable spores.

A thin section (33626) of carbonaceous siltstone from the middle of the formation revealed a modal grainsize of the clastic particles between 0.03 and 0.045 mm. with variation from very fine silt to very fine sand. Aggregates up to about 0.4 mm. long of clay grade carbonaceous matter comprise about 30% of the rock, the only other clay grade material being a very minor amount of interstitial clay mineral. Clear unstrained quartz is the commonest constituent of the rock, about 55%, but a little quartz with globular inclusions in lines also occurs. Plagioclase (oligoclase) is about 1% of the rock and there is a surprising amount of biotite (about 12%) and some muscovite (about 3%). The quartz and plagioclase grains are predominantly angular and very few are as rounded as subrounded. Their sphericity varies from equidimensional to very elongate and many have lengths exceeding three times their breadth. The quartz and feldspar grains lie in a felted matrix of biotite and muscovite laths and elongate stringers of carbonaceous matter all held by a minor clay cement.

This section is thinner than that recorded from the Mount Cygnet Coal Mine area (fig. 1B, 2) and apparently differs from it in containing less sandstone. The section on Balfs Hill near Cradoc is even thinner (Leaman 1966). Facies change or subsequent erosion may explain the variations in thickness but the disconformity everywhere present in this area above the coal measures suggests that erosion was the more important factor controlling the thickness locally.

Johnston (1888, p. 203) recorded *Vertebraria australis* and *Gangamopteris spathulata* from shales below the coal at Mount Cygnet and Lewis (1940) amended the record of *G. spathulata* to *Glossopteris* sp. The Cygnet Coal Measures at Cygnet contain spores of the *Dulhuntyispora* Microflora (Balme 1964, pp. 63-4) and from Welling Creek, Cradoc, a number of spore types have been recorded by Dulhunty and Dulhunty (1949) (see Table I).

The Cygnet Coal Measures may thus be defined as that formation about six metres thick at Coal Mine Bay (497.6, 677.7) *of carbonaceous saudstone, carbonaceous siltstone and coal which contains a* Glossopteris *flora and spores of the* Dulhuntyispora *Microflora, overlies the Ferntree Mudstone and underlies a formation of feldspathic sandstone, the Barnetts Member of the Springs Sandstone. It is Upper Permian in age.*

Carbonaceous shale occurs below Triassic sandstone south-west of Huonville (Mather 1955, p. 196) and may represent the Cygnet Coal Measures. A little further west Ford (1956, p. 150) was unable to find any definite Cygnet Coal Measures. South of Cygnet in the Police Point area the Ferntree Mudstone is overlain by black mudstone with quartz pebbles and plant stems and these latter by carbonaceous, micaceous shales (Hale 1953, p. 114) and at Dover the Cygnet Formation is represented by micaceous, carbonaceous siltstones with some cross-bedding (Hale 1953, p. 113). At Dover and Police Point the contact with overlying rocks is a disconformity, shown by undulatory contacts, increase in heavy mineral content and the presence of pieces of Ferntree Mudstone in the overlying rocks (Hale 1953, p. 117).

East of Cygnet, this formation occurs in the valley of Garden Island Creek, in the bed of Snug Rivulet, and at Gordon (Reid in Hills *et al.* 1922, pp. 145-6) where coal overlies about two metres of carbonaceous shale and underlies sandstone. Still further east the Cygnet Formation occurs at several places on South Bruny Island but the best exposure is that at Adventure Bay, just south-east of the neck, where a fine section is exposed in shore platforms and cliff faces and the coal measures apparently grade up into Triassic sandstones. This section has not yet been adequately studied. Johnston (1886) recorded and later figured (1888, pl. x) two species of *Gangamopteris*, a *Glossopteris* species and fruit and stems.

In the Hobart area Lewis (1946, pp. 35, 95) reported Cygnet Coal Measures from near Silver Falls Creek and in the headwaters of New Town Creek. The formation also occurs below the Springs Hotel where the section (fig. 1B, 3-5) was measured by Banks and Anand Alwar. In that section the Ferntree Mudstone is overlain by a poorly-sorted feldspathic sandstone passing up into interbedded fine-grained, feldspathic sandstone and carbonaceous siltstone both with fragmentary plant remains. Several gaps in outcrop break the succession which is capped by a medium-grained, thickly-bedded, light olive brown cliff-forming sandstone with an estimated feldspar content of 25-30%, thus suggesting that it is an arkose. This is followed after a gap of only 0.5 metres approximately by quartz sandstone, taken, for convenience, as the base of the Springs Sandstone. Carbonaceous shales up to about 10 metres thick were reported by Lewis from Silver Falls Creek and New Town Creek, in the latter area being pyritic and containing wood fragments. Read (1960) reported at least three metres of carbonaceous shale passing up into interbedded carbonaceous shale and fine-grained, cross-bedded, micaeous sandstone with worm burrows overlain by carbonaceous shale from the Sky Farm Road west of Claremont. South of Richmond about 60 cm. of black shale appear to separate Ferntree Mudstone from Triassic sandstone and may be Cygnet Formation (Gatehouse, this volume, p. 2). A metre or so of dark-coloured material separates Ferntree Mudstone from sandstones in sea cliffs north of Eaglehawk Neck on Forestier Peninsula and may represent the Cygnet Coal Measures. No ground survey has been done in the area.

In cliffs and shore platforms on the western shore of Southport a fine section is exposed which probably covers the Permo-Triassic transition. Interbedded feldspathic sandstone and carbonaceous siltstone about 20 m. thick are overlain by a carbonaceous siltstone very rich in *Vertebraria.* This is overlain by 1.5 m. of carbonaceous siltstone, a 2.5 m. gap in outcrop along a pocket beach, one metre of carbonaceous siltstone with thin beds of sandstone, two metres of interbedded carbonaceous siltstone and siliceous sandstone with current ripple marks, 1.25 m. of carbonaceous siltstone, 1.9 m. of interbedded carbonaceous siltstone and some fine-grained, cross-bedded sandstone with slump structures, 0.9 m. of sandstone becoming thinly-bedded and current rippled near the top, 1.5 m. sandstone interbedded at the base with carbonaceous siltstone in beds 1 to 10 mm. thick and capped by 0.25 m. carbonaceous siltstone. This siltstone is overlain disconformably by thickly-bedded, coarsely cross-bedded, medium-grained quartz sandstone at least 40 m. thick which could be taken, for convenience, as the basal unit of the Triassic. These sandstones include a bed about 0.15 m. thick of carbonaceous siltstone with equisetalean stems, the siltstone lying about 20 m. above the base of the thickly-bedded sandstone. Milligan (1849) and Johnston (1893) commented on the sediments from which the latter reported *Vertebraria* and, probably incorrectly, *Pecopteris lunensis*. Twelvetrees (1915, pp. 11-12) gave details of the rocks passed through by a bore starting, presumably, somewhat above the *Vertebraria* bed. These details have been used in constructing column d of fig. 2.

A very good section of the Cygnet Coal Measures is exposed on the northern face of Mount La Perouse. Preliminary studies and measurements have been made by B. F. Glenister and Banks and an approximate section is provided as fig. 3 e. *Glossopteris* and *Vertebraria* are present. The contact with overlying rocks is gradational and the unit shown at the top of the Cygnet Coal Measures, thinly-bedded micaceous sandstone with thickly-bedded, cross-bedded, feldspathic sandstone may be equivalent to the Barnetts Sandstone which overlies the Cygnet Coal Measures at Cygnet.

At Maydena carbonaceous shales 4.5 m. thick are overlain disconformably by 16 m. of feldspathic sandstone (Jago 1965) but on the flanks of the Misery Range about 30 km. north of Maydena the Cygnet Coal Measures are represented by about 30 m. of interbedded carbonaceous siltstone and sandstone lying beneath thickly-bedded quartz sandstone (Corbett 1964).

The thickness of the Cygnet Coal Measures increases northwards to the Lake St. Clair and Pelion Range area (Gulline 1965, McLeod *et al.* 1961) where carbonaceous shale, thin coal seams, feldspathic sandstone, some quartz sandstone and a bed of conglomerate occur. An incomplete section on Mount Inglis is predominantly feldspathic sandstone (Gee 1964).

South-west of Zeehan a thickness of at least 45 m. of cross-bedded, ripple-marked quartz sandstone interbedded with carbonaceous siltstone overlies Ferntree Mudstone disconformably (Banks and Ahmad 1962).

In northern Tasmania, Cygnet Coal Measures (or its correlates Jackey Shale and Clog Tom Sandstone) have been mapped near Mole Creek (Jennings 1963), along the Western Tiers to Poatina (with some breaks) (McKellar 1957), at Beaconsfield (Green 1959) and near Lilydale (Longman 1966). These coal measures may also overlie the Kelcey Tier Beds on the western slope of Bonneys Tier as suggested by comparison of Twelvetrees' plate 2 (1911) with later maps (Burns 1964, p 103), and Brill (pers. comm.) reported coal high on the flanks of Bonneys Tier in Coal Creek.

Rock Types

The Cygnet Coal Measures and its correlates consist of sandstone, predominantly feldspathic but siliceous in many places, carbonaceous and micaceous siltstone and thin seams of coal. Conglomeratic beds are rare but occur at Mount La Perouse, Zeehan and Launceston at the present limits of outcrop of this formation and at Hugel Creek near Lake St. Clair. The sandstones are commonly carbonaceous and in many places are cross-bedded and ripple-marked. No study has yet been made of current directions. The sandstones predominate in most sections especially on Bruny Island, at Mount La Perouse, Zeehan, the Du Cane Range, Mount Inglis, Beaconsfield and Lilydale, again areas close to the present limits of outcrop. Although insufficient sand-shale ratios are available for accurate depiction of variations there is a suggestion that the silt content of the formation is higher at Poatina, Mole Creek, the Pelion Range, some areas near Lake St. Clair, Maydena, Southport, Cygnet and Hobart than around the margins of present outcrop. This in turn suggests derivation from higher source areas not far outside the present limits of outcrop in the north-east, north, north-west, west and south.

The presence of feldspar as a common constituent of the sandstone is unusual. The non-marine sandstones of the Lower Permain Mersey Group do contain feldspar but not in significant amounts and the prominent sandstones of the Lower Triassic are quartz-rich sandstones. No detailed petrographic studies have been made and the type of feldspar not determined.

Coal occurs at Coal Hill near Lake St. Clair, Southport, and Kelceys Tier (probably a single seam at each place) and two or more seams occur on the Pelion Range, Mole Creek, Bruny Island and Cygnet, the thickest known being at Cygnet (1.5 m., Thureau 1881).

Flora

Johnston (1888, p. 143) recorded *Gangamopteris spathulata, G. obliqua, Glossopteris browniana* var. *praecursor* and other indefinite plant remains from Adventure Bay and *G. spathulata* and *Vertebraria australis* from Cygnet (ibid. p. 203). Subsequently Lewis (1940) suggested that the *Gangamopteris* from Cygnet should be referred to *Glossopteris* sp. and Johnston's determinations from Adventure Bay require revision. From Southport Johnston (1893) reported *Vertebraria australis*. McLeod *et al.* (1961, p. 25) reported *Glossopteris, Gangamopteris* and *Vertebraria* near Thetis saddle and Banks and Ahmad (1962, pp. 9-10) recorded these fossils, *Phyllotheca* and *Schizoneura* from the Malanna area, near Zeehan. *Glossopteris* and *Vertebraria* occur in the Mount La Perouse area.

Spores from the Cygnet Coal Measures and their correlates have been reported by Dulhunty and Dulhunty (1949), Balme and Hennelly (1955, 1956a, 1956b), Balme (in Jennings 1963) and Balme (1964), and their distribution is summarised below as Table I

TABLE I

	1	2	3	4
Acanthotriletes tereteangulatus		x		
Anapiculatisporites ericianus	x	x	x	
Anapiculatisporites cf. *ericianus*				x
Bascanisporites undosus				x
Cycadopites vetus	x	x	x	
Deltoidospora directa	x	x	x	x
Granulatisporites micronodosus	x			x
Granulatisporites trisinus	x	x	x	x
Marsupipollenites triradiatus	x	x	x	
Pilaspora plurigenus	x	x	x	
Protohaploxypinus amplus	x	x	x	
Protohaploxypinus sewardi				x
Punctatisporites gretensis			x	
Retusotriletes diversiformis		x		x
Schopfipollenites sinuosus			x	
Striatoabietites multistriatus	x	x	x	x
Striatopodocarpites fusus	x	x		
Thymospora cf. *hamatus*				x

1 = Cradoc (Welling Ck.)
2 = Mount Pelion.
3 = Mole Creek.
4 = Western Bluff.

Taxonomic combinations after Hart (1965).

The spores listed indicate correlation of the coal measures at Cradoc, Mount Pelion, Mole Creek and Western Bluff with one another and with the Newcastle Coal Measures of New South Wales which are Kazanian or Tartarian. The Jackey Shale at Western Bluff in particular is probably equivalent to the upper part of the Newcastle Coal Measures. Balme (*in litt.*) reported that the coal measures at Cygnet, Sky Farm, Hobart and Malanna were of the same age. The Kazanian or Tartarian age is suggested because of the occurrence of the same *Duihuntyispora* assemblage in the Condren Member of the Liveringa Formation of Western Australia, underlain by the Lightjack Member with goniatites of Upper Artinskian or Lower Kungurian age (Glenister and Furnish 1961, p. 688) and overlain by the Hardman Member with *Aulosteges ingens* and *Waagenoconcha imperfecta* which occur in the Basleo Beds of Timor and are similar to species in the Kazanian of Russia (Coleman 1957, p. 139) thus suggesting a Kazanian age. The spores from the Newcastle Coal Measures may however range beyond the limits of the Condren Member but are clearly pre-Scythian.

Stratigraphic Relationships

The stratigraphic relationships of the Cygnet Coal Measures as here used are summarised in fig. 2. In north-eastern and eastern Tasmania the formation is missing. A disconformity is found at the base of the formation in northern and western Tasmania whereas in the central and southern parts of the basin, where the formation is thickest, the basal contact is conformable. This, with the smaller grainsize in the central parts of the basin, suggests lower stream velocities, and probably grades) in those areas, indicating perhaps a low-lying, flattish central area bounded by low, rather distant hills.

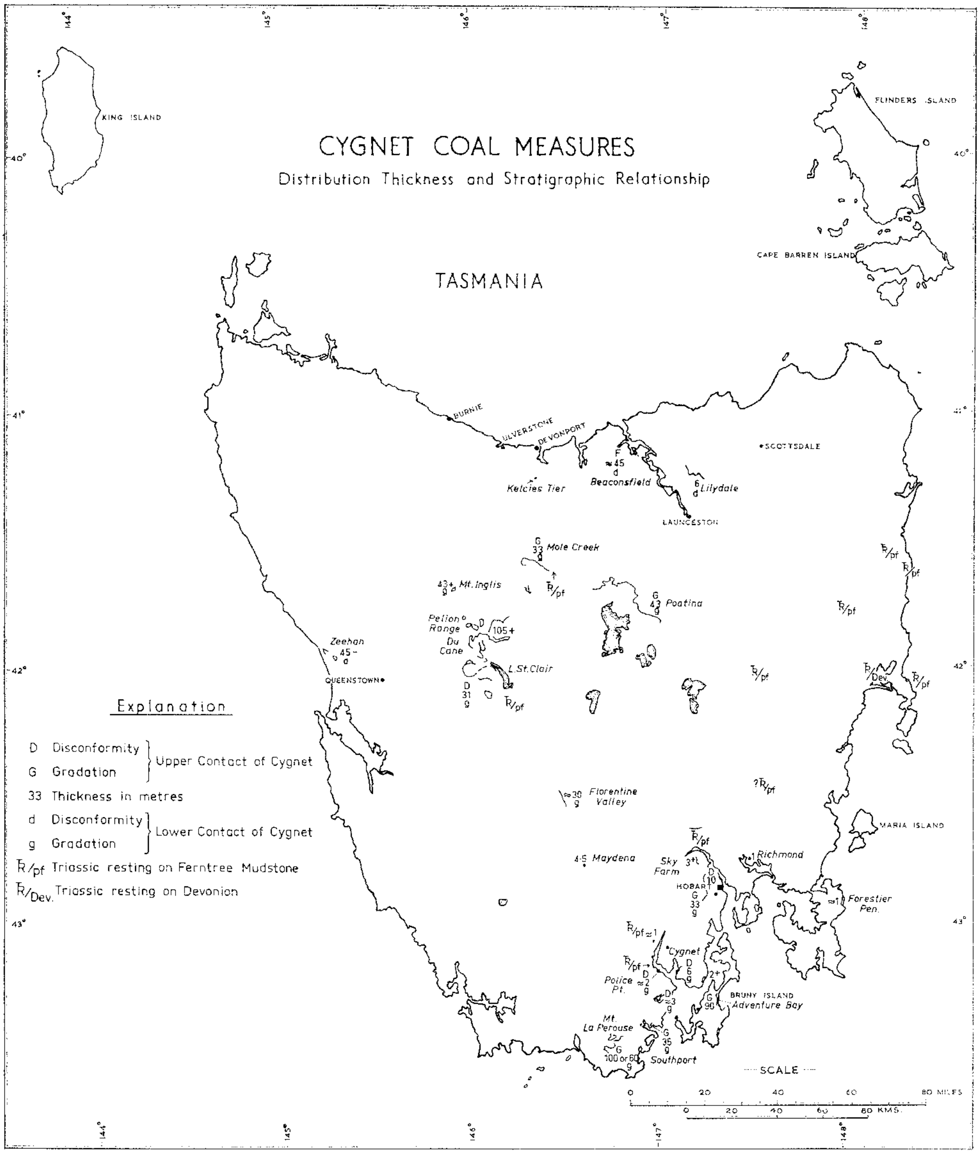

FIG. 2.—Map of Tasmania showing distribution, thicknesses and stratigraphic relationships of the Cygnet Coal Measures.

The upper contact shows less systematic variation in its character although again gradation occurs in most of the thicker sections and disconformity in the thinner. Variation in thickness of the formation and type of upper contact in the area around Cygnet suggests considerable differential erosion and possibly uplift before deposition of the overlying Barnetts Sandstone (see fig. 1 A).

The thickness of the formation varies up to about 105 m. but measured sections are exposed too sporadically to make construction of useful isopach maps possible in view of the likely effects of disconformities and until detailed correlations between sections become feasible. A zone of thicker Cygnet Formation appears to extend from south of Zeehan through the Du Cane and Pelion Ranges to Mole Creek, Poatina and Beaconsfield but this has an area within it at Westmoreland Creek, just east of Mole Creek, where Triassic rocks rest directly on Ferntree Mudstone (Jennings 1963). Another zone of thicker sediments appears to extend from Mount La Perouse through Southport to Bruny Island and Hobart.

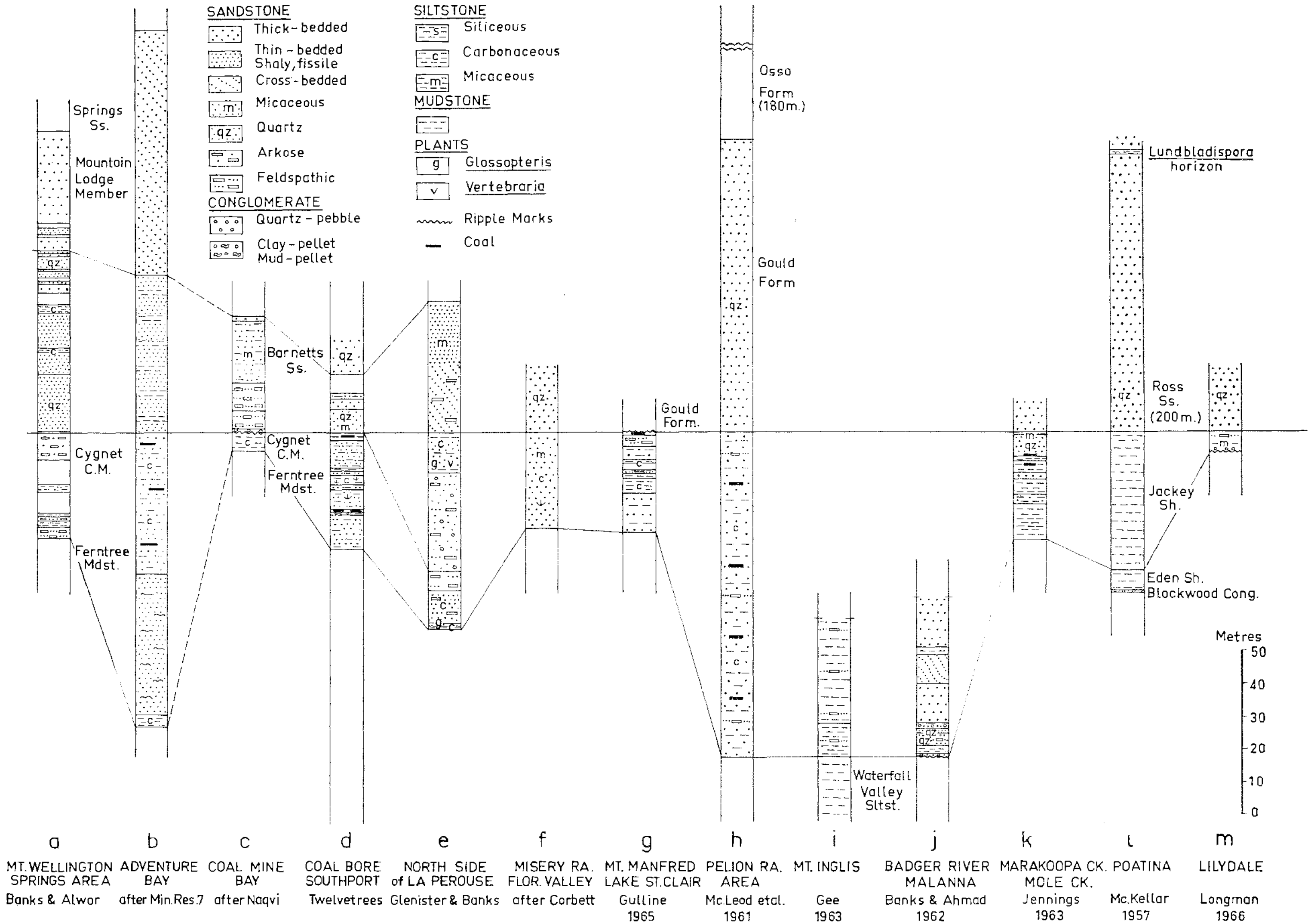

FIG. 3.—Columnar sections of the formations close to the Permo-Triassic boundary in Tasmania.

SPRINGS SANDSTONE

The name was first used, casually, by Lewis (1940) and explained more fully by Lewis (1946, pp. 23, 35) by whom the thickness on Mount Wellington was given as 800 feet, 200 feet more than the average elsewhere. Elsewhere in that publication (*Ibid.* p. 46) the thickness was given as 500 feet, or even, it would appear, 1,000 feet (p. 67). It was described as massive sandstone. Lewis did not define the term very stringently and it is not clear if he considered the Springs Sandstone as only the cliff-forming sandstone or as all the rock between the Ferntree Mudstone and the dolerite contact on the Pinnacle Road.

A section was measured from the top of the Ferntree Mudstone on the Pinnacle Road to the dolerite contact (fig. 1 C) by M. Anand Alwar and one of the authors (M.R.B.) some years ago and is recorded here as figs. 1 B, 3, 4, 5, and the lower part of it as fig. 3 A, and in more detail in an Appendix. The cliff-forming, "massive" sandstones below the Springs Hotel (A-E on fig. 1 C) form a distinctive mappable unit above which the section is very discontinuous.

It is proposed therefore to define the Springs Sandstone as that unit of quartz sandstone with minor siltstone and clay-pellet conglomerate overlying the Cygnet Coal Measures and underlying a unit of sandstone and siltstone, probably equivalent to the Knocklofty Sandstone and Siltstone, in track, road and cliff sections below the Springs Hotel. It is about 92.5 m. thick in its type section. (511.45 *E.* 717.05 *N. to* 511.52 *E.* 716.53 *N.*). *No fossils have been recorded in it from its type section but it is probably Lower Triassic.*

In its type area it may be considered as consisting of two members, a lower one about 55 m. thick of sandstone, especially sandstone with beds of the order of 10 cm. to a few tens of centimetres thick and fissile sandstone, siltstone and rare clay-pellet conglomerate, the upper one about 37.5 m. thick of coarsely cross-bedded cliff-forming sandstone in beds mostly of the order of one metre thick. The lower member may be correlated with the Barnetts Member, well-exposed in cliff and shore-platform sections south of Coal Mine Bay, Cygnet.

Unit G (see Appendix) may conveniently be taken as the base of the upper member in the track section "A"-"C" and unit j in the road section "D"-"C". The lower member consists predominantly of well-sorted medium to fine-grained sandstones with minor developments of coarse-grained sandstone near the base, and some carbonaceous siltstone with plant fragments. The sandstones consist predominantly of quartz with minor quantities ($<10\%$) of muscovite, graphite and feldspar. They are cross-bedded and have beds a few centimetres to about 75 cm. thick and some are fissile. The carbonaceous siltstone contains plant fragments (probably sphenopsid), sandy beds a few millimetres thick and some clay pellets. Outcrop of this member is somewhat subdued in contrast to the strong development of cliffs by the upper member.

The upper member, which may be called the Mountain Lodge Member, outcrops well in the cliffs beneath the Springs Hotel and at Sphinx Rock. It may be considered to include units G to Y in the road, track and cliff sections between "C" and "E" (fig. 1 C). The main rock type is a well-sorted, medium to coarse-grained quartz sandstone, cross-bedded and with beds generally more than 75 cm. thick but with some units more thinly bedded.

Current ripple marks occur on some bedding planes and suggest currents from the northerly quarter. The cross-bedding suggests currents from northerly, westerly or south-westerly areas. The cross-bedding commonly shows current drag effects at the top of the set. The predominant mineral is quartz, often with sparkling surfaces which are crystal faces resulting from authigenic outgrowth, with very minor amounts of muscovite, graphite and feldspar ($<2\%$). Clay-pellet and quartz pebble conglomerates also occur. A few grains of pink garnet were seen by hand-lens in the basal unit.

The section above the Springs Sandstone, as here used, on the Pinnacle Road reveals sandstones and some siltstones, the sandstones finer-grained and more thinly-bedded on the whole than those in the Mountain Lodge Member. Some beds with 10%-20% feldspar occur and a green micaceous mineral, probably a chlorite, occurs on several horizons. Cross-bedding is common and ripple-marking present. Dips of cross-bedding appear to be too variable to allow assessment of current directions without statistical analysis.

Fossils have not been found in any of the units in this section. The Mountain Lodge Member is like the lowest sandstone units in the Knocklofty Formation a few miles to the east and these sandstones are overlain by fossiliferous siltstones of Scythian age. The most likely age for the Springs Sandstone is Scythian but there is no reliable, direct evidence for this.

In the Coal Mine Bay area near Cygnet, the Cygnet Coal Measures are overlain by a sandstone formation, divisible into a lower member called the Barnetts Sandstone and an upper member, lithologically similar to the Sphinx Rock Member of the Hobart area.

The Barnetts Sandstone may be defined as the lower member of the Springs Sandstone disconformably overlying Cygnet Coal Measures at Coal Mine Bay. It consists of 27 m. of feldspathic sandstone, and is named for Barnetts Trig. Point (498.20, 678.00) *near Coal Mine Bay. It is probably Triassic but may be Upper Permian.*

The section of the formation (see fig. 1 B and Leaman & Naqvi 1967) commences with a basal conglomeratic unit (plate 1, f. 1) about one metre thick, consisting of granule and pebble conglomerate, feldspathic sandstone and thin beds (1-2 mm.) of coal and carbonaceous siltstone. The granules and pebbles are composed of quartz, carbonaceous siltstone, a mudstone (probably Ferntree Mudstone), and rarely of schist. Most of the larger fragments are 3-4 cm. long but some of the angular fragments of carbonaceous matter lying across the bedding reach a length of 10 cm. The matrix consists of angular quartz fragments with a minor clay cement. Quartz comprises about 60% of the rock. Kaolinised feldspar in the matrix comprises about 10% of the rock. Muscovite and graphite are common, and rutile, limonite and distinctive patches of pink garnet are present. The conglomerate is disconformable on the Cygnet Coal Measures. The conglomerate is cross-bedded, the current having come from 50°.

Above the conglomerate is a bed of coal and carbonaceous shale nine cm. thick and at least three metres long (plate 1, f. 2, 3). In places just below the coal is a bed five cm. thick of interbedded sandstone and carbonaceous siltstone like that immediately beneath the basal conglomerate. The sandstone and siltstone unit passes west into a unit up to 30 cm. thick of interbedded coal, carbonaceous siltstone and sandstone (plate 1, f. 3).

A fine to medium-grained, fairly well-sorted sandstone overlies the coal and, where coal is absent, the basal conglomerate. This is cross-bedded, the individual laminae being a few millimetres to a few centimetres thick, and in the top part ferruginous concretions form up to 2% of the rock. The sandstone (33624 in the University of Tasmania Geology Department collection) consists of angular and a few subangular grains of quartz (about 50%), kaolinised plagioclase (about 30%) which is oligoclase where it is determinable, some microcline (1%), muscovite (5%) and a few quartzite fragments in a limonitic (10%) and sericitic (5%) cement. The clastic grains are equidimensional to elongate (length up to five times breadth) and are fine sand (modally) but range from medium silt grade up to coarse sand grade. The quartz is predominantly clear and unstrained but some with undulose extinction is present. A few sand grade grains of zircon and rutile occur. The framework is closed. Many quartz grains have sutured contacts against one another whereas the boundaries of others appear to be sericitised. The ferruginous cement seems to have been emplaced before development of the sericite in most places but in a few the sericite appears to be earlier. The rock is an arkose.

This richly feldspathic sandstone is overlain by thinly-bedded (beds a few cm. thick) feldspathic sandstone (33623) with pieces of carbonaceous siltstone like that of the Cygnet Formation forming about 8% of the rock. At the top of this unit is a bed 17 cm. thick of conglomerate of which up to 75% comprises this siltstone (plate 1, f. 4). A thin section of the sandstone showed the following composition: quartz, mainly unstrained, some with undulose extinction, some with lines of globular inclusions, 60%; rock fragments, quartzite, siltstone, micaceous siltstone, 5%; feldspar, mainly plagioclase not determinable with certainty, some microcline, 20%; muscovite, 2%; carbonaceous matter, 1%; ferruginous cement, 7%; sericitic cement, 5%; rutile, tourmaline, zircon in small quantities. The framework is closed and the rock consists of angular to subangular and a few subrounded fragments most of which are nearly equidimensional but a few have lengths up to four times the breadth. The modal grade is fine sand and particles range in size from coarse silt to medium sand. Some boundaries between quartz grains or between quartz and feldspar grains are sutured but ferruginous or sericitic cement separates others.

The next unit is a pale red to purple, fine-grained, well-sorted, strongly cross-bedded (plate 1, f. 5) feldspathic sandstone (33622). Examination of a thin section showed that the rock consists of quartz (about 65%); fresh and sericitised feldspar (oligoclase where determinable, 5-7%); muscovite (5-7%), fragments of very fine-grained quartzite, siltstone and clay (3%), graphite (1%) and a few grains of zircon in a matrix of ferruginous material (7%), kaolin (3%) and felted masses of sericite (10%). The clastic particles are mainly equidimensional although a few quartz grains and some muscovite laths appeared to have length about four times breadth. The grains are angular and subangular but a few are subrounded. The framework is intact. The modal grainsize is fine sand with very little coarse sand, much medium sand and very fine sand and some coarse silt. A few lenses of clay pellet conglomerate occur in this sandstone. The cross-bedding indicates currents from the northwest.

A reddish, fine-grained, well-sorted, fissile, quartz sandstone (33621) overlies the feldspathic sandstone. This rock is predominantly quartz (80%) with very little muscovite (2%) and plagioclase (2%) which is probably oligoclase. The clastic grains are predominantly in the fine sand grade, a few only in the medium sand grade, some in the very fine sand and little, if any, in the coarse silt grade. The framework is intact, made mainly of angular, equidimensional quartz grains with a few quartz and muscovite grains about three times as long as broad. Many of the quartz grains have sutured contacts but others are separated by a felted sericitic matrix composing ten to fifteen per cent of the rock.

The final unit is a thin, transitional bed of medium-grained, well-sorted, finely laminated sandstone (33620) which consists of quartz (75%), feldspar (sericitised, 10%), muscovite (3%), graphite (2%) and an iron-rich argillaceous matrix.

This member differs significantly from other rock units in the abundance of feldspar, the good sorting, the thinly-bedded, cross-bedded units and the abundance of small, spheroidal ferruginous concretions. The abundance of clay pellets at Coal Mine Bay helps to differentiate it from the overlying member. The pellets are discoidal to ellipsoidal structures up to eight cm. long and although the majority are siltstone, some are of feldspathic sandstone, suggesting contemporaneous erosion. Graphite from this member was examined by X-ray diffraction methods and its identity established.

The quartz sandstone conformably and transitionally overlying the Barnetts Member at Coal Mine Bay (plate 1, f. 8) is at least 27 m. thick in this and the Randalls Bay area. It is medium-grained, well-sorted, cross-bedded with beds of the order of one metre or more in thickness. Limonitic concretions and clay pellets are present but not so common as in the Barnetts Member. The rock (33619) consists of angular and subangular quartz particles (80%), muscovite (5%) and fragments of siltstone, carbonaceous siltstone, and some fine-grained sandstone (10%) with common particles of zircon, rutile and tourmaline with a minor cement of felted sericite laths (about 5%). Many of the quartz particles showed sutured, almost stylolitic, contacts with other particles. Most of the quartz is equidimensional but a few particles up to four times as long as broad occur. The quartz grains are predominantly of clear, unstrained quartz but some strained quartz, some quartz with rutile needles and some with euhedral zircon crystals and lines of inclusions occur. A few grains may show signs of regrowth. The tourmaline in this as in other thin sections from the Barnetts Member is green. The zircons are predominantly euhedra or broken euhedra. Limonite staining is present but minor. The grains are mainly in the medium sand grade with some coarse, some fine and some very fine sand particles. Tourmaline, ilmenite, melanite and some zircon and magnetite were separated as heavy minerals and comprise in all about 0.2% of the rock. This member corresponds in character and position to the Mountain Lodge Member in the Hobart section.

Rocks apparently similar in character to the Barnetts Member and overlain by thickly-bedded, usually cliff-forming quartz sandstones have been reported by Mather (1955, pp. 96-7) from the Huonville area, and Hale (1953, p. 122) from Brooks Bay where they are 45 m. thick and overlain by cliff-forming quartz sandstone between 30 and 45 m. thick; from the Police Point area (*Ibid.* pp. 122-3) and from the eastern shore of Port Esperance (*Ibid.* p. 124). An outcrop on the Esperance River south-west of Geeveston (Ford, 1954, p. 155) may be a correlate of the Barnetts Member. Further afield the top 40 m. of the section beneath the thickly-bedded sandstones on Mount La Perouse may correspond to the Barnetts Member and 15 m. of feldspathic sandstone overlies carbonaceous siltstone near Maydena and may be a correlate of the Barnetts Member (Jago 1966).

Neither the Barnetts Member nor the overlying member at Coal Mine Bay has yielded fossils.

The Barnetts Member in its type area has some unusual features. The second unit (33624) is an arkose with a high proportion of kaolinised plagioclase and very few rock fragments. Its composition and texture suggest relatively short transportation by water from a terrane of granitic and metamorphic rocks. Higher units contain progressively less feldspar. Although in each case the modal grade is fine sand, the estimated mode decreases from about 0.2 mm. (33624, 33623) to 0.15 mm. (33622) and 0.12 mm. (33621), and the range in grainsizes decreases in general from six grades (33624) to four (33623, 33621), and an impression of better sorting and longer transport emerges from this preliminary study. No change in terrane during deposition of this member is evident. The cementing material in all sections studied is sericitic and ferruginous.

The upper member at Coal Mine Bay shows a marked increase in modal grainsize (about 0.35 mm.) and in the size of the coarsest fragment present (1.1 mm.), with a continued decrease in the feldspar content. The current velocity of the depositing streams apparently increased but feldspar was no longer available in the source area due to deep weathering of quartzo-feldspathic rocks or to the earlier source of feldspar having become covered.

Correlations

Suggested correlations, based on lithological similarity and stratigraphic position are shown in fig. 3. The most significant point emerging from these correlations is that if correlation with the Ross Sandstone at Poatina is correct, the Springs Sandstone is Scythian and may be roughly correlated with the Knocklofty Formation which contains two spores of stratigraphic significance also present in the Ross Sandstone. Thus at Cygnet and Hobart the Permo-Triassic boundary lies within the range of the Cygnet and Springs Formations.

THE PERMO-TRIASSIC BOUNDARY IN TASMANIA

Evidence has been presented earlier that the Cygnet Coal Measures are Upper Permian, contain the *Dulhuntyispora* Microflora, and at Western Bluff at least may be correlated with the upper part of the Newcastle Coal Measures of New South Wales. A siltstone 85 m. above the base of the Ross Sandstone at Poatina contains *Lundbladispora brevicula* and *Densoisporites playfordi* (Playford 1965) and a siltstone at Crisp and Gunn's Quarry, Knocklofty, in the Knocklofty Formation also contains these spores (G. Playford *pers. comm.*). The presence of these spores suggests correlation with the Collaroy Claystone of the Narrabeen Group of New South Wales (Evans 1966) and with the Kockatea Shale of Western Australia (Playford 1965) which is Otoceratan (basal Scythian). The two lower spore assemblages (Tʀ 1a, Tʀ 1b) reported from New South Wales and Queensland (Evans 1966) have not yet been found in Tasmania. In New South Wales the thickness of sediment separating the Collaroy Claystone from the Newcastle Coal Measures is nearly 400 m. (Hanlon *et al.* 1953) considerably more than that between the *Lundbladispora* horizon and the Jackey Shale. At this stage it is impossible to fix with any precision the boundary in Tasmania corresponding to the base of the Narrabeen Group in New South Wales, and, of course, to divide the Tasmanian succession accurately in terms of a world standard Permo-Triassic boundary (top of the *Cyclolobus* Zone).

For local convenience in field mapping this boundary has been taken at the base of the first thickly-bedded sandstone above the highest carbonaceous siltstone. This may well correspond to the base of the Sphinx Rock Member as both on Mount Wellington and at Cygnet the Barnetts Member contains carbonaceous siltstone, is relatively thinly-bedded and has a subdued outcrop whereas the Sphinx Rock Member outcrops boldly and the obvious place for a field mapping boundary is at the base of this member. The entry of cross-bedded, feldspathic sandstones is probably not a suitable horizon for distinguishing the Cygnet from the Springs Formation as the Cygnet contains feldspathic sandstones in many places although at others, e.g., Malanna, it does not seem to have significant quantities of feldspar. The base of the Barnetts Member is a convenient boundary as, in some places at least, there is a disconformity and a thin conglomerate at this level. However, in the type areas and elsewhere the conditions of deposition did not change significantly at this horizon; coal and feldspathic sandstone occur both above and below the contact. In addition, disconformities, even those overlain by thin conglomerates, within fresh-water successions may well be of very local extent and short duration. Angular unconformities between the Ferntree Mudstone and Springs-type sandstone have been reported by Woolley (1959) and Alwar (1960) but the evidence is not incontrovertible. Attempts to determine the age of this boundary at Cygnet and Southport by palynological studies failed because of poor preservation of spores. Disappearance or virtual disappearance of feldspar from the section does not appear to be a good criterion for separating Barnetts and Mountain Lodge Members as this seems to have occurred at different levels in different places. In fact, some of the sandstones above the Mountain Lodge Member on Mount Wellington appear to contain considerable quantities of feldspar. The appearance and disappearance of feldspar is probably related to uncovering and covering of different source areas at different times. At Cygnet and elsewhere the contact between Barnetts and Mountain Lodge Members appears to be gradational and the main objective criteria for distinguishing them are bedding thickness, grainsize and outcrop behaviour.

Finally, delineating formations in a persistent fluvial environment is very difficult just because of the environment and no less difficult if the fluvial environment changes slowly with time as may be suggested for the interval from Cygnet to Mountain Lodge.

Thus no *a priori* case can be established for preferring the base of the Barnetts to the top of the Barnetts as a system boundary and neither may correspond to the top of the *Cyclolobus* Zone. A floral change occurred at about the time of deposition of the Barnetts Member and establishment of the position of this change in different sections may eventually provide a better time marker than is now available. As is widely realized by Australian palaeontologists this change itself may not correspond to the system boundary elsewhere.

CONCLUSIONS

The Cygnet Coal Measures of Upper Permian age are followed disconformably or gradationally by the Springs Sandstone, the basal member of which, Barnetts Sandstone, is thinly-bedded, fine-grained and in places arkosic and the upper member, Mountain Lodge Member, a more thickly-bedded, coarser-grained protoquartzite. The Springs Sandstone has few identified fossils but by correlation with the Ross Sandstone is probably basal Triassic (Otoceratan). The most convenient horizon to take as the Permo-Triassic boundary in Tasmania is probably the base of the Mountain Lodge Sandstone but this is debatable and certainly may not correspond temporally to the Permo-Triassic boundary elsewhere.

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APPENDIX I

Section from Dolerite Contact on Pinnacle Road to Cygnet Coal Measures

TOP—dolerite contact, "F" on fig 1 **C**

Unit		
F_2	1.20 m.	fiss., fine-gnd ss and coarse sltst, 10 Y R 6/6.
E_2	2.73 m.	c.b. ss, cross-bedded sets approx 5 cm. thick; beds of order or one m. thick.
D_2	1.36 m.	very fine-gnd ss, cross-bedded sets abt 10 cm. thick; beds 10 to 30 cm. thick approx.
C_2	0.91 m.	bed of qz ss with some feld; base cross-bedded.
B_2	4.12 m.	fine-gnd qz ss with some graph; fiss, c.b.
A_2	1.06 m.	ss with beds of order of 30 cm. thick.
Z_1	1.21 m.	coarse-gnd sltst, beds 7:5 to 25 cm. thick; non-fiss; 5 Y 6/4.
	Gap of 50.14 m.	
Y_1	1.21 m.	c.b. ss; sets 2.5 cm. thick; cross-bedding dips 207° at 15°.
X_1	2.12 m.	thick bedded (beds about 0.75-1 m. thick) ss.
W_1	1.06 m.	med to fine-gnd, c.b. ss, containing qz, feld, musc; c.b. sets 10-12 cm. thick; c.b. dips 170° at 12°, 5 B G 6/2.
V_1	1.06 m.	c.b. ss with discoidal ferruginous clay concretions up to 2.5 cm. long; c.b. sets 0.5 to 2.5 cm. thick, thinner near base; thicker near top.
U_1	0.91 m.	thick bedded ss.
	Gap of 16.14 m.	
T_1	2.74 m.	med-gnd ss; qz, musc; feld uncommon; beds 30 cm. to 1.25 m. near base, 2.5 to 5 cm. thick near top; 10 Y 6/2 or 5 BG 5/2.
	Gap of 50.75 m.	
S_1	0.61 m.	med-gnd ss with qz, musc, graph, feld (<5%); c.b.; bedding 15 cm. to 20 cm. thick.
	Gap of 3.02 m.	
R_1	2.25 m.	friable med to coarse-gnd ss.
Q_1	0.60 m.	med to coarse-gnd ss, qz, feld (abt 10% some fresh), beds 22-40 cm. thick.
P_1	0.35 m.	coarse to med-gnd sltst, qz, musc, graph, very fiss.
O_1	3.50 m.	f to med-gnd ss, qz, feld (5%), musc, clay pellets, bedding up to 1.25 m. thick; 10 YR 6/6.
	Gap of 108 m.	
N_1	0.76 m.	fine-med-gnd ss, qz, musc, feld rare, single bed, friable; 10 YR 7/4.
M_1	2.29 m.	c.b. ss; basal part with sets 0.5 to 1 cm. thick, overlain by ss with eroded current ripples, clay pellets and current drag; c.b. dips 310° at 16°; overlain by c.b. ss sets 7.5 to 10 cm. thick.
L_1	0.46 m.	one bed ss.
K_1	0.61 m.	ss, beds order of few cm. thick.
J_1	2.74 m.	med to fine-gnd ss, qz, musc, feld (<5%), graph uncommon, green biot or chlor, beds 7.5 cm. to 1 m. thick; 10 YR 4/2.
I_1	0.75 m.	med.gnd ss, musc, feld (>5%); c.b. sets 2.5-5 cm. thick, c.b. dipping 130° at 12°; 10 YR 6/6.
H_1	0.75 m.	clay-pellet conglom.
G_1	0.75 m.	med-fine gnd ss, qz, musc, graph, feld (<5%); beds 0.5-10 cm. thick, 10 YR 6/6.
F_1	4.42 m.	med-gnd ss, qz, feld, musc, graph, clay pell. up to 5 cm. long 5 Y 5/2; beds up to 2.5 m. thick.
	Second road to chalet above Mountain Lodge.	
	Gap of 17.22 m. including first road to chalet above Mountain Lodge.	
"E" on fig. 1.		
E_1	0.45 m.	med-gnd ss, qz, feld (<5%), musc (rare), graph, green biot, or chlor; contains large rounded frags up to 5 cm. long which look like Ferntree Mudstone and garnetiferous ? phyllite; bedding up to 2.5 cm. thick; c.b., 10 YR 8/2.
D_1	5.50 m.	ss, beds up to 1 m. thick.
C_1	0.07 m.	6 beds, each less than 0.5 cm. thick of clay pellet conglom; pebbles up to 1 cm. long in arenite (gns up to 1 mm.) matrix, qz, feld (5-10%); (some bands up to 20% feld and in these gns are more angular than in others), musc, rare graph, chlor; beds of conglom lenticular, 10 YR 4/2.
B_1	2.40 m.	ss.
A_1	0.60 m.	med-gnd ss, qz, feld (5-10%), musc, graph (rare), beds 45-15 cm. thick, 10 YR 6/6.
Z	1.20 m.	fiss, fine-gnd ss with qz, musc, feld, graph, in beds 0.5 to 6 cm. thick; ripple marked, 10 Y 6/2, interbedded with coarse-gnd sltst, 5 Y 5/2, with ? animal tracks.
Y	14.94 m.	c.b.; ss beds 30 cm. and more thick; current drag structure present; cliff forming; some small ferrug, concretions.
X	0.30 m.	ss, beds 0.5 to 2.5 cm. thick.
W	0.02-0.05 m.	clay pell and qz conglom; pell up to 7.5 cm. long; changes along strike to N.
V	6.70 m.	ss, beds abt 1 m. thick; cliff-forming.
U	3.94 m.	c.b. ss, sets 20 cm. thick; c.b. dips 25° at 17°.
T	1.50 m.	10 R 6/2 ss, few clay pellets; top with current ripples from north; beds about 0.9 cm. thick.
S	0.05 m.	fine-gnd fiss ss; beds approx 1 cm. thick; qz, musc, graph.

Unit

R 1.60 m. med-gnd ss, qz, musc (rare), feld (rare) clay pell (rare), c.b. beds 0.5 to 1 cm. up to 60 cm.; 10 YR 5/4.

Gap of 0.4 m.

Q 0.50 m. one bed ss.

P 0.15 m. ss, qz, musc, graph; beds <0.5 cm. thick.

Gap of 1.2 m.

O 1.80 m. fine-gnd ss, qz, musc, graph; bedding 2.5 cm. thick.

N 1.60 m. fine to med-gnd ss, qz, musc, graph, feld (<5%); beds 0.5-1 cm.; c.b. with dip 90° at 13°, 10 YR 6/6.

Gap of 1 m.

M 4.60 m. med-gnd ss, qz, graph, feld (<2%); beds 15-60 cm. thick, c.b.; cliff forming, 10 YR 6/6.

L 0.20 m. friable white ss.

K 0.20 m. c.b. fiss ss, fine-gnd, qz, graph, musc, one set.

Third step on track above road at "C" (fig. 1 C).

"C"—"D"

l 1.80 m. ss, qz, musc, graph, clay pell, beds 7.5 to 15 cm. thick.

k 0.15 m. c.b. ss, qz, graph, musc.

j 1.70 m. med- coarse-gnd ss, beds 0.8-1 m. thick; with qz, graph, clay pell near top; near base sets 7.5 to 30 cm., c.b. with current drag; 10 YR 6/6; ss.

i 1.50 m. fine-gnd ss, musc, qz, beds 0.5-2.5 cm.

h 0.30 m. c.b. ss, sets 1-2.5 cm. thick.

g 0.45 m. one set c.b. ss.

f 0.30 m. fine-gnd ss, qz, musc, graph, beds 1.0-2.5 cm.

Gap of 0.75 m.

e 0.60 m. med-fine gnd ss, qz, musc, graph, 10 YR 6/4.

Gap of 0.30 m.

d 0.15 m. c.b. ss; sets 1-2 cm. thick.

c 2.25 m. ss, beds 75 cm. thick.

b 0.60 m. ss.

Gap of 3.5 m.

Unit

a 2.59 m. med-fine gnd sltst, qz, musc, feld, rare plant frags, non-fiss; irregular blocky fracture.

"D"

"C"-"A"

J 0.90 m. ss, beds more than 30 cm. thick.

Road (approx 2.45 m. gap).

I 1.25 m. med to coarse-gnd ss, with clay pell, c.b., qz, feld (<5%), musc (rare), graph (rare), beds 10 cm. or more thick.

H 0.50 m. fine-gnd qz, clay pell conglom.

G 1.50 m. med to coarse-gnd ss, qz, feld (<5%), musc (rare), graph (rare), pink garnet (very rare), beds 10 cm. or more thick; some conglom bands 10 YR 6/6.

Gap of 10.36 m.

F 10.67 m. fine-gnd ss, qz, musc, beds less than 1 cm. thick, very fiss near base, less so near top 5 Y 5/2.

E 1.50 m. med to coarse-gnd, carb sltst with qz, musc, feld, plant frags (? sphenopsid), some beds fine-gnd ss and clay pell conglom, somewhat fiss, N4-N5.

D 6.40 m. very fiss, micaceous, fine-gnd ss, beds less than 1 cm. thick, 5Y 5/2.

C 1.20 m. ss, beds 1-1.5 mm. thick, 5 Y 7/2.

B 1.70 m. ss, beds 1-2.5 cm. thick; otherwise as A.

A 14.60 m. med. to coarse-gnd ss, qz, feld (<10%), musc, graph, 10 YR 8/4.

Base of Springs Sandstone on track from "C" to "A" on Pinnacle Road (Pillinger Drive).

Thicknesses by abney levelling or by measurement on outcrop by steel tape.

Abbreviations.—*biot*—biotite; *c.b.*—cross-bedded or cross-bedding; *chlor*—chlorite; *conglom*—conglomerate; *feld*—feldspar; *ferrug*—ferruginous; *fiss*—fissile; *frags*—fragments; *gnd*—grained; *graph*—graphite; *med*—medium; *musc*—muscovite; *pell*—pellet; *qz*—quartz; *rnded*—rounded—*sltst*—siltstone; ss—sandstone.

Colour symbols quoted are from *Rock Colour Chart*, Goddard *et al.*

EXPLANATION OF PLATES.

1. Basal conglomerate with cross-bedding, Barnetts Member in type section; note coal lense immediately above it in right-hand side of photograph.
2. Coal lense between basal conglomerate and second unit of Barnetts Member.
3. Second unit of Barnetts Member in type section shown basal conglomerate at lower left passing up and right in interbedded feldspathic sandstone, carbonaceous siltstone and coal; second unit at top of photograph.
4. Clay pellet conglomerate, Barnetts Member, Coal Mine Bay.
5. Cross-bedding and ferruginous concretions, Barnetts Member, Coal Mine Bay.
6. Thinly-bedded sandstone showing diffusion rings and weathering pattern, Barnetts Member, Coal Mine Bay.
7. Thinly-bedded sandstone, Barnetts Member, Coal Mine Bay.
8. Contact between Barnetts Member below and thickly-bedded, cross-bedded sandstone above as seen in cliff section at Coal Mine Bay 493.3, 677.42. Hammer lying immediately below contact.

[Photos by A. Goede for I. H. Naqvi.

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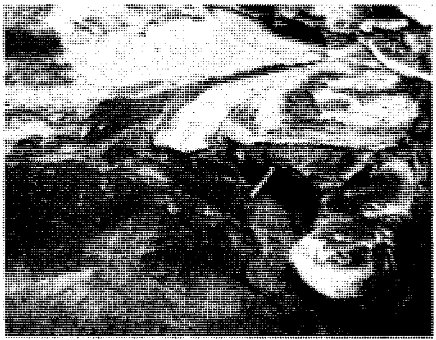

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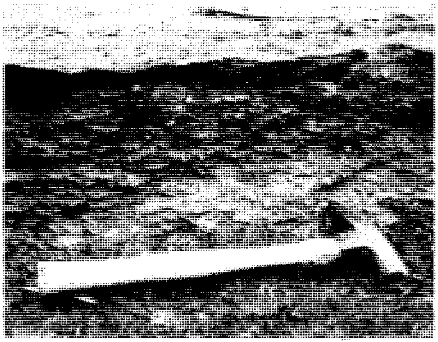

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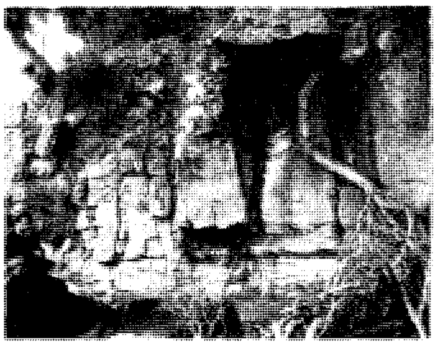

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F.P.30