



Review of the Upper Parmeener Supergroup

by S. M. Forsyth

INTRODUCTION

Strata of Late Carboniferous to Late Triassic age are widespread in Tasmania. The strata are essentially flat-lying and were named the Parmeener Supergroup by Banks (1973). The Parmeener Supergroup has been formally subdivided into a Lower division that includes all known glaciomarine strata and an Upper division that consists of freshwater strata (Forsyth *et al.*, 1974).

Strata of the Parmeener Supergroup rest (commonly with pronounced landscape unconformity) or granitic and folded rocks. They obtain a maximum composite thickness of about 2 km. Most of the initial basement irregularities were buried during deposition of the Lower Parmeener Supergroup. Local disconformities, very slightly angular erosive unconformities and condensed sequences indicate surface subsidence was not entirely uniform during deposition of the Parmeener Supergroup and uplift may have occurred in some area.

The youngest major deposit of the Lower Parmeener Supergroup consists of about 200 m of muddy lagoonal or estuarine rocks (Banks and Clarke, 1987). The association of facies normally regarded as typical of the gradual progradation of a major delta has not been identified in either these Lower Parmeener strata, nor in the overlying Upper Parmeener strata. The change from rocks of a restricted glaciomarine environment to rocks of a fluvial environment is relatively abrupt in stratigraphic sections. A eustatic fall in sea level or perhaps regional uplift in eastern Australia may have contributed to the minimal record of transitional facies at the Lower/Upper Parmeener Supergroup boundary.

The Upper Parmeener Supergroup consists predominantly of sandstone, siltstone, mudstone and coal measures and subordinate, usually lenticular, conglomerate layers and tuff. Two basalt flows occur locally in north-eastern Tasmania. The rocks were deposited in fluvial and fluvio-lacustrine environments by both low and high sinuosity rivers. The composite thickness is less than one kilometre. During Triassic times, the basin was flanked on the west by a continental block or a recycled orogen province and may have been flanked on the east, by a magmatic arc province (Eggert, 1983). The initial sand detritus of arkosic to quartzose composition was deposited by easterly flowing rivers during the Late Permian and Early Triassic. A more complex situation during the Middle Triassic involved gentle tilting and basaltic lava extrusion in the north-east, erosion and redeposition of some earlier deposits, changes to the palaeodrainage and the initiation of lithic sand deposition. Sand deposited during the Late Triassic was almost entirely of lithic composition with a greater volcanic component. Associated pyroclastics and clasts respectively indicate contemporaneous acid volcanism and erosion down to fossiliferous strata of the Lower Parmeener Supergroup in areas probably outside of the preserved or exposed part of the basin, late during deposition.

During the mid-Jurassic, pipes, dykes and inclined sheets of dolerite magma penetrated the basement rocks to

intrude Parmeener Strata, largely as transgressive sheets and dykes several hundred metres thick (Schmidt and McDougall, 1977; Leaman, 1975). Metamorphism caused by the intrusions is minimal, but disruption of the host strata particularly above feeders and at steeply transgressive sheet segments and at junctions of intrusion segments, caused significant breaks in the continuity of lithological units. Further disruption of the strata has been caused by subsequent block faulting. Erosion has completely removed the Parmeener strata from some area. The uppermost strata tend to be preserved only in grabens or where Jurassic dolerite sheets or Tertiary basalt flows have slowed erosion.

This review deals largely with the stratigraphy and palaeontology of the Upper Parmeener Supergroup and is an expanded version of the section on the stratigraphy of the Upper Parmeener Supergroup in the Geology and Mineral Deposits of Tasmania (Burrett and Martin, 1989). Readers are directed to (Burrett and Martin, *op cit.*) for a review of Upper Parmeener volcanic rocks and aspects of economic geology.

Sandstone diagenesis has been described by Eggert (1983). Appendix A lists many unpublished Tasmania Mines Department reports prepared largely by C. A. Bacon in preparation of a major review of coal in Tasmania. A list of company reports dealing with coal and held on open file at the Department of Mines is given in Appendix B. Upper Parmeener sandstone has been used as building stone and two useful reports on this aspect are Sharples (1984) and Sharples *et al.* (1986).

LITHOSTRATIGRAPHIC MAPS AND SUBDIVISION OF THE UPPER PARMEENER SUPERGROUP

Traditionally the Upper Parmeener Supergroup has been subdivided using features such as sandstone lithology, proportion and the nature of lutite and the presence or absence of coal measures or other carbonaceous rocks. Coal measures near the base contain a Permian glossopterid flora, whereas coal measures near the top contain a Late Triassic *Dicroidium* flora. Above the basal Permian coal measures, the sandstone composition changes up the succession in a general way from quartzose to lithic. Lutite tends to be more common towards the middle of the Upper Parmeener succession.

The simplest and most widely applied subdivision has consisted of basal Permian coal measures – where these rocks are developed or recognised – a quartzose association and an upper lithic (earlier referred to as 'feldspathic' – association usually containing coal measures. Certain problems exist with this subdivision, certain lithic sandstone sequences do not contain coal seams, some quartz sandstone sequences contain coal seams, and quartz and lithic sandstone interdigitate. Sequences that contain both lithic sandstone and quartz sandstone have been included in the lithic association and in the quartzose association depending on the locally predominant lithology or depending on other criteria.

The subdivision used here is indicated in table 1.

Table 1

top	Unit 4	Volcanic lithic sandstone and coal measures sequence (Karnian)
	Unit 3	Sequence with quartz and lithic sandstone. (Pre-Anisian? to Ladinian)
	Unit 2	Quartz sandstone sequence and associated rock types (Griesbachian to pre-Anisian?)
bottom	Unit 1	Upper Permian coal measures and associated rocks

The main features of the traditional subdivision are employed here with some amendments and additions. This subdivision was chosen to conform to recent mapping practice and does not necessarily provide the best natural subdivision of the Upper Parmeener Supergroup based on current knowledge. McKellar's (1957) subdivision of the Upper Parmeener Supergroup succession at Poatina is the best formal subdivision and has been widely accepted as a standard section for the Upper Parmeener Supergroup. McKellar's subdivision was not adopted here as it is based largely on subsurface data and little attempt has been made to map the formations of the surface or to correlate successions elsewhere with the formations at Poatina. The relationship between the Poatina formations and the subdivision employed here is shown in Table 2.

Table 2

4	Brady Formation
	Tiers Formation
	Cluan Formation
3	Ross Formation
	Jackey Formation

Compared to much earlier practice, the subdivision used here differs primarily by:

- (1) the grouping of non-coal bearing, arkosic or otherwise characteristic Late Permian rocks with the laterally equivalent Late Permian coal measures.
- (2) a greater appreciation of the nature of the change from quartzose to lithic sandstone and of the recognition of hiatuses. In some area the change from quartzose to lithic sandstone involves repeated interbeds of both quartz and lithic sandstone, enabling the recognition of Unit 3 and further subdivision of this unit as discussed later.
- (3) the recognition of rocks younger than the Karnian coal measures (but for convenience discussed within under Unit 4).

The concept of a greater proportion of lutite near the middle of the Upper Parmeener succession finds

expression here in the subdivision of Unit 2 to recognise an upper lutite-rich interval. This conforms to some previous usage, but not to other in which lower lutite-rich parts of Unit 2 and/or lutite-rich parts of Unit 3 have been considered to form part of the middle lutite-rich part of the Upper Parmeener Supergroup. The lower lutite-rich intervals of Unit 2 form useful mapping units but appear to be facies variants of only local extent. Grouping of lutite rich intervals in Unit 3 and at the top of Unit 2 forms an effective mapping unit and shows some stability of primary depositional environment, but masks important changes of provenance, other changes of environment and possibly changes in climate and possibly a significant hiatus. Some subdivisions of the Upper Parmeener that stemmed from concepts developed during the nineteenth century, incorporated an upper quartz sandstone unit above the Triassic coal measures. The existence of such a quartz sandstone unit with a regional distribution cannot be substantiated and the concept is partly founded in incorrect correlation of quartz sandstone overlying lithic sandstone and/or coal measures in Unit 3. Other factors that may have contributed to the concept include the occurrence of tuff layers high in the Triassic coal measure sequence and siliceous thermally metamorphosed rocks near the contact between coal measures and overlying dolerite intrusions. Locally very rare quartz-rich sandstone occurs within Unit 4.

Systematic mapping of the Upper Parmeener Supergroup is not complete. The Department of Mines Geological Atlas series, 1:50 000 and inch to the mile (1:63 360) gives a coverage of about 60% of the area with Upper Parmeener strata (see fig. 1, 3). The University of Tasmania, Geology Department inch to the mile, 10-kiloyard square series, gives some additional coverage (see fig. 2, 4). Further maps at a variety of scales are included in other Department of Mines and University publications, unpublished reports and theses, company reports etc. Some of these sources are listed in Appendices A and B, some others may be found under the listing of sources for the Department of Mines Geological Atlas 1:250 000 series. Despite the age of the maps in Hills *et al.* (1922), some maps retain significance as they are the only maps available for particular areas.

The degree of lithostratigraphic resolution varies from map to map, generally increasing with compilation date. Changes through time of the subdivision applied to the Upper Parmeener and changes of the interpretation of the lithostratigraphic units, complicates detailed correlation between most areas. Some lithostratigraphic units have been formalised, but few are entirely satisfactory. Discontinuity of outcrops or of mapping coverage has necessitated the use of local formation names or other informal units.

Hale (1962) noted several causes of difficulty in correlating strata even over short distances – lack of marker beds and biostratigraphic zonation, repetition of similar beds and lateral variations of thickness and lithology that occur over short distances. These difficulties still remain but some have been alleviated. Advances in the knowledge of the processes and deposits of a variety of fluvial systems has enabled a greater understanding of the lateral changes of rock types in the Upper Parmeener Supergroup and has improved the ability to select horizons that may be more persistent laterally. Detailed mapping and close drilling patterns have located some marker beds of at least local extent. Biostratigraphic zonations based on fossil plants – for example that of Retallack (1977) – and especially based on palynomorph ranges in the Sydney Basin, Queensland and in Tasmania, provide further means of correlation. Unfortunately, for many areas there is not detailed lithostratigraphic description nor palynological data and for these areas the problems outlined by Hale remain valid.

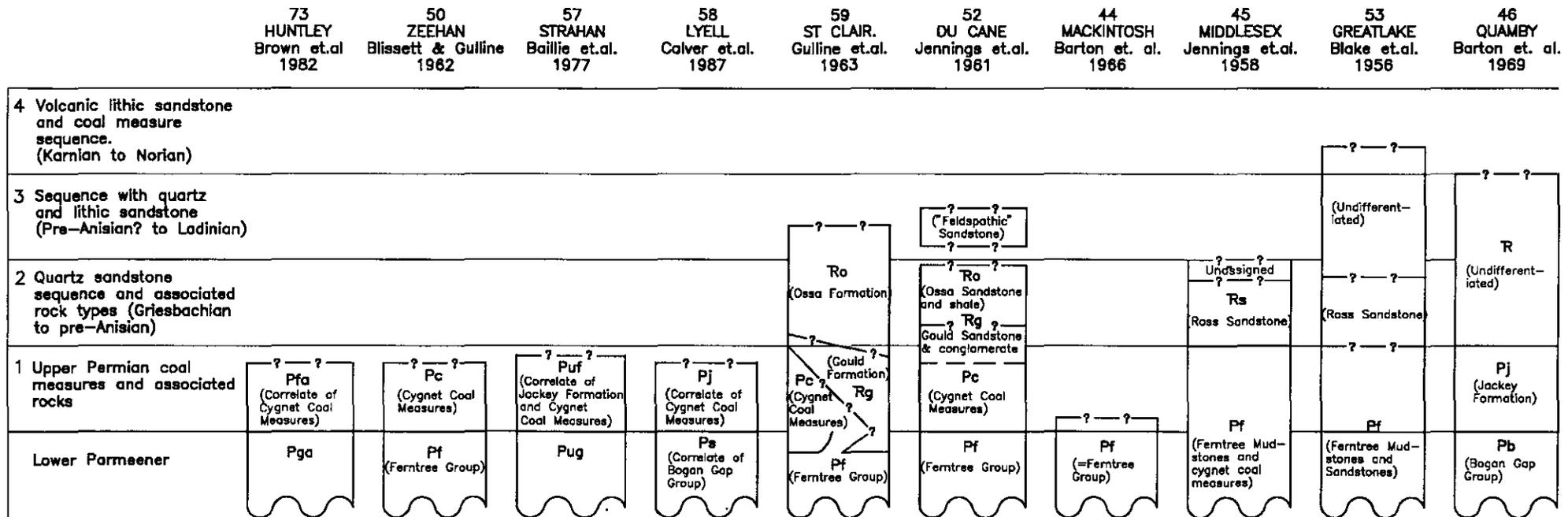


Figure 1. Correlation chart for Upper Permian Supergroup rocks shown on Geological Survey of Tasmania 1:63360 and 1:50 000 maps (continued on next page).

3/4/83

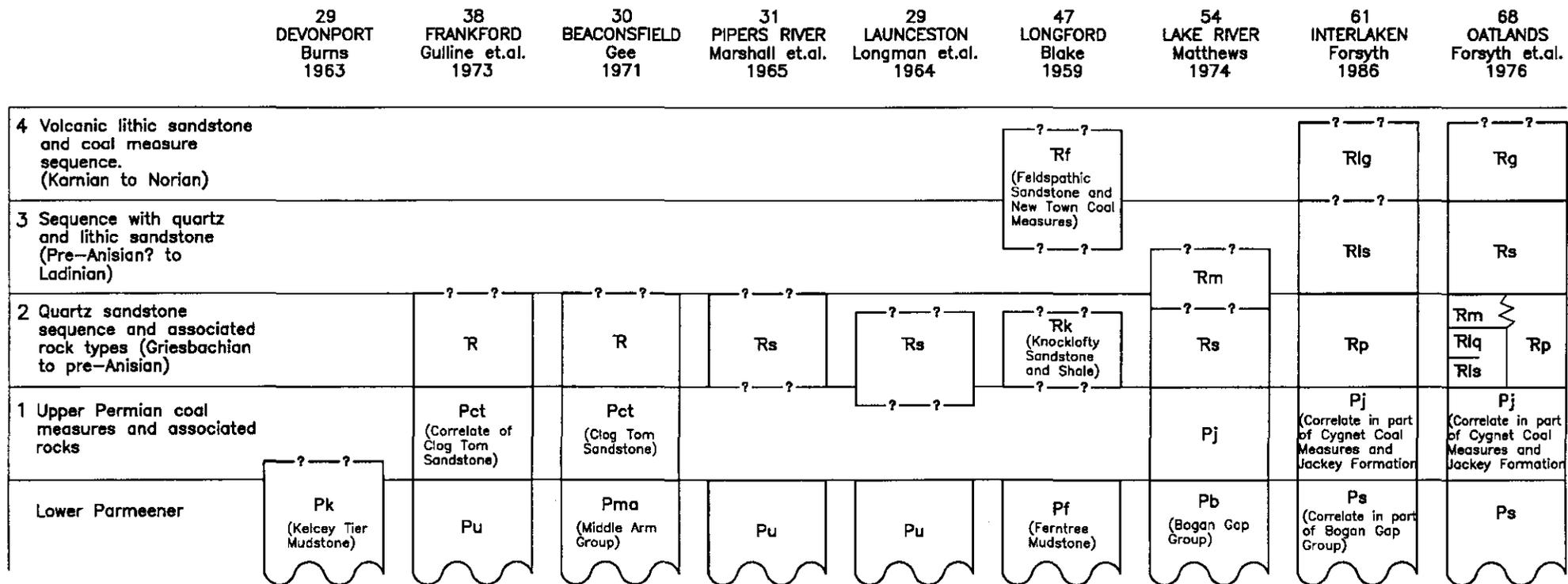


Figure 1. Correlation chart for Upper Permian Supergroup rocks shown on Geological Survey of Tasmania 1:63360 and 1:50 000 maps (continued on next page).

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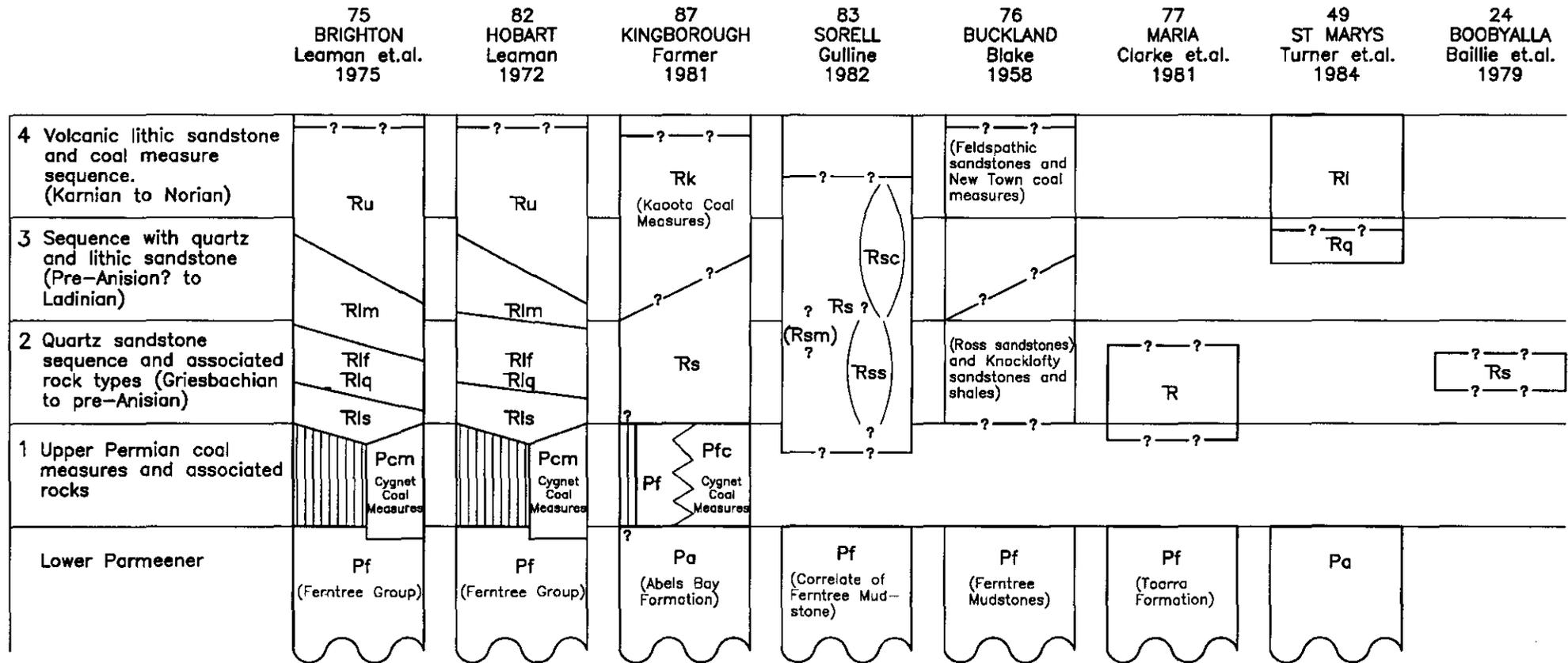


Figure 1. Correlation chart for Upper Permian Supergroup rocks shown on Geological Survey of Tasmania 1:63360 and 1:50 000 maps (continued on next page).

24/11

MAP SHEET	FISHER RIVER	DELORAINE	GOLDEN VALLEY	JACKEY	DRYS BLUFF	MACRAE	WESTON	PALMER	BEACONSFIELD
SHEET NUMBER	4286	4688	4687	4686	4786	4886	4785	4885	4792
AUTHOR	R.J. Ford	A.T. Wells	A.T. Wells	J.B.A. McKellar	D.H. Green				
Compilation date	1956	1954	1954	April 1956	1956				
Publication date	1960	* 1957	* 1957	* 1957	* 1957	* 1957	* 1957	* 1957	* 1959
	<i>In Pap. Proc. R. Soc. Tasm.</i>								
	<i>* In Rec. Queen Vict. Mus. N.S.</i>								

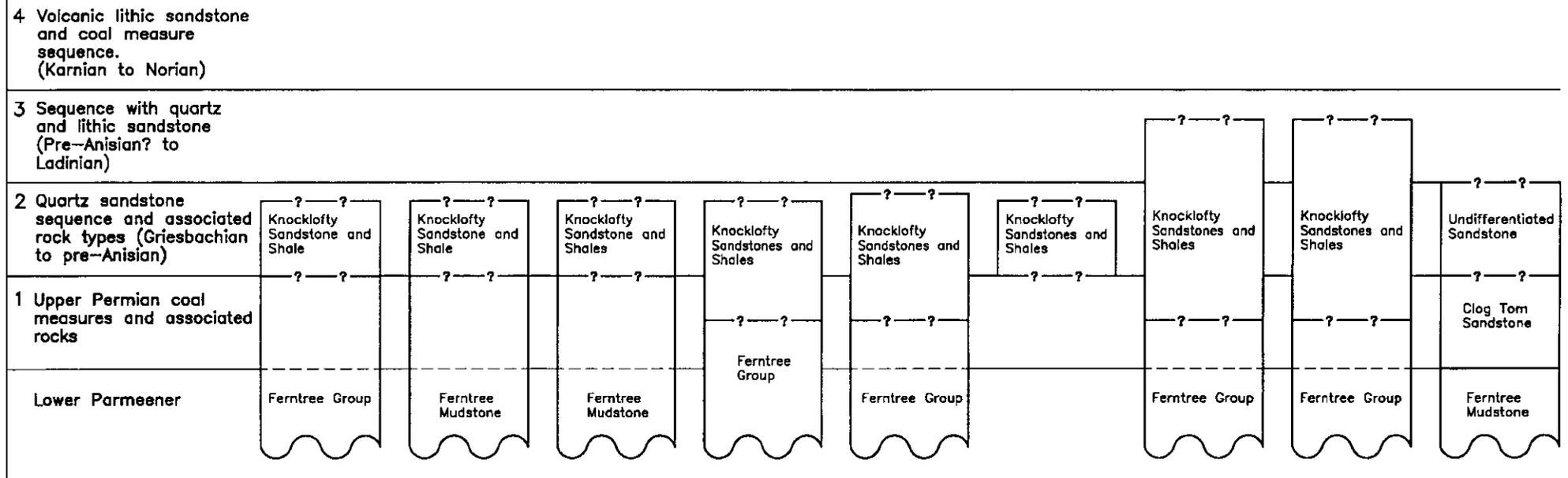


Figure 2. Correlation chart for Upper Parmeener Supergroup rocks shown on University of Tasmania maps (continued on next page).

6/13

MAP NAME	MAYDNA AREA	LONG SPUR	BLACK BOBS	REPULSE	MOUNT SPODE	GLENORA	MACQUARIE PLAINS	PLENTY	BLACK HILLS	NEW NORFOLK
SHEET NUMBER		4477	4577	4576	4875	4774	4874	4873	4974	4973
AUTHOR	J.B. Jago	I.B. Jennings	I.B. Jennings	I.B. Jennings	M.A. Anandalwar	M.A. Anandalwar	M.A. Anandalwar	M.A. Anandalwar	D. Woolley	D. Woolley
Compilation date	1965	Sept. 1954	Sept. 1954	Sept. 1954	1957	1957	1957	1957	1956	1956
Publication date	1972	1955	1955	1955	1960	1960	1960	1960	1959	1959

In Pap. Proc. R. Soc. Tasm.

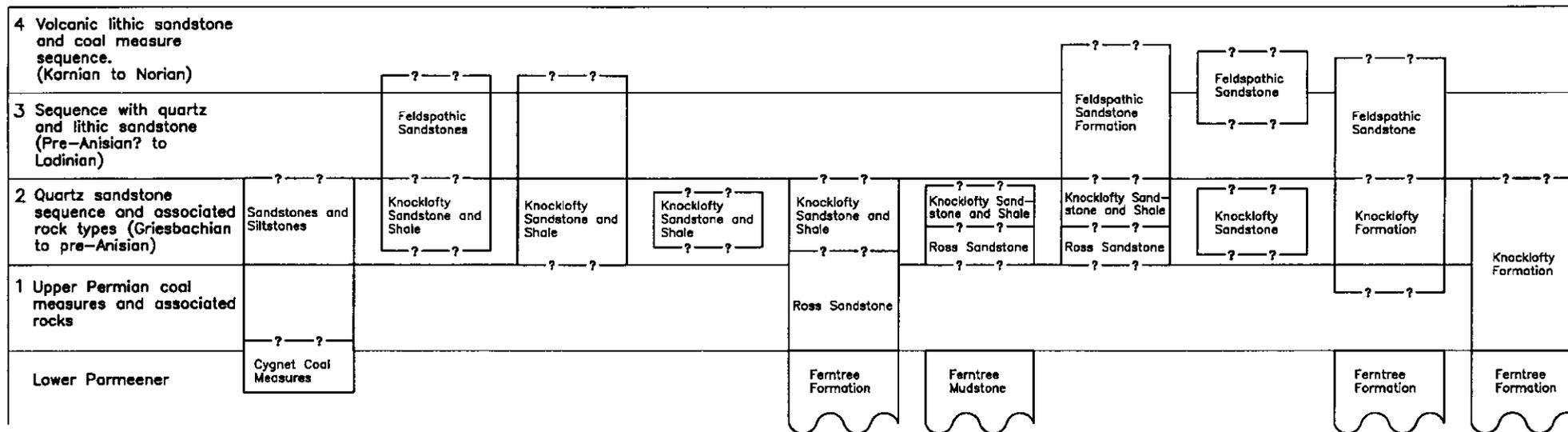


Figure 2. Correlation chart for Upper Permian Supergroup rocks shown on University of Tasmania maps (continued on next page).

MAP NAME	DROMEDARY	PONTVILLE	COLLINSVALE	RICHMOND	SORELL	SOUTH ARM AREA	SANDFLY	"KINGSTON AREA"	MT. ELEPHANT-PICCANINNY POINT	FALMOUTH
SHEET NUMBER	5074	5174	5072	5273	5373		5070		6086,6087	6088
AUTHOR	I. McDougall	I. McDougall	F.L.Sutherland	C.G.Gatehouse	C.G.Gatehouse	D.C. Green	T.H. Rodger	G.C. Paxton	R.D. McNeil	K.R. Walker
Compilation date	1956	1956	1963	1960	1960	1959	1952	1964	1953	1953
Publication date	1959	1959	1964	1967	1967	1961	1957	1968	1965	1957

In Pap. Proc. R. Soc. Tasm.

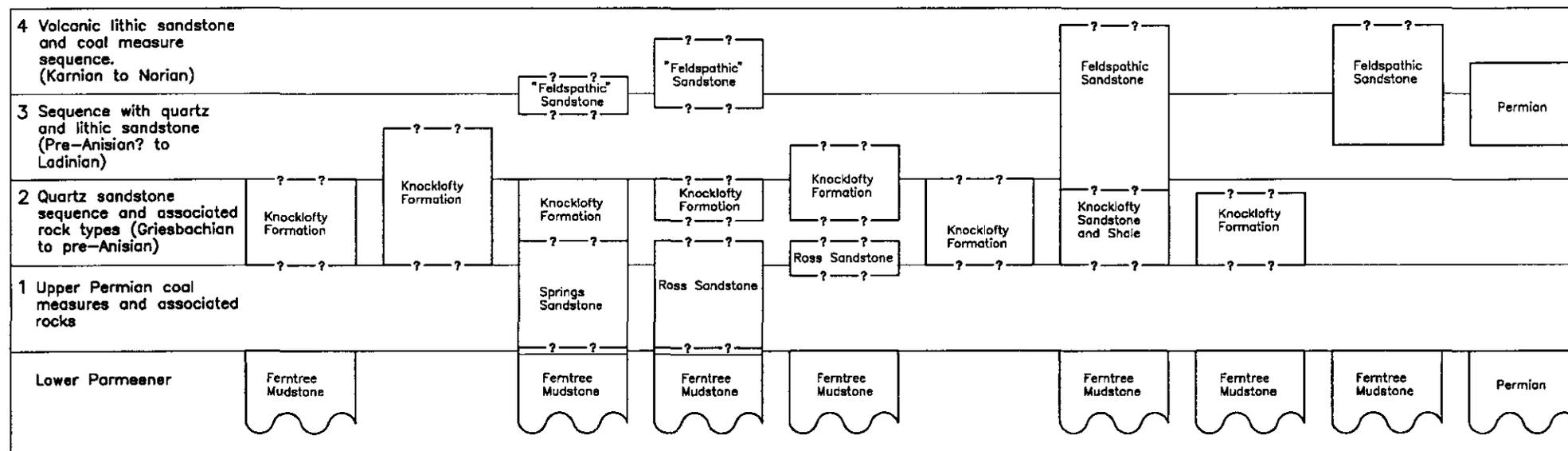


Figure 2. Correlation chart for Upper Permian Supergroup rocks shown on University of Tasmania maps (continued on next page).

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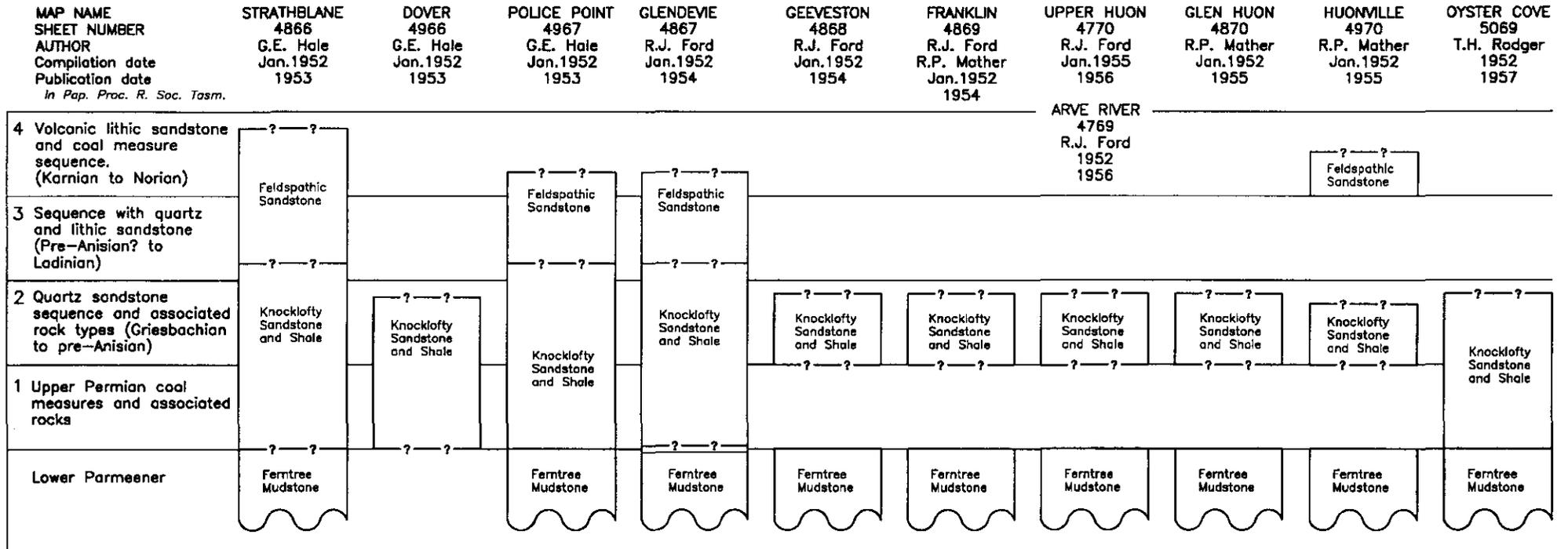


Figure 2. Correlation chart for Upper Permian Supergroup rocks shown on University of Tasmania maps (continued from previous pages).

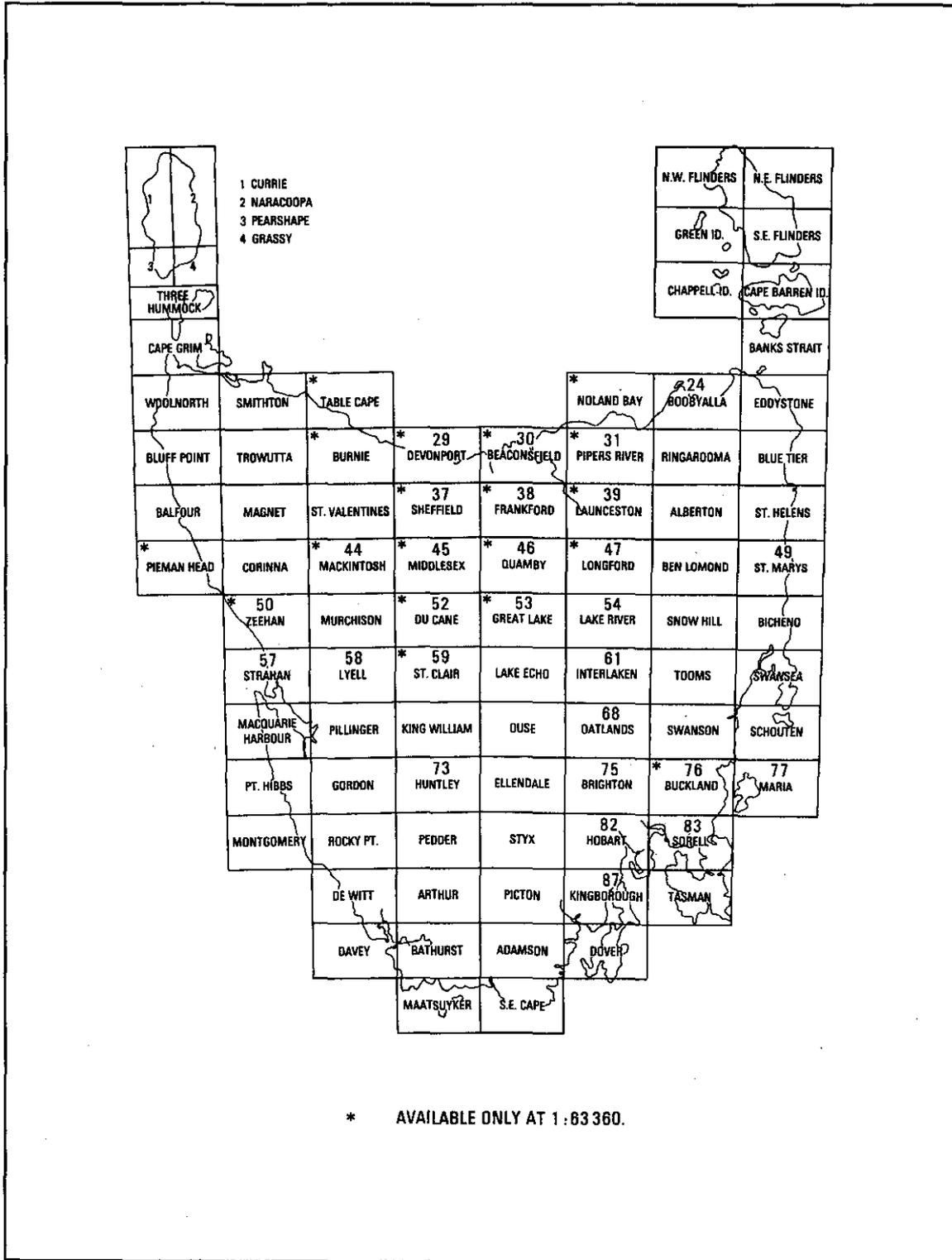


Figure 3. Index to Geological Survey of Tasmania 1:63 360 and 1:50 000 maps depicting Upper Permian Supergroup rocks.

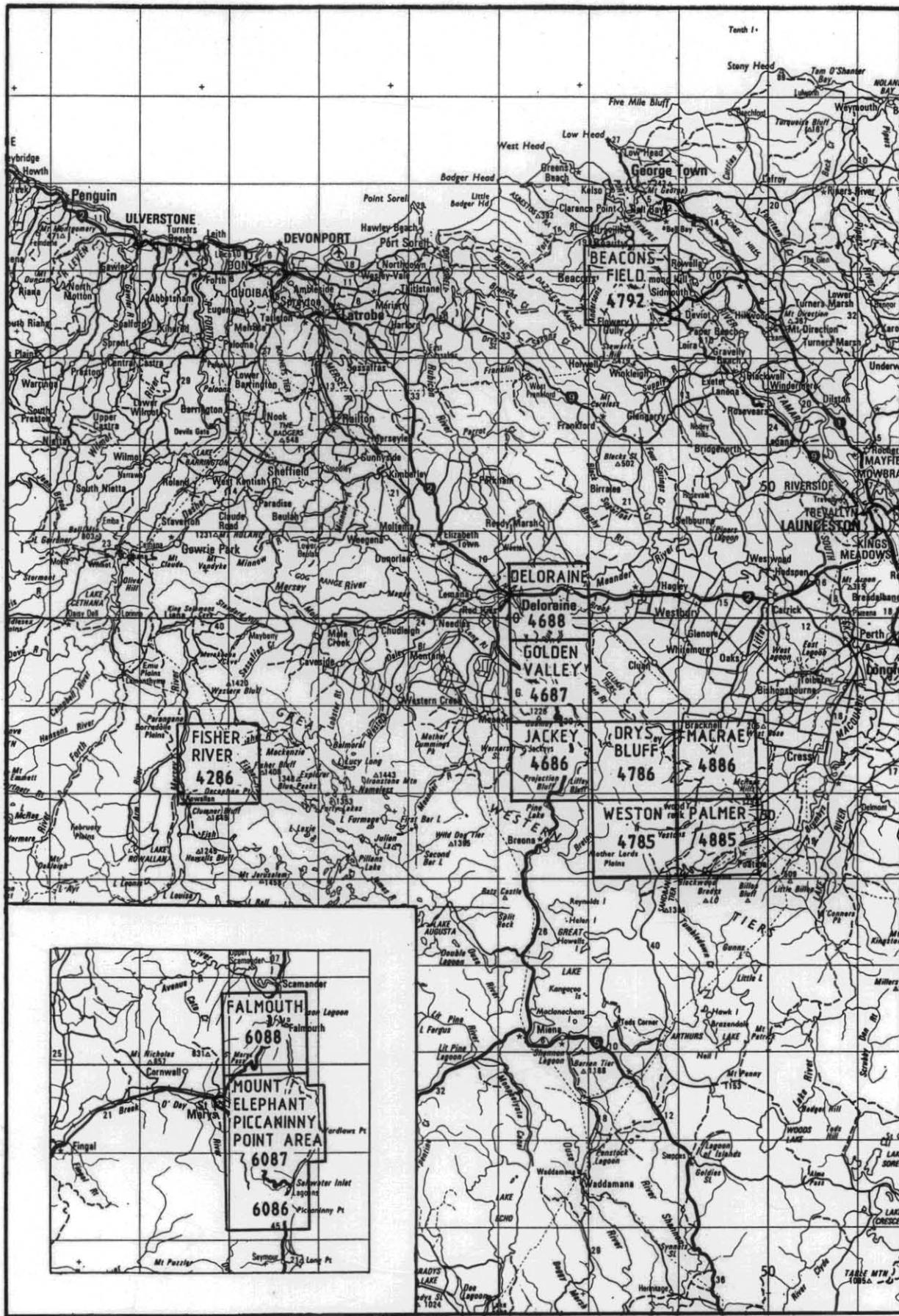


Figure 4. Index to University of Tasmania maps depicting Upper Permian Supergroup rocks (continued on next page).

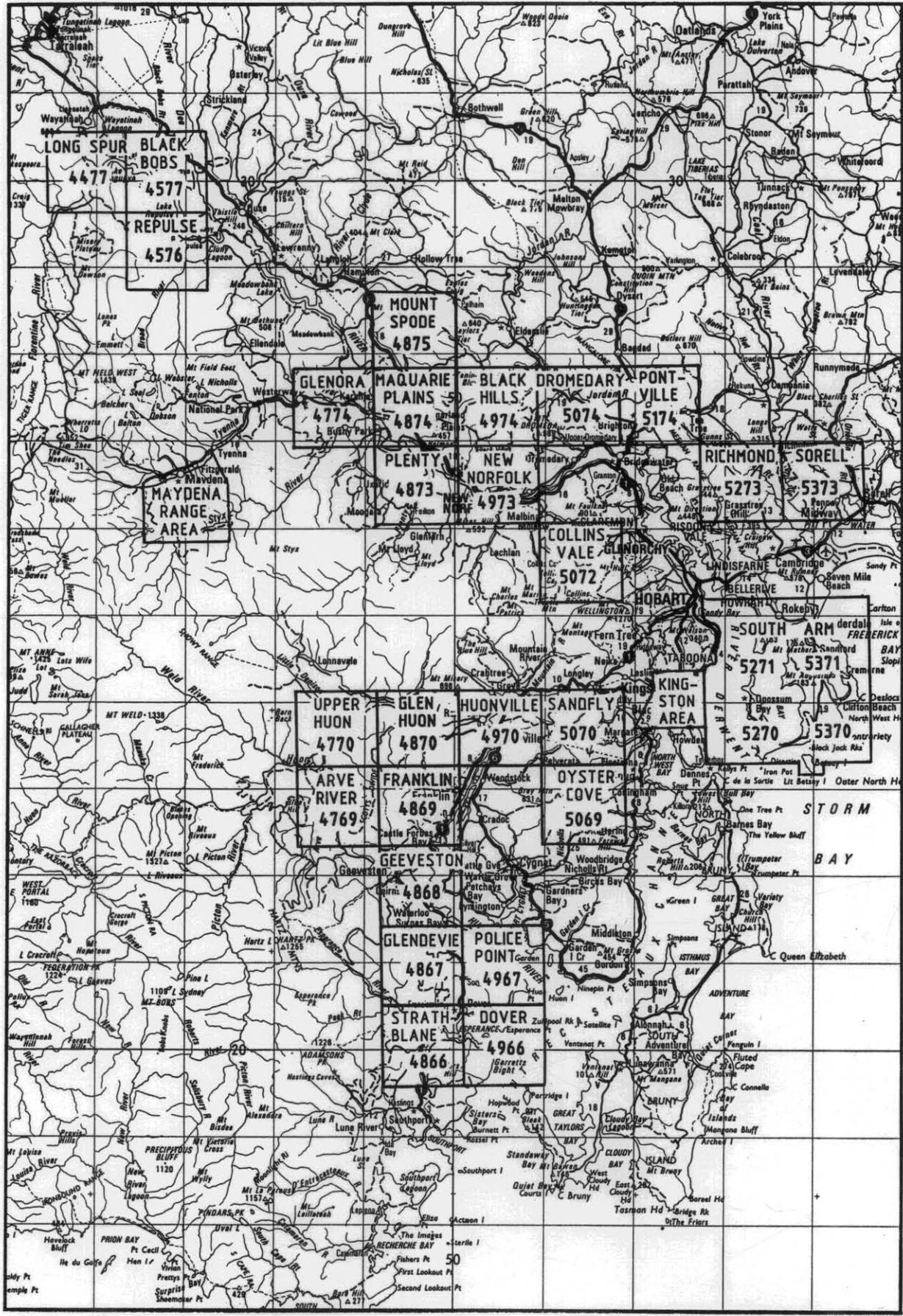
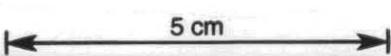


Figure 4. Index to University of Tasmania maps depicting Upper Parmeener Supergroup rocks (continued from previous page).



NATURE OF THE LOWER /UPPER PARMEENER SUPERGROUP BOUNDARY

In north-eastern Tasmania, the Upper and Lower divisions of the Parmeener Supergroup are separated by a hiatus spanning at least the Lower Triassic (fig. 5b, 8). Elsewhere, in the most complete sections, the boundary may be transitional. However, the transitional interval is generally eroded to some degree and the preserved part of the interval or older rocks are abruptly overlain by coarse-grained, often pebbly Upper Parmeener sandstone. Locally, the thickness of the transitional interval is inversely related to the thickness of the overlying Permian coal measure sequence.

In western-central Tasmania, a second interval of strata similar to the transitional interval occurs stratigraphically lower, below a sandstone correlative of the regressive Blackwood Conglomerate. This gives support to the concept that the rocks forming the transitional interval were deposited in an environment transitional between glaciomarine and non-marine conditions and that the change of environment was induced by a relative lowering of sea level. In the Midlands the transitional interval was initiated by a reduced frequency of dropstones and bioturbation with a corresponding decrease in dropstones and bed thickness and increase in carbonaceous matter (Forsyth, 1984). At numerous localities from Adventure Bay (Rigg, 1970) to the southern Midlands (Forsyth, 1984), at Goulds Sugarloaf and possibly at West Arm (Gee and Legge, 1974) the glaciomarine rocks pass up into a few metres of uniform dark grey muddy siltstone that commonly contains light-coloured, coarser laminae. In a general way the coarser grained laminae become more numerous, thicker and coarser up the sequence, with some being cross-laminated. Affinity with the Lower Parmeener Supergroup is indicated by the rare occurrence of large agglutinated Foraminifera and bioturbation or occasionally by granules (dropstones?).

In the thicker transitional intervals for example those in southern Midlands boreholes, Mobil MPT3 (11 m. - Williams, 1984) and Department of Mines Thorpe 1, and that at the top of the Abels Bay Formation (Farmer, 1985; Banks and Naqvi, 1967), very thin to thin interbeds of massive to ripple-laminated, well sorted sandstone are present and in places are dominant. The lithological associations forming the thicker transitional intervals may be similar to, and perhaps indistinguishable from, higher lutite-rich intervals in the overlying coal measure sequence. The similarity is greater if Foraminifera, dropstones and bioturbation occur intermittently and rarely, or do not persist to the top of the interval. These indicators are absent through a significant part of the thick transitional interval in Mobil borehole MPT3 but common bioturbation reappears at the top of the interval.

Following Farmer (1985), the base of the Upper Parmeener Supergroup in partly transitional intervals is taken at the lowest coarse-grained channel deposit or thick unit of well sorted, current-deposited sandstone. In the absence of such deposits the boundary is drawn where any persistent lithological change suggests a change to freshwater deposition.

Silicified wood occurs precisely at the Upper/Lower boundary near Remarkable Cave on Tasman Peninsula and silicified wood-bearing (tuffaceous?) rock occurs immediately near the boundary at Ross (Forsyth, 1989). Near Baden, silicified clasts, some with bisulphate crystal moulds, occur in the basal bed of the Upper Parmeener Supergroup. The silicification and crystal moulds may indicate a break in sedimentation and evaporative concentration of sea water in some areas.

Regional thickness variations of the interval between the regressive Lower Parmeener Blackwood Conglomerate and the base of the Upper Parmeener Supergroup are noteworthy. This interval is about 30-40 m at Goulds Sugarloaf in the west, 23-33 m in the southern Midlands, but northward falls to about 15 m at Poatina (HEC log of bore 5153), 4 m near Ross and 0-10 m west of the Tamar Estuary (Gee and Legge, 1974; Gulline, 1981; Forsyth, 1984, 1989).

UNIT 1: Upper Permian coal measures and associated rocks

Introduction

These sequences overlie glaciomarine (estuarine?) rocks of the Lower Parmeener Supergroup and include carbonaceous rocks and coal measures associated with interbedded, well sorted, cross-bedded or ripple-laminated sandstone and lutite. They contain a Permian flora. Near Cygnet, the coal-bearing facies (Cygnet Coal Measures) passes laterally into facies in which coal has not been found (Farmer, 1979, 1985).

Formations typical of the sequence in northern Tasmania include the Clog Tom Sandstone (Green, 1959) and Jackey Shale (McKellar, 1957); and, in southern Tasmania, the Cygnet Coal Measures and laterally equivalent rocks *sensu* Farmer (1985).

The main coal basins occur in the Cygnet-Bruny Island area (Cygnet Coal Measures, Adventure Bay Coal Measures) and near Pelion Range (Farmer, 1985; Rigg, 1970; MacLeod *et al.*, 1961; Gulline, 1965). The coals are generally too thin to be of economic value and production has been very small.

Where coal is absent, the sequence may be distinguished from the overlying quartz sandstone sequence by the sandstone composition and the common presence of clayey or calcareous cement or matrix that has reduced the tendency for development of glistening quartz grain overgrowths. This is in contrast with non carbonaceous, usually coarser-grained, more massive and thickly bedded glistening quartz sandstone of the overlying quartz sandstone sequence.

Lithologies

SANDSTONE

In southern and central Tasmania, the sandstone is characteristic where it is of a carbonaceous, arkosic or richly feldspathic type. In northern Tasmania carbonaceous, micaceous, quartz sandstone is characteristic (Green, 1959; Gee and Legge, 1974).

The sandstone composition varies in southern Tasmania. In places, quartz sandstone occurs especially near the top of the sequence (Rigg, 1970; Forsyth, 1984) or the sandstone may become generally less feldspathic up the sequence (Banks and Naqvi, 1967; Farmer, 1985). Banks and Naqvi (1967) indicated sandstone near Cygnet contained up to 31% feldspar (oligoclase and microcline where determinable), up to 7% muscovite, and much (usually 10-20%) sericitic or ferruginous matrix or cement even where quartz, which ranged between 50-80%, was relatively common. Beds at Mount La Perouse are especially feldspathic (up to 55% feldspar) with mostly orthoclase, some albite and lesser microcline (Davidson, 1969). Davidson considered much of the orthoclase was authigenic. Carbonate is common as concretions and/or cement in the southern Midlands and at Mount La Perouse, and siderite concretions occur in the Bruny Island-Cygnet-Huon area (Hale, 1953; Banks and Naqvi, 1967; Davidson, 1969; Rigg, 1970; Forsyth, 1984). Graphite, relatively prominent garnet and traces of rutile, limonite, zircon, tourmaline, melanite, topaz and black

spinel occur in the Cygnet-Lower Huon area (Hale, 1953; Banks and Naqvi, 1967). Garnet is also prominent in sandstone of the Midlands (eclogitic; Brown *in* Forsyth, 1984) and in possible correlatives at Maydena (Jago, 1972) and Collinsvale (Sutherland, 1964).

LUTITE

Lutite is usually micaceous and may be shaly, massive or interbedded to interlaminated with sandstone. It tends to be more common in the upper part of sections, in coal measures and at places along the Great Western Tiers. Coal measure lutite is usually medium to dark grey but elsewhere paler colours are common.

BASAL BEDS

Lenticular quartz pebble conglomerate or pebbly sandstone occurs discontinuously in the basal few metres of the sequence throughout much of southern Tasmania (Basal grits: Hale, 1953; Rigg, 1970; Forsyth, 1984, 1989; Farmer, 1985). These lithologies are prominent at Mount La Perouse and in far western Tasmania (Banks and Ahmad, 1962; Davidson, 1969), but have not been reported from northern Tasmania. Clasts include quartzite, slate, schist and granite. At Coal Hill in western central Tasmania, pebble beds that are probably part of the sequence, overlie the coal measures, but the basal beds of the sequence were deposited in a low energy environment.

Stratigraphy

SOUTHERN TASMANIA

The Cygnet Coal Measures are typified by strata drilled at Mount Cygnet and exposed at Sandrock Bay (Farmer, 1979, 1985). These strata have also been described as the synonymous Barnetts Member of the Springs Sandstone (Banks and Naqvi, 1967). In the type area, the Cygnet Coal Measures vary between sections of predominantly cross-bedded sandstone to sections with significant interbedded micaceous carbonaceous siltstone, sandstone and coal (Farmer, 1985). The Cygnet Coal Measures *sensu* Farmer (1985) and *sensu* Banks and Naqvi (1967) are however, mutually exclusive.

Elsewhere mapping practice has followed either one or both concepts. The Measures have also been restricted to exclude all rocks above the highest locally occurring coal seam. For example, strata correlated with the Cygnet Coal Measures by Jago (1972) are correlatives of the Cygnet Coal Measures *sensu* Banks and Naqvi (1967). The Adventure Bay Coal Measures Units 2-12 (Rigg, 1970), Cygnet Coal Measures correlative of Davidson (1969) and possibly some overlying rocks, and the Cygnet Coal Measures correlative of Forsyth (1984) equate with the Cygnet Coal Measures *sensu* Farmer (1985). Strata correlated with the Cygnet Coal Measures by Leaman (1976, 1977) and probably strata correlated with the Cygnet Coal Measures by Gulline (1965) include sequences of both concepts.

Correlatives occur at Southport (Banks and Naqvi, 1967) and near Adamson Peak (Hughes, 1955). Correlatives in the Hobart area include part of Cygnet Coal Measures (Leaman 1976, 1977), probably the basal part (>31 m) of the Springs Sandstone correlative (Sutherland, 1964), Cygnet Coal Measures correlative and possibly the lower member of the Springs Sandstone (Banks and Naqvi, 1967). Although the coal-bearing facies appears to be absent near Hobart, sandstone and siltstone are probably more widespread than mapped. A correlative of the Cygnet Coal Measures occurs in the Florentine Valley (Corbett, 1964; Brown *et al.* 1982). At Maydena Range the basal 15 m, or possibly 54 m of the Upper Parmeener Supergroup (Jago, 1972) is comparable to the Cygnet Coal Measures. The sequence is probably present near Mt

Lloyd and may extend eastward to Remarkable Cave on Tasman Peninsula (Cromer *et al.* 1976).

Strata correlated with the Cygnet Coal Measures in the southern Midlands mainly consist of characteristically mottled, cross-bedded, slightly carbonaceous sandstone with minor lenses of carbonaceous lutite. They fine upward to an upper part dominated by micaceous lutite with interbedded sandstone. Coalified logs and very thin lenticular coal seams occur. Comparable sequences extend from near Meadsfield Creek in the west to east of Whiteford and north to Ross, where lutite dominates the upper half of the sequence. In the south, the sequence was intersected in diamond drill holes near New Norfolk and Pelham (Williams, 1984) and partly included in the Cygnet Coal Measures correlative (Leaman, 1977), especially north of Elderslie and near Eldon. The distinctive feldspathic sandstone that forms much of the sequence occurs farther afield in the Jackey Formation near Parson and Clerk Mountain and at Goulds Sugarloaf and Mount Rufus in western-central Tasmania.

WESTERN-CENTRAL TASMANIA

In western-central Tasmania between Lake St Clair and Pelion Range, massive cliff-forming arkosic or feldspathic sandstone, carbonaceous shale, subordinate thin coal seams and, in places, thin pebbly beds and lenses have been correlated with the Cygnet Coal Measures (MacLeod *et al.* 1961; Gulline, 1965). Feldspathic sandstone beds capping Mt Inglis further north may represent an isolated remnant (Gee and Burns *in* Collins *et al.* 1981). At Goulds Sugarloaf, a prominent thin unit of cross-bedded, pebbly coarse-grained sandstone has been mapped as the basal unit of a sequence previously correlated with the Cygnet Coal Measures (Gulline *et al.*, 1963). Recent mapping in the Lyell Quadrangle (Calver *et al.*, 1987) has shown that the coarse-grained sandstone unit occurs about 30 m below the Upper Parmeener Supergroup and that it is probably a correlate of the Blackwood Conglomerate. This coarse-grained sandstone unit has been incorrectly correlated with Upper Parmeener rock units at other localities in the St Clair Quadrangle. For instance it has been correlated with the Gould Formation west of Lake King William [DP354240] and at Mount Rufus [DP270334, DP243362] (Gulline *et al.* 1963). Creek traverse data (W. L. Matthews *pers. comm.*) and air photo interpretation suggest that the coarse-grained sandstone unit has been included in the Cygnet Coal Measures correlative of Gulline *et al.* (1963) south east of Coal Hill.

The base of Unit 1 at Goulds Sugarloaf and on the northern side of Mount Rufus [DP 243362] consists of 10-15 m of fine- to medium-grained sandstone. Pebbly beds may occupy a basal stratigraphic position in a tributary of Hugel Creek (Gulline, 1965). It is possible that shale and mudstone previously recorded from near the base of the Cygnet Coal Measures correlative at Coal Hill and Mount Manfred (Gulline, 1965) would now be referred to the Lower Parmeener Supergroup. Feldspathic sandstone at Coal Hill has previously been correlated with the Ossa Formation (Gulline, *et al.*, 1963), but the presence of coal fragments up to 15 m above the base of Ossa Formation correlative (W. L. Matthews *pers. comm.*) indicates this interval is part of Unit 1.

Equal proportions of feldspathic sandstone and shale occur at Pelion Range coincident with the thickest (530 mm) coal seams in this area, but further south massive sandstone predominates in units up to 5 m thick (MacLeod *et al.*, 1961). The overlying Ossa Formation is lithologically similar but devoid of coal. The Cygnet Coal Measures correlative (MacLeod *et al.*, 1961) appears to be 30 m thinner at Gould Plateau where it is overlain by the Gould Conglomerate. The Gould Conglomerate (92

Table 3
THICKNESS OF UNIT 1 IN THE SOUTHERN MIDLANDS

DDH	Location	AMG Coordinates	Thickness (m)	Reference
Mobil MPT4	Meadsfield	DP941510	91	A. Williams, 1984; Forsyth, unpubl. data
DoM Bothwell ('Thorpe')	3 km east of Bothwell	EP035060	71	Sharples, 1984
DoM Bothwell 2	8 km east of Bothwell	EP089054	77.3	Forsyth, 1984
DoM Baden 1	near Baden	EP379033	52.6	Forsyth, unpubl. data

m) is composed of massive cross-bedded sandstone, arkose and conglomerate. It may represent less mature basal beds of the Lower Triassic quartz sandstone sequence (MacLeod *et al.*, 1961) or, at least in part, be channel deposits of similar age to the Permian coal measures.

WESTERN TASMANIA

Near the Henty River in western Tasmania, a small outlier of coal measures has been correlated with the Cygnet Coal Measures (Banks and Ahmad, 1962; Blissett, 1962; Baillie and Corbett, 1985). These coal measures are anomalous in generally showing easterly derived palaeocurrents, a more siliceous make-up and a higher proportion of coarse-grained sandstone and conglomerate than elsewhere (Banks and Ahmad, 1962). No younger Parmeener Supergroup rocks are known in the area and an alternative correlation may be possible. The sub-angular form of some pebbles (Blissett, 1962) and marked disconformity with underlying rocks (Banks and Ahmad, 1962) may indicate a local provenance. Intra-stratal brecciation and faulting, bioturbated horizons, slumping and other soft sediment deformation have been reported (Banks and Ahmad, 1962; Baillie and Corbett, 1985).

NORTHERN TASMANIA

In the Tamar Estuary, the Clog Tom Sandstone near its type section at West Arm consists of thin- to medium-bedded (<600 mm), fine- to medium-grained micaceous quartz sandstone with shaly partings of micaceous and carbonaceous siltstone, some planar cross-bedding, mud pellets and fossil plants (Green, 1959; Gee and Legge, 1974). Rocks correlated with the Clog Tom Sandstone extend west to Parkham and Frankford, near where coaly matter occurs, and south towards Launceston (Gulline, 1981). Conglomerate at the base of the sequence has been correlated with the Blackwood Conglomerate (Lower Parmeener Supergroup). East of the Tamar, carbonaceous mudstone similar to cannel coal was tentatively regarded as the formation base at Tippogoree Hills (Gee and Legge, 1974). Further coal occurrences east of George Town were assigned to this formation (Bacon, 1986). Near Lilydale, the basal 7 m of the Upper Parmeener Supergroup may equate with the Clog Tom Sandstone (Longman, 1966).

Correlatives of the Jackey Shale have been reported from discontinuous areas along the Great Western Tiers from Parson and Clerk Mountain to Western Bluff (McKellar, 1957; Jennings, 1963; Pike, 1973; Matthews, 1974). In some intermediate areas, Westmoreland Falls creek (Jennings, 1963) and near Quamby Bluff (Wells, 1957), the formation is absent or includes anomalously coarse basal granule rocks. Near its type section in Jackey Creek, the Jackey Shale contains subordinate sandstone and abundant plant remains (McKellar, 1957). Pike (1973) described the Jackey Creek section as commonly comprising cross-bedded quartz sandstone, 'grit' and

carbonaceous feldspathic sandstone with some mud pellets, interbedded with thinly laminated dark grey shale. The sandstone is well sorted and micaceous. Coal occurs near the top of a grey-lutite-dominated interval (26 m) with thin sandstone beds that forms the base of the sequence near Western Bluff (Jennings, 1963).

Thickness variation

Because of stratigraphic uncertainty, thickness variation in the sequence is difficult to determine. The coal measure thickness in the Pelion area (92–108 m; MacLeod *et al.* 1961) is the thickest known (fig. 5a). Southward, although the coal seam bearing interval is progressively cut out by the Gould Conglomerate (MacLeod *et al.* 1961) or by correlatives of the Gould Conglomerate and Ossa Formation (Gulline, 1965), thinning of the sandstone envelope enclosing the coal measures may not be as marked. Certainly at places within the St Clair Quadrangle the mapped correlative of the Gould Formation (Gulline *et al.*, 1963) is not the correct horizon to mark the top of the coal measure sequence and similarly the sandstone envelope enclosing the coal measures extends into the Ossa Formation correlative (see above).

Easterly thinning of the sequence occurs across the southern Midlands. This is evident from fully cored borehole intersections listed in Table 3. Fluctuation from the region trend is caused largely by different degrees of erosion and infill into the Lower Parmeener Supergroup.

The sequence may be absent from Maria Island (Clarke and Baillie, 1984) and from east of Richmond (Gulline, 1984). North of the southern Midlands, the sequence is also thinner and may be absent in places. The thickest development in southern Tasmania is 78 m at Adventure Bay. In the Kingborough area a thickness of 30–40 m is typical, but may range 0? 20–60 m (Farmer, 1985).

Provenance

Banks and Naqvi (1967) noted the abundance of feldspar contrasted with some older and younger rock units. Granitic terrain may have been the main source area, but metamorphics including high grade (eclogitic) rocks contributed to the detritus. Some rocks may be tuffaceous (Davidson, 1969). The Henty River sequence appears to be of different provenance.

Depositional environment

The depositional environment has generally been regarded as a freshwater, sandy, coastal plain. Sequences at Mount La Perouse and at Adventure Bay were considered to be deltaic (Davidson, 1969; Rigg, 1970) and those in the southern Midlands fluvial, deposited on an easterly dipping palaeoslope (Forsyth, 1984). Excluding some southerly to westerly basal palaeocurrents attributed to local effects (Forsyth, 1984), palaeocurrents elsewhere (fig. 5a) also suggest an easterly to south-easterly palaeoslope, except in far western Tasmania.

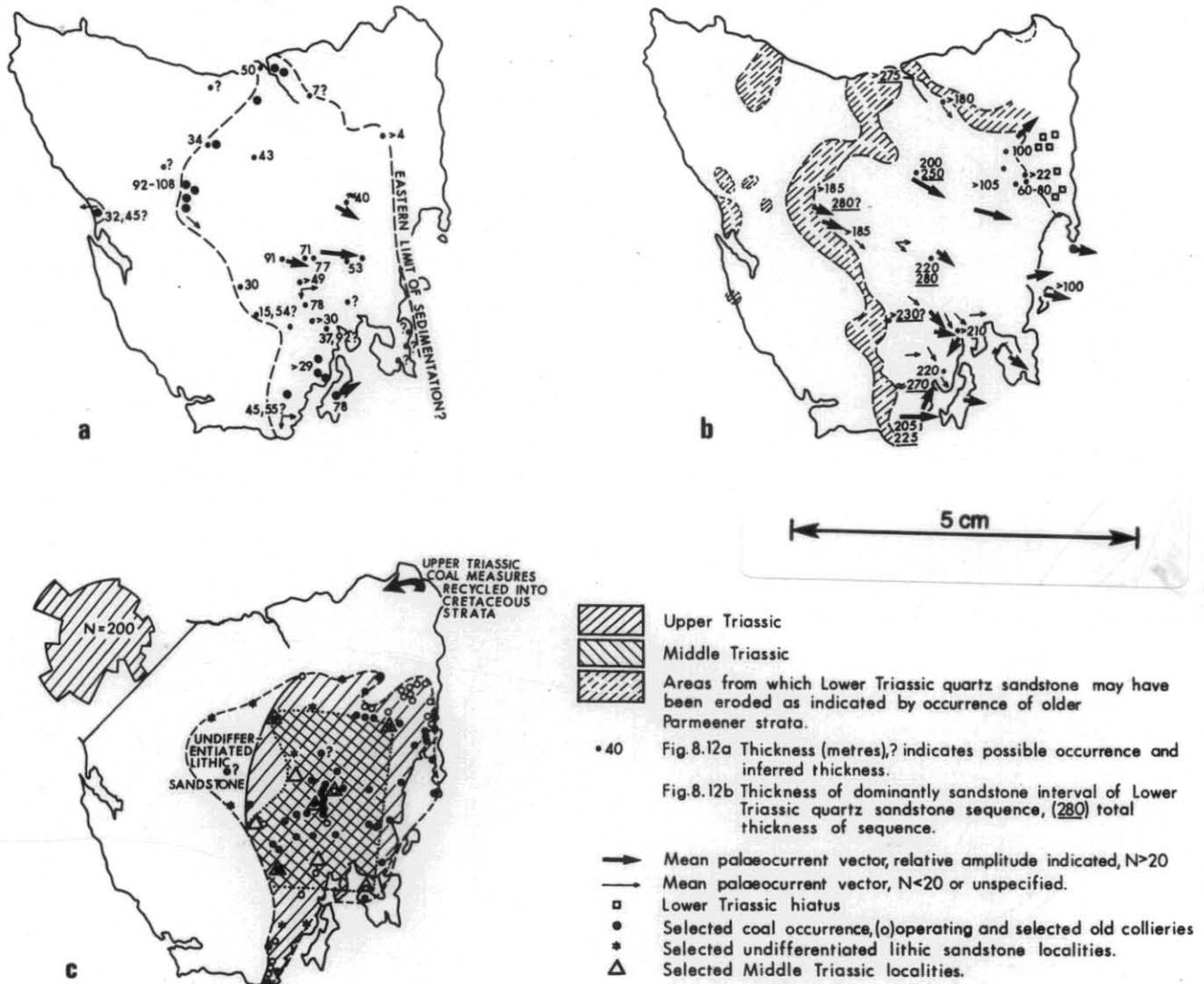


Figure 5. Distribution, limits, palaeocurrents, thicknesses and coal occurrences of the Upper Parmeener Supergroup: **a** – upper Permian coal measures and associated non-coal-bearing facies; **b** – lower Triassic quartz sandstone sequences, and **c** – lithic sandstone sequences. [From *Spec. Publ. geol. Soc. Aust.* 15 (1989)].

After Anandalwar (1960), Anon. (1979a–b, 1983), Bacon (1985a–b, 1986), Banks and Ahmad (1962), Banks and Naqvi (1967), Banks, Cosgriff and Kemp (1978), Blissett (1959), Bornman (1981), Bravo (1968), Camp and Banks (1978), Clarke and Baillie (1984), Corbett (1964), Cromer *et al.* (1976), Davidson (1969), Eggert (1983), Fairbridge (1949), Farmer (1985), Forsyth (1984, 1988), Gatehouse (1967), Gee and Burns in Collins *et al.* (1981), Gee and Legge (1974), Green (1959), Gulline (1965, 1981), Hale (1953), Hills *et al.* (1922), Hughes (1955), Jago (1972), Jennings (1963), Johnston (1885), Longman (1966), Mather (1955), McClenaghan *et al.* (1982), McLeod *et al.* (1961), McKellar (1957), Morrison (1981), Pike (1973), Prider (1948), Read (1960), Rigg (1970), Sharples (1984), Summons (1984), Sutherland (1964) and Williams (1984).

The depositional environment appears to have been an extremely restricted marine or lacustrine muddy lowland across which the deposits of sand-laden rivers rapidly prograded. The rivers carried a pebble bed load and shallowly eroded the underlying deposits. The higher-energy channels carrying pebbles do not appear to have entered northern Tasmania. In south-eastern Tasmania, their influence is rarely apparent above the basal 20 m of the sequence. Subsequent channel deposits consist of cross-bedded sandstone that tends to fine upward. In the Midlands, they were probably deposited by low-sinuosity rivers several hundred metres broad and at least 10 m deep (Forsyth, 1984). Williams (1984) considered the South Saskatchewan braided stream model

best explained the distribution and composition of the coal measures.

Peat-forming conditions may have existed from the cessation of marine influence (Gee and Legge, 1974), but the main coal basins appear to have formed coevally with, or, in some cases later, than the channel deposits elsewhere. The coal seams usually occur in intervals dominated by carbonaceous siltstone with interbedded sandstone. Such sequences usually contain layers with root systems (*Vertebraria*) but extensive bioturbation has rarely been reported (Banks and Ahmad, 1962; Rigg, 1970). In the Midlands, bioturbation in dark lutite occurs as sparse burrows. Rigg (1970) considered that the coal facies was deposited in inter-distributary bays of a delta

complex. No definite marine deposits are known and the low sulphur content of the coals (Hills *et al.*, 1922) favours a lacustrine or flood-basin environment.

The proportion of overbank deposits in the fining upward fluvial cycles in the southern Midlands increases near the top of the sequence and pale green-grey siltstone becomes prominent. Purple mottling, red-purple mud pellets, possible bioturbation and desiccation suggest a more exposed flood plain environment or changing climatic conditions at the closing stage of deposition.

Palaeontology and age

In western Tasmania, the flora includes *Glossopteris*, *Gangamopteris*, *Vertebraria*, *Phyllothea* and *Schizoneura*. One or more of the first three typical Permian genera occur at Mount Cygnet, Adventure Bay (with *Glossopteris indica*), Southport, Mount La Perouse, Pelion Range, Bothwell, Poatina (small-leafed glossopterids) and possibly at Tippogoree Hills (Johnston, 1889; Lewis, 1940; MacLeod *et al.* 1961; Banks and Naqvi, 1967; Davidson, 1969; Rigg, 1970; Forsyth, 1984). Kemp *et al.* (1977) in reference to their modification of the zonal scheme of Evans (1967, 1969) have regarded the microflora as being probably equivalent to the upper part of Stage 5. The rarity/absence of key species does not facilitate precise application of the zonal scheme of Price (1983). *Didacritiletes ericianus*, which appears at the base of lower Stage 5b, occurs below the sequence in Midlands (Forsyth, 1984) and in the sequences at Mount Cygnet, Mount Pelion and Mole Creek and a comparable form occurs in coal at Western Bluff (Balme *in* Jennings, 1963; Banks and Naqvi, 1967). Moreover, spores probably referable to *Dulhuntyispora dulhuntyi*, the lower Stage 5c index, occur near the Henty River (B.E. Balme pers. comm.) and *D. parvithola*, the upper Stage 5 index, is present at Byatts Razorback in north-eastern Tasmania. Better biostratigraphic control seems to be provided by Upper Lymingtonian fauna below the sequence throughout south-eastern Tasmania (Clarke, 1989).

Microfloras about 40 m above the base of the sequence at Adventure Bay and at Mount La Perouse were assigned to Evans' (1966) palynological unit TR1a (Davidson, 1969) and the presence of forms like *Brevitriteles hennellyi* occurring with numerous older Permian species suggests equivalence to the *Protohaploxylinus microcorpus* Zone (Helby 1973; Foster 1979). The microflora at the top of the sequence in the lower Midlands is of younger aspect containing *Lundbladispota springsurensis* and displaying a marked decrease in the diversity and abundance of species extending upward from Stage 5 and older microfloras. Forsyth (1984) assigned it to the upper *P. microcorpus* Zone indicative of a latest Chhidruan to early Griesbachian age (Foster 1979).

UNIT 2: Quartz sandstone sequence and associated rock types (Griesbachian-pre-Anisian?)

Introduction

The quartz sandstone sequence consists predominantly of well-sorted, commonly cross-bedded and glistening, quartz sandstone, and feldspathic quartz sandstone and subordinate coloured lutite. The sequence rests on Permian coal measures or their lateral equivalents. Where the coal measures are absent as in parts of eastern Tasmania, the quartz sandstone sequence rests on the Lower Parmeener Supergroup. The top of the quartz sandstone sequence is drawn at the base of a lithic sandstone and siltstone sequence which locally contains a thin, discontinuous, but distinctive basal quartzose

interval; or at a marked hiatus in less complete successions.

The distribution and thickness of the quartz sandstone sequence is indicated in Figure 5b. The sequence probably underlies much of the Central Plateau and extends from the periphery of this area to reach the southern and eastern coasts between South Cape and Schouten Island. Outcrops also occur in the relatively downfaulted area east of the Central Plateau from where they extend to the north coast in a zone bordering the Tamar Estuary. The thickness of the quartz sandstone sequences ranges 200-300 m over much of Tasmania, except in the north east where the sequence is much thinner. Near Avoca the thickness is <100 m (Blissett, 1959) and further east the thickness continues to decrease and the sequence is absent near St Marys and Cranbrook. Remote outliers probably occur in far north-eastern Tasmania at Tomahawk Island and near Cape Portland (Baillie *et al.*, 1979; Baillie *in* McClenaghan *et al.*, 1982).

Stratigraphy

A tendency for an upward increase of the proportion of lutite in the sequence and also commonly an upward increase in the proportion of mica and feldspar has been noticed in some areas for instance by Rodgers (1957), Gulline (1965) and Jago (1972). In some areas these trends have enabled a subdivision of the sequence into a lower, predominantly sandstone interval, and an upper, interbedded sandstone and lutite interval (Jennings, 1955; Anandalwar, 1960; Sutherland, 1964). As indicated by Anandalwar (*op cit.*) and Leaman (1976) such subdivisions are applicable only locally. Regionally, the sequence may be divisible into a lower dominantly sandstone interval with various proportions of lenticular lutite and a much thinner top interval predominantly of lutite in most areas. Only at Poatina, can this subdivision adequately be related to formally named rock units:- The Ross Formation (200 m) of McKellar (1957) is typical of the lower sandstone interval and the basal part (approx. 40 m) of the overlying Cluan Formation (McKellar, *op cit.*) is typical of the upper lutite rich interval. In the Midlands, the informal quartz sandstone sequence (Rp) and muddy floodplain facies (Rm) respectively correspond to the lower and upper intervals (Forsyth, 1984). In southern Tasmania, the upper member (Mountain Lodge Member 37.5 m), or the lower (unnamed member 55 m), of the Springs Sandstone (Banks and Naqvi, 1967) forms the basal part of the lower interval. The Knocklofty Sandstone and Siltstone (about 185 m; Camp and Banks, 1978; Johnson and Morton, 1890) forms part of the quartz sandstone sequence but the relationships of this formation with older and younger rock units are not known with precision. The formation has been assumed to overlie the Mountain Lodge Member (Banks and Naqvi, 1967) and underlies a lutite-dominated sequence. A significant lutite-rich unit (Poets Road Member; 35 m) occurs near the middle of the Knocklofty Formation (Camp and Banks, 1978), below about 120 m of sandstone. Mappers in some areas of southern Tasmania have equated the Knocklofty Formation with the Springs Sandstone and the Ross Formation. However there has been a tendency to correlate whole sequences, or parts of sequences, containing significant lutite, with the Knocklofty Formation. In western-central Tasmania, the quartz sandstone sequence is probably represented by the Ossa Formation and possibly part of the Gould Conglomerate (MacLeod, *et al.*, 1961).

Since 1963, formal stratigraphic names have not been applied to the sequence on quadrangle maps of the Geological Survey Atlas Series. The sequence is considered to be approximately equivalent to the single 'Triassic' sandstone rock unit mapped in the following

quadrangles - Beaconsfield, Boobyalla, Frankford, Launceston, Maria, Quamby and Pipers River. In the Hobart and Brighton Quadrangles the sequence corresponds approximately to units Rls, Rlq, Rlf and in part Rlm, in the Interlaken Quadrangle to unit Rp, in the Kingborough Quadrangle to unit Rs, in the Lake River Quadrangle to unit Rs and in part? Rm, in the Oatlands Quadrangle to unit Rp and Rm and in Sorell Quadrangle to unit Rss and Rsm (see also fig. 1, 3).

Some sequences that have been regarded as correlatives of the Knocklofty Formation, Ross Sandstone, Ossa Formation or similar units, contain basal beds that now would be referred to the Upper Permian coal measures or their laterally equivalent non-coal-bearing facies. The thickness (200-300 m) of the quartz sandstone sequence is such that its perceived 'continuous' distribution is little affected where allowance is made for these incorrect correlations. In contrast, the underlying Upper Permian coal measures and equivalent strata are more widespread than once believed. However, the concept of a period of erosion prior to deposition of the quartz sandstone sequence (Banks *in* Spry and Banks, 1962) remains an appealing interpretation.

The sequence tends to fine upwards from medium- and coarse-grained sandstone to fine- to very fine-grained sandstone. Basal beds in the Midlands and at Poatina may be more feldspathic (up to 15% feldspar) than overlying beds (Eggert, 1983; Forsyth, 1984). Generally, granules or small quartzose pebbles in places forming thin conglomerate lenses or dispersed in sandstone, are common only in the basal few metres of the sequence and rare at higher horizons (Jennings, 1963; Banks and Naqvi, 1967; Forsyth, 1984, 1989). At the Florentine River outlet milky quartz granules are dispersed in sandstone that probably occurs low in the sequence (Jennings, 1959). Milky quartz granules and rare pink quartz are present low in the sequence near Table Mountain and Ellinthorpe Plains (Forsyth, 1989). The occurrence of granules at higher horizons is generally at the base of major cycles or as thin beds (crevasse splay?) in lutite-rich intervals. The distribution of the coarser horizons is imprecisely known where the top and bottom of the sequence are inadequately established (Prider, 1948; Wells, 1957; Anandalwar, 1960; Gulline, 1965). Pebbly beds are probably more common upstream, being recorded at horizons throughout the Ossa Formation at Mt Olympus (Gulline, 1965). Cross-bedded sandstone, arkose and quartz pebble conglomerate (Gould Conglomerate; 92 m) have been considered to form the base of the sequence (MacLeod, 1961) but the age of this formation is unknown and correlatives further south (Gulline, 1965) mostly underlie the quartz sandstone sequence.

LOWER, SANDSTONE-DOMINATED INTERVAL

Thick intervals (60-80 m) consist only of sandstone (Jennings 1955; McKellar, 1957; Bormman and Murphy, 1980; Sharples, 1984). Near Bothwell an interval (135 m) consists of sandstone (98%) and lutite in beds <200 mm thick. Such intervals are composed of cycles or eroded cycles that grade up from medium- to coarse-grained sandstone to finer, rarely muddy rocks. Mud-pellet conglomerate and less commonly quartz granules may occur especially in the bases of cycles and mud pellets may be dispersed in higher beds. Typically, the basal beds of a cycle overlie an erosive break and may be massive, tabular-cross-bedded or in places contain cosets of festoons. They may also form almost planar-laminated scour fills. Low-angle cross-bedding occurs both high and low in cycles and fine-scale planar lamination and ripple cross-lamination occurs high (Eggert, 1983; Forsyth, 1984). Current-drag overturned cross-bedding is very common. Most sandstone beds are <600 mm, rarely >1 m

thick. Planar cross-bedded bars of height ~1.5 m are not common. Rare examples of deep (20 m) channelling (Davidson 1969) and some mud-drapes on dunes occur.

Locally, palaeocurrent directions show little dispersal and deposition from low-sinuosity rivers is indicated (Eggert, 1983; Forsyth, 1984). The average direction is usually to the south-east or east (fig. 5b). In a few places palaeocurrents to the north-east are indicated and less commonly a broad spectrum of palaeocurrent directions extending from north-west to south-west is found.

Lutite occurs as isolated lenticular beds of mainly grey-green uniform claystone and siltstone, or in thicker intervals of more variable character with interbedded sandstone. In some sandstone intervals, mud pellets are the only lutite present. Mud pellets and associated bones and coprolites indicate mud deposits of various types were frequently disturbed and redistributed (Banks *et al.*, 1978; Rigg, 1970; Forsyth, 1984).

The proportion and position of the lutite-bearing intervals preserved in the dominantly sandstone part of the sequence is probably random. Above the basal beds in the Hobart and Brighton Quadrangles, the proportion of shale changes laterally and upwards from 10% to 25% or at places up to 30% (Leaman, 1976, 1977). Near Bothwell, lutite is more prominent in the lower half (92 m) of the sequence and the thickest lutite interval (17 m) occurs in the lower third of the sequence whereas in the upper part, lutite beds <200 mm thick form 2% of the strata over an interval of 135 m (Donaldson and Forsyth *in* Sharples, 1984). The 17 m lutite interval consists of interbedded grey, green and reddish siltstone and minor cross-bedded and ripple-laminated sandstone. Bioturbation is poorly developed. The stratigraphic position of this interval (65 m above the sequence base) may be comparable to a prominent interval (7 m) of red siltstone overlain by pebbly beds about 90 m above the sequence base on North Bruny Island (Farmer, 1985) and also to the stratigraphic position of the red bed-bearing unit - Poets Road Member - at Hobart (see below).

MAIN LUTITE-RICH INTERVALS

In many areas, a transition to a lutite-dominated interval (20-60 m) occurs at or near the top of the quartz sandstone unit about 200 m above its base. The lutite is well developed in the southern Midlands. Similar rocks, which occur further north near Ross and at Poatina (basal 40 m of the Cluan Formation) and in the far south at Mount La Perouse, are palynocorrelates (Playford, 1965; Davidson 1969; Forsyth, 1984, 1989). Although the Poets Road Member is >100 m stratigraphically lower and contains an older microflora, it is similar in many ways to the top lutite-rich interval. The lutite includes red, purple, grey carbonaceous and various mottled lithologies. Pale blue-grey and green-grey rocks in the Midlands weather orange on exposure. Mudcracks, lycopsid and seedfern flora and bioturbation occur.

The Poets Road Member (35 m) includes a thick sandstone interval that exhibits tetrapod tracks, red siltstone with green mottles, interbedded red, purple and green siltstone and interbedded sandstone and siltstone bearing plant fragments. Thin beds of mud pellet conglomerate and cross-bedded sandstone occur in the siltstone. Worm tracks, mudcracks and vertebrate fossils have been found (Camp and Banks, 1978).

The top lutite-rich strata differ from the Poets Road Member in showing features that suggest less frequent channel migration. These features include more intensely bioturbated layers, e.g. of orthoquartzite and possible palaeosols (Forsyth, 1984) and at Mount La Perouse, red beds interpreted as redeposited laterite (Davidson, 1969). Microfloras also differ but macrofloras are similar. The intensely bioturbated silicified beds are well developed

and restricted to the top interval in the Midlands. If this is so regionally, correlation is indicated with similar rocks south of Hobart at Kaoota, in the far south at Mt Wyllie and possibly near Orford in the east. In the northern Midlands (Interlaken Quadrangle - Forsyth, 1989) the silicified bioturbated, fine-grained sandstone beds are widespread. They contain abundant characteristic microfossils of uncertain affinity and at places, abundant conchostracans. At Poatina intensely bioturbated and silicified rocks occur in separate beds.

Near Melton Mowbray in the southern Midlands, the top lutite rich interval is about 60 m thick and probably occurs about 220 m above the sequence base or perhaps 20-40 m lower (Forsyth, 1984; Donaldson and Forsyth *in* Sharples, 1984). The interval includes up to three multi storeyed, cross-bedded sandstone units. At places, highly indurated, oxidised, finely laminated mudstone and subordinate thin lenticular sandstone beds form a significant part of the interval. Also present are more variable units of interbedded sandstone and siltstone that include dark grey carbonaceous siltstone, green, mottled green/purple, purple and pale blue-grey siltstone, poorly sorted sandstone and thin beds of granule sandstone enclosed in lutite. It is in this type of unit that the thin to medium beds of proto-quartzite and intensely bioturbated and commonly silicified horizons occur. Fossil leaves, stems and cones occur abundantly on some horizons and mudcracks are present.

At Poatina, the top lutite dominated interval occupies the basal (40 m) part of the Cluan Formation and occurs 200 m above the sequence base. This interval was intersected by numerous H.E.C. boreholes logged by J. B. A. McKellar and E. A. Clothier. It is evident from the original bore logs and from the little extant core, that this part of the Cluan Formation contains siltstone of various hues, includes grey, blue-grey, purple-grey, grey-green, purple and mottled purple. In most boreholes the base of the Cluan Formation is marked by a persistent interval of grey and bluish grey siltstone (6 m). The siltstone is overlain by a lenticular (medium- to coarse-grained) sandstone body (9-12, 157 m). This sandstone unit was intersected in the last section of tunnel above the penstock. A complete photographic record of the tunnel walls and roof indicates the sandstone is strongly cross-bedded and was deposited by currents that flowed towards the south-east. This sandstone unit may change laterally into interbedded fine-grained sandstone and grey, blue or purple siltstone that is overlain by another lenticular fine to medium-grained sandstone unit (2-6 m). The succeeding interval (>14 m) consists of interbedded sandstone and siltstone.

The siltstone includes grey, blue and purple lithologies. This interval is commonly overlain by several metres of coarse- to very coarse-grained sandstone that contains rare quartz pebbles (20 mm) and a higher feldspar content than that of lower sandstone beds. The coarse-grained sandstone is tentatively taken as the base of the succeeding sequence. This horizon is difficult to recognise from some of the original bore logs as thin beds of coarse-grained sandstone occur slightly lower in some bores and because the degree of erosion at the boundary is unknown. Bioturbated beds and slightly silicified beds are exposed in road cutting in the top lutite dominated interval. In the road cuttings the top of the interval is recognised by the introduction of quartz-rich lithic sandstone.

The Cluan Formation extends along the Great Western Tier from Palmer River to Drys Bluff (McKellar, 1957) and may occur near Mother Cummings Peak (Burns *in* Jennings, 1963). Further west and also near Launceston, the reported thickness of the quartz sandstone sequence (185 m) (Jennings, 1963; Ford, 1960; Longman, 1966) seems insufficient to include any of the Cluan Formation.

Similarly at Quamby Bluff, an interval of shale (30 m) that overlies an interval of sandstone only 125 m thick, appears to be too low stratigraphically to be the Cluan Formation (Wells, 1957). The Cluan Formation crops out on Cluan Tier (McKellar, 1957; Pike, 1973). Equivalent strata may be present at West Arm, near the top of the sequence (275 m) of sandstone with abundant mica, 'grit' lenses with pink weathering grey shales with interbedded fine-grained, micaceous sandstone and upper beds of featureless mudstone. (Green, 1959; Gee and Legge, 1974). Similar mudstone occurs also at Tippogoree Hills (Gee and Legge, 1974).

Elsewhere, probable lithocorrelates are recognised by their stratigraphic position, whereas lutite-rich intervals with a *Dicroidium zuberi* Oppel-zone macroflora (Retallack, 1977) are possible correlates. Probable correlates occur between Midlands and Mount La Perouse at Constitution Hill, Austins Ferry, Kaoota, Dalys Hill and nearby, and west of Hobart near Mount Lloyd and Hamilton. Possible correlates occur in the Derwent Valley possibly as far west as Lake St Clair, scattered east of Hobart to Dunalley and on Tasman Peninsula, and in the north near the Tamar Estuary.

In southern Tasmania near Kaoota, an interval of strata (~50 m) is probably the top lutite dominated interval. The interval consists of interbedded sandstone, siltstone and mudstone and contains thin silicified, bioturbated beds (Farmer, 1985). Further south, the interval overlies quartz sandstone that it at least 160 m and probably 220 m thick (Farmer, 1985). Bioturbated rocks occur elsewhere in the Kingborough area, commonly associated with prominent chocolate-coloured, weathered siltstone or red or red-purple siltstone.

At Mt La Perouse only a thin part (20 m) of the top lutite dominated interval has survived erosion and occurs about 215 m above the base of the La Perouse Formation and approximately 205 m above the interpreted base of the quartz sandstone sequence. Further west at Mt Wyllie, thin beds of silicified bioturbated sandstone associated with chocolate coloured siltstone are probably equivalent to the top lutite-dominated interval at Mt La Perouse.

In the Hobart-Brighton area the top lutite-dominated interval may be included in assemblage 5 of Leaman (1976, 1977), (see also section on macroflora Palaeontology and Age p. 22). The stratigraphic position of probable correlative strata is well established at Austins Ferry and in road cuttings at Constitution Hill. Strata possibly part of the interval have been described from south of Jews Hill (McDougall, 1959) and from Duck Hole Creek near Richmond (Gatehouse, 1967). Other possible occurrences occur further east, north of Sorrell and south of Copping (Gulline, 1982) and on Tasman Peninsula. The interval is absent from Schouten Island.

West of Hobart the interval is probably present in the Mt Lloyd area and in the Derwent Valley at Hamilton Hill. Further west near Wayatinah, an incomplete Upper Parmeener succession has been established on bore hole information (Jennings, 1955). The succession has no base, but at least 95 m of the dominantly quartz sandstone interval underlies a thick interval of interbedded sandstone, shale, claystone and mudstone correlated by Jennings (*op cit.*) with the Knocklofty Formation. This interval probably includes correlative strata of the top lutite dominated interval. Jennings (*op cit.*) considered that the Knocklofty Formation correlative was 154 m thick or thicker because of the uncertainty of correlating between boreholes separated by a fault. Conversely the correlative of the Knocklofty Formation may be thinner (85-92 m) and include strata above the quartz sandstone sequence. At Father of Marshes, rocks intersected in a borehole were correlated with the top lutite dominated interval (Anon, 1983).

Near the western limit of the quartz sandstone sequence, the sequence (Ossa Formation, 185 m, Macleod *et al.*, 1961) is probably too thin to include the top lutite dominated interval. Near Lake St Clair, strata correlated with the Ossa Formation are thicker (280 m at Mount Olympus) and do include equal proportions of shale and siltstone near the top (Gulline, 1965). Pink shale is present 215 m above the base at Mt Rufus (Gulline, *op cit.*)

Sandstone composition

LOWER SANDSTONE-DOMINATED INTERVAL AND UNSPECIFIED HORIZONS

In fresh drill core the sandstone is usually white to grey occasionally cream in colour, but weathering may persist for a depth of over 100 m (McKellar, 1957; Jennings, 1955; Hale, 1962; Sharples, 1984). Sandstone in weathered outcrops is typically porous with a small amount of ferruginous or clayey matrix or grain coatings imparting a creamy yellow to brown or red colour. With more intense weathering, particularly of coarser grained sandstone, the rock exhibits a white surface appearance.

Eggert (1983) described exposed sandstone rocks sampled from random stratigraphic horizons mostly within the quartz sandstone sequence with the following grain compositions:

- quartz 45 - (84±10) - 100%
- feldspar 0 - (11±8) - 47%
- lithics 0 - (5±3) - 18% (see also fig. 6)

- a low plagioclase to total feldspar ratio 0.34;
- a low volcanic proportion of lithics 0.31;
- a low polycrystalline quartz to total quartz ratio 0.06.

Locally, Cainozoic weathering has selectively destroyed the labile grains, generally resulting in more quartzose rocks. This is commonly the case where the sandstone is well sorted and exhibits numerous horizons with clearly defined cross-bedding forming cosets. Non-sparkling rocks with much matrix or deformed labile grains occur occasionally, and tend to be found in intervals with solitary cross-bedded layers and planar beds. Mica and graphite may be locally abundant especially on bedding planes or in finer-grained sandstone layers deposited in lower-energy environments. Rarely thick beds consist mainly of mica (Jennings, 1955). In bore core from near the top of the sequence, feldspar and especially lithic grains are more common and quartz falls below 70%. This may reflect stratigraphic position as much as reduced weathering. Strained and clear, unstrained quartz grains occur, some with vacuoles or inclusions of zircon, biotite, muscovite, apatite, green tourmaline, rutile and chlorite (Banks and Naqvi, 1967; Eggert, 1983). Lithic grains are mostly siliceous metasedimentary with only minor other metamorphic grains. In some beds, locally derived sedimentary rock fragments are common. Clay minerals include kaolinite, illite and mixed layer illite/smectite with chlorite near lutite rich associations (Sharples, 1984). Gypsum and halite are present, their distribution appearing to be controlled by groundwater movement (Sharples, 1984). Heavy minerals include magnetite, green and blue tourmaline, rutile, zircon, ilmenite, melanite, garnet, zoisite, clinozoisite and chromite (Banks and Naqvi, 1967; Davidson, 1969; Eggert, 1983). Cassiterite-bearing Upper Parmeener rocks may belong to the quartz sandstone sequence (W. L. Mathews pers. comm.)

UPPER LUTITE-RICH INTERVAL

Sandstone in the top lutite-rich interval varies from slightly feldspathic quartz sandstone to less quartzose micaceous rocks rich in ferruginous matrix. The less

quartzose rocks at Poatina and Melton Mowbray contain 65-80% monocrystalline quartz and at Poatina feldspar ranges up to 19% and lithic grains up to 26% (Eggert, 1983; Forsyth, 1984). In the Midlands these rocks contain matrix or degraded labile grain (15-30%), dispersed muscovite (≤5%) and in some rocks microcrystalline quartz (5-10%) and recognisable feldspar (<5%) (Forsyth, 1984). Possible correlates of similar composition and stratigraphic position (230 m above the base of the quartz sandstone sequence at the top of a 'feldspathic sandstone sequence') at Maydena Range contain quartz (60%), 10% plagioclase, mostly albite, Mica (≤10%) and hydrous iron oxides in a clayey matrix (Jago, 1972).

Lutite

The lutite is generally micaceous, fissile to massive and silty, although a thick interval of indurated dark and mottled purple mudstone has been reported (Jennings, 1955). Especially in the thinner lutite-rich intervals the lutite is predominantly grey-green in colour, but light to dark grey carbonaceous beds, green, light green-blue-grey beds and less commonly red and purple beds occur. Upon weathering the lutite may exhibit yellow, orange, brown and chocolate coloured hues. Near Bothwell, only the thicker (10 m) lutite intervals contain redbeds and occur with green siltstone and chloritic sandstone (Sharples, 1984). Purple and purple-mottled green and grey beds also tend to be found only in thick lutite intervals. Haematite occurs in some redbeds (Camp and Banks, 1978) along with limonite, chlorite, quartz and muscovite and minor chamosite, illite and apatite (Davidson, 1969). Concretions of siderite and phosphate nodules have been reported from siltstone; and green nodules, interpreted as filled amphibian burrows, contain chamosite and glauconite (Banks *et al.*, 1978; Camp and Banks, 1978; Davidson, 1969).

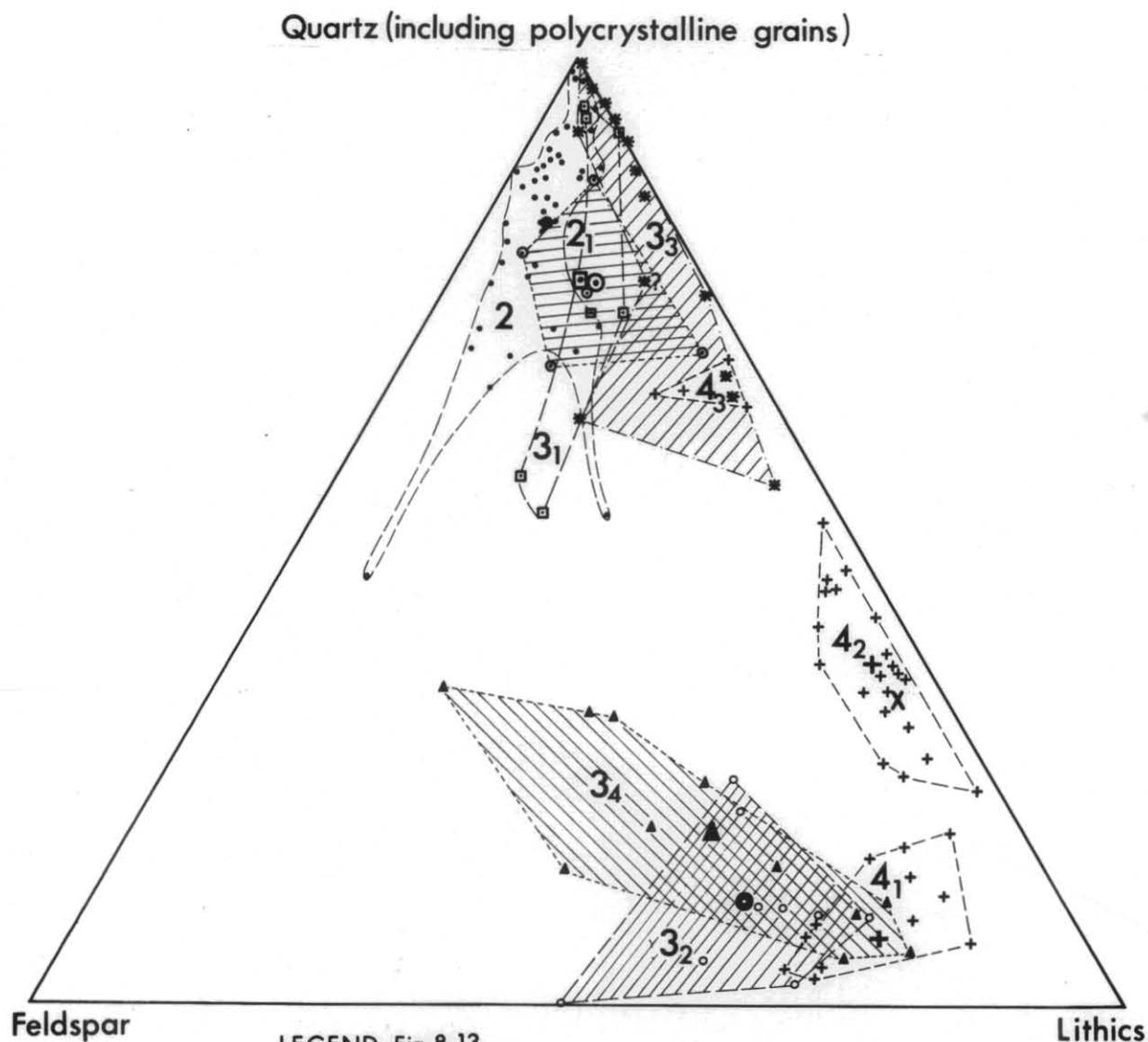
Provenance

Eggert (1983) suggested a provenance from a cratonic block and/or recycled orogen *sensu* Dickinson and Suczek (1979) situated in western Tasmania or beyond in Antarctica or south-eastern Australia. The source included granite pegmatite and probably some sedimentary and volcanic rocks. Clay mineralogy indicates a basic volcanic tuff component may have been present (Sharples *et al.*, 1984).

Depositional environment

The quartz sandstone sequence was deposited primarily by low sinuosity rivers flowing on average towards the east or south-east (fig. 5b), perhaps with a slight swing towards more northerly flow during the closing phase of sedimentation. The lutite was probably deposited in abandoned channel, slack-water, lacustrine and overbank environments. Frequent reworking of the sandy plain destroyed most overbank or slack-water deposits. The apparently random variation of the position and proportion of lutite in the sandstone dominated interval of the sequence is probably related to the normal processes of channel migration. Some lutite-rich intervals may be related to fluctuations of climate and/or regional changes of river competency. Certainly in some areas channel migration was infrequent enough for thick overbank deposits to develop. Such deposits became more extensive during later deposition probably as river size decreased. The floodplain became more vegetated and bioturbated, and silicified horizons and precipitates of siderite and phosphate were formed. Palaeosols and laterite horizons probably developed.

Rocks of the upper lutite-dominated intervals and the Poets Road Member have been interpreted as the deposits of subaerial overbank environments that locally

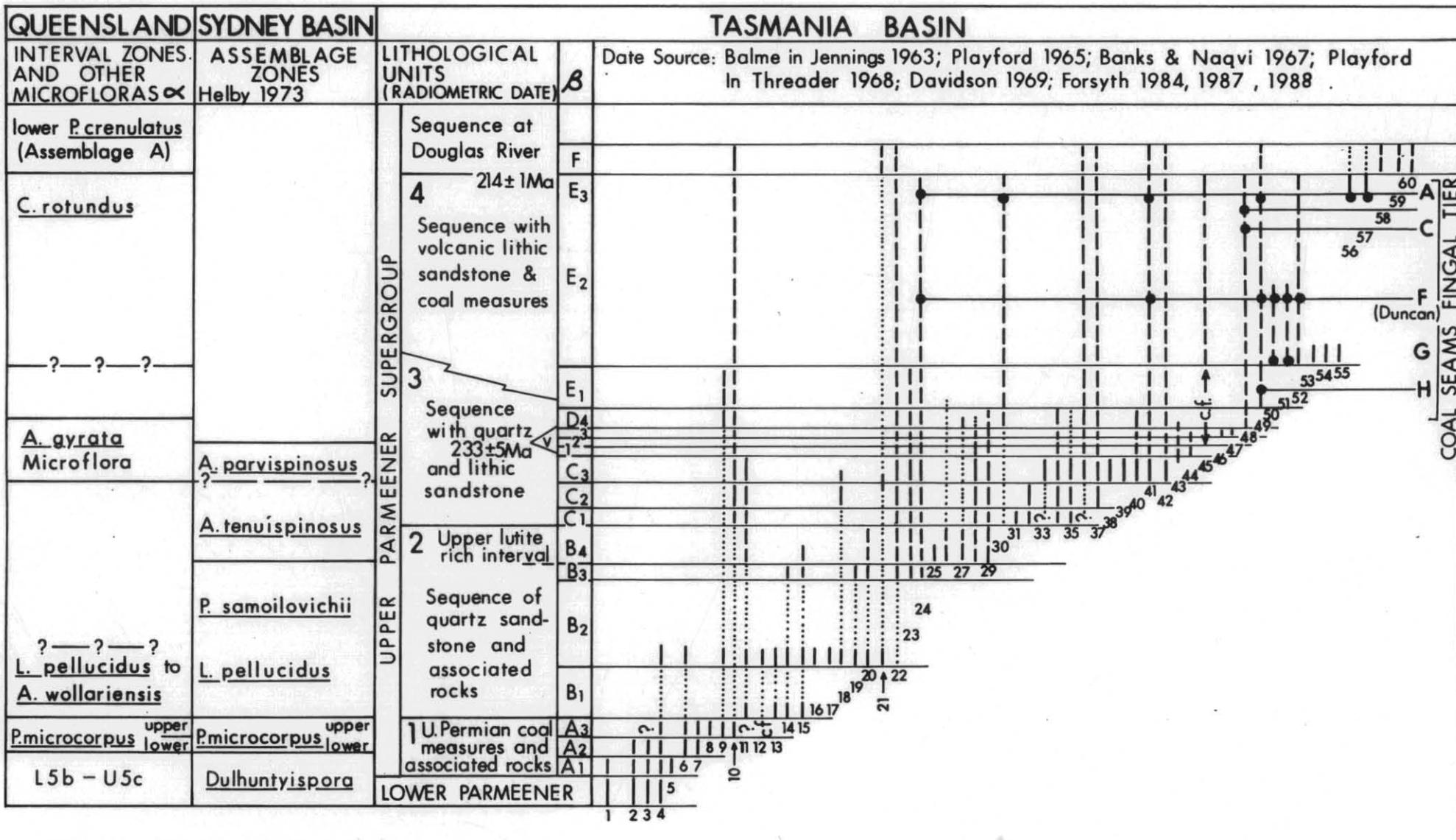


LEGEND Fig. 8.13

+	VOLCANIC LITHIC SANDSTONE SEQUENCE + Volcanic lithic sandstone (field 4 ₁) and quartz rich lithic sandstone (field 4 ₃) + average of field 4 ₁ , average of field 4 ₂ X average of fields 4 ₂ & 4 ₃ but with chert included with lithics.
▲	SEQUENCE WITH QUARTZ & LITHIC SANDSTONE * Younger interval with quartz sandstone (field 3 ₃) ▲ Age equivalents of younger interval with quartz sandstone (field 3 ₃) ▲ average of field 3 ₄
○	○ Lithic sandstone (field 3 ₂) ● average of field 3 ₂ □ Basal interval with quartz sandstone (field 3 ₃) □ average of field 3 ₁
○	SEQUENCE WITH QUARTZ SANDSTONE ○ Sandstone of upper lutite rich interval (field 2 ₁) ● average of field 2 ₁
•	• Sandstone (field 2) ● average of field 2.

Figure 6. Compositional variation within Upper Parmeener Supergroup sandstones. Fields 1–4₁ after Eggert (1983); fields 4₂–4₃ after Bacon (1979). [From *Spec. Publ. geol. Soc. Aust.* 15. (1989)]

5 cm



5 cm

22/1/83

Figure 7. Composite spore/pollen range chart for the Upper Parmeener Supergroup and relationships with palynological zones in eastern Australia. Queensland zones based on de Jersey (1975, 1976, 1979), Foster (1979), Playford et al. (1982) and Price (1983). β - microfloras indicated in Figure 8. [From Spec. Publ. geol. Soc. Aust. 15](1989).

1. *Phaselisporites cicatricosus*, *Striatopodocarpites fusus*, *Bacanisporites multistriatus*, *Granulatisporites trisinus*, *Marsupollenites triradiatus*. 2. *Protophloxypinus amplus*, *P. limpidus*, *Granulatisporites micronodus*. 3. *Acanthotriletes tereteangulatus*, *Hornidtriletes ramosus*. 4. *Scheuringipollenites ovatus*. 5. *Dulhuntyispora dulhuntyi*? *D. parvithola*. 6. *Brevitriletes hennellyi*. 7. *Protophloxypinus microcorpus*. 9. *Weylandites lucifer*, *Lundbladispota springsurensis*, *Thymospora ipsvicensis*. 10. *Cycadopsis* spp. 11. *Limatulasporites fossulatus*. 12. *Lundbladispota willmotii*. 13. *Kraeuselisporites saeptatus*. 14. *Lundbladispota brevicula*. 15. *Densiosporites playfordii*. 16. *Polycingulatisporites dejerseyi*. 17. *Lunatisporites novialensis*. 18. *Lunatisporites pellucidus*. 19. *Kraeuselisporites cuspidus*. 20. *Protophloxypinus samoilovichii*. 21. *Rewanispora foveolata*. 22. *Aratrisporites* spp. 23. *Aratrisporites stigosus*. 24. *Aratrisporites banksii*. 25. *Aratrisporites rugulatus*. 26. *Aratrisporites wollariensis*. 27. *Aratrisporites tenuispinosus*. 29. *Triploxisporites playfordii*. 30. *Semiretisporis denmeadii*. 31. *Aratrisporites plicatus*. 32. *Aratrisporites* sp. A. 33. *Rugulatisporites stonecrofti*. 34. *Lophotriletes bauhinae*. 35. *Protophloxypinus* sp. cf. *jacobae*. 36. *Clavitriletes conspicuus*. 37. *Hornidtriletes* spp. 38. *Equisetosporites* sp. 39. *Cadargasporites senectus*. 40. *Aratrisporites paenulatus*. 41. *Uvaesporites verrucosus*. 42. *Asseretospora gyrata*. 43. *Rugulatisporites trisinus*. 44. *Kraeuselisporites verrucifer*. 45. *Foveosporites moretonensis*. 46. aff. *K. verrucifer*-*S. denmeadii*. 47. *Apiculatisporites clematisi*. 48. *Aratrisporites parvispinosus*. 49. *Annulispora folliculosai*. 50. *Circulisporites parvus*. 51. *Rogalskisporites cicatricosus*. 52. *Annulispora microannulata*. 53. *Acanthotriletes bradiensis*. 54. *Aratrisporites flexibilis*. 55. *Cyathidites* sp. 56. *Craterisporites rotundus*. 57. *Polycingulatisporites densatus*. 58. *Polycingulatisporites crenulatus*. 59. *Densiosporites raceviewensis*. 60. *Retitriletes rosewoodensis*.

accumulated pond, sheetflood and crevasse-splay sediments (Davidson, 1969; Camp and Banks, 1978; Forsyth, 1984). Thick sandstone units enclosed in the lutite, for instance in the Poets Road Member and at Poatina and Melton Mowbray, are interpreted as channel deposits. Near Melton Mowbray, thick units of oxidised laminated lutite with minor sandstone were interpreted to be lacustrine deposits whereas thin organic rich deposits were probably deposited in small ponds of restricted circulation (Forsyth, 1984). Beds in the Poets Road Member were considered to be oxidised after deposition (Camp and Banks, 1978).

Initially conditions may have been too severe for large plants to grow or to be preserved, but amphibians, probable lycopodiacean marsh plants (Balme, 1970), pteridophytes and reed-like sphenopsids lived. Later, seed-ferns, lycopsids and rarer ferns were preserved, in places abundantly, in small ponds, but larger lakes appear to have been too oxidising to preserve plant fossils. Mud cracks, conchostracan fauna (Tasch, 1975) and at times saline conditions (Davidson, 1969) indicate that shallow ponds on the flood plain evaporated to dryness. Halite and epsomite are probably secondary minerals and no definite evaporite or aeolian sandstone is known. The varied life-forms including ferns, fish and reptiles indicate that extremes of temperature and aridity normally did not occur (Camp and Banks 1978; Banks et al., 1978). Laterite high in the sequence suggests a low seasonal rainfall and temperatures $\geq 20^{\circ}\text{C}$ (Davidson, 1969). Fluctuating, perhaps seasonal river flow is also indicated by sedimentological evidence.

Palaeontology and age

The fossils found in the sequence are almost entirely of freshwater character. They include macro- and microflora, freshwater fish, amphibians and a reptile, conchostracan and malacostracan arthropods, possible insects and various trace fossils including vertebrate footprints. Spinose acritarchs occur at one locality east of the southern Midlands.

Microfloras are broadly grouped into an older assemblage in which *Aratrisporites* is absent or rare and a younger assemblage usually with common to abundant *Aratrisporites*. The older assemblage has been found at approximately similar horizons near the middle of the lower sandstone-dominated part of the sequence (Playford, 1965 - Ross Formation; Davidson, 1969 - unit 20, La Perouse Formation; Forsyth, 1984 - quartz sandstone (Tp)). It includes *Densiosporites nejburgii*, *Marsupipollenites klausii*, *Grebespora concentrica* and the species indicated in Figure 7. Correlation of the older assemblage with the *Kraeuselisporites saeptatus* Assemblage Zone in the Perth Basin (Dolby and Balme, 1976), the combined *Lunatisporites pellucidus*-*Protophloxypinus samoilovichii* Assemblage Zones in the Sydney Basin (Helby 1973) and the informally defined *Lunatisporites pellucidus* - *Aratrisporites wollariensis* interval zone in the Bowen Basin (de Jersey, 1979) is indicated. On this basis it is assigned a Griesbachian to mid Smithian (possibly pre-mid Dienerian) age. Locally palynocorrelates occur on the east and south coast of Schouten Island and near Ross. The distribution of individual species through the sequence is poorly known, but *D. playfordii*, *K. saeptatus*, *Lundbladispota brevicula* and ?*Lunatisporites* sp. occur in a microflora dominated by *Limatulasporites fossulatus* near the base in DDH Baden in the southern Midlands. Davidson (1969) reported a similar microflora containing *Lundbladispota brevicula*, *Lundbladispota* sp., *Limatulasporites* and *Kraeuselisporites* sp. from near the base of the quartz sandstone sequence, i.e. about 47 m above the base of the La Perouse Formation. A meagre, older microflora with

Quadrisporites horridus and reworked *Protohaploxypinus limpidus* specimen was recorded from about 10 m above the base of the La Perouse Formation (Davidson *op. cit.*), however this horizon may be below the quartz sandstone sequence.

About 215 m above the base of the La Perouse Formation *K. cuspidus*, *Lundbladispora brevicula*, *Aratrisporites banksii* and *A. strigosus* occur above a data gap exceeding 100 m (Davidson, 1969). This microflora may represent a transition into the younger assemblage, as 6 m higher in the youngest bed, abundant *Falcisporites australis* is associated with *Osmundacidites* spp., *A. strigosus* and *A. tenuispinosus*; *K. cuspidus* and *L. brevicula* are absent. This microflora is typical of the younger assemblage that also occurs at similar stratigraphic horizons in the southern and northern Midlands (muddy fluvial plain facies Rm and Rp'; Forsyth, 1984, 1989) and at Poatina (basal Cluan Formation; Playford, 1965).

The Cluan Formation microflora was described by Playford (*op. cit.*) who believed the samples were derived from the Tiers Formation. The older 'Tiers Formation' assemblage described by Playford (*op. cit.*) is from the quartz sandstone sequence, and the younger 'Tiers Formation' assemblage is from shales at the boundary between the quartz sandstone sequence and the overlying sequence with quartz and lithic sandstone. The younger assemblage in the southern Midlands and at Poatina contain very common *Aratrisporites* spp. (including *A. tenuispinosus*). *Osmundacidites* spp., *Limatulusporites limatulus* and possibly *A. strigosus* occur in both areas. *Aratrisporites wollariensis*, *A. rugulatus* and *D. playfordii* occur in the Midlands and *A. banksii*, *A. sp. cf. A. granulatus*, *Protohaploxypinus samoilovichii*, *Triplexisporites playfordii* and very rare *Semiretisporis denmeadii* occur at Poatina. The microflora indicates correlation with part of the *Aratrisporites tenuispinosus* Assemblage Zone in the Sydney Basin (Helby 1973), part of the upper Rewan Formation - Clematis Sandstone interval in the Bowen Basin (de Jersey, 1968, 1970) and part of the *T. playfordii* Assemblage Zone (mid-Smithian - early Anisian?) of western Australia (Dolby and Balme, 1976).

Macrofloras associated with younger microfloral assemblages are referable to the *Dicroidium zuberi* Opper-zone (Retallack, 1977). In the Midlands they include *D. dubium* var. *australe*, *D. zuberi* var. *zuberi*, *Karibacarbon feistmantelii*, and cone scales of *Skulliostrongobus australis* and *Cylostrobos sydneyensis*. From Mount La Perouse, Davidson (1969) listed *C. sydneyensis*, *Lepidopteris madagascariensis*, the frond *barrealensis*, *D. feistmantelii*, '*Cladophlebis australis*' and *Equisetites??* roots. *D. zuberi* var. *papillatum* may also occur at Mount La Perouse. A similar *D. zuberi* Opper-zone flora that includes *C. sydneyensis*, '*Pterorrachis*' *barrealensis*, *Dicroidium zuberi* (Camp and Banks, 1978) and *Cladophlebis sp.* occurs in the Poets Road Member, but the associated microflora contains *Lundbladispora brevicula* and lacks *Aratrisporites* (Camp and Banks, 1978). The lack of *Aratrisporites* may be unusual (see Helby and Martin, 1965), but is consistent with the low stratigraphic position of the flora.

Other occurrences of the *D. zuberi* Opper-zone include localities at Baskerville with *Skulliostrongobus australis* (Ash, 1979) and at Constitution Hill with *C. sydneyensis* - both included in Assemblage 5 of the Quartz Association Rlm of Leaman (1976, 1977) - and shale with *C. sydneyensis* in the Wayatinah village. M.R. Banks has recorded *C. sydneyensis* and *D. zuberi* in a sandstone, carbonaceous shale and red bed sequence on Tasman Peninsula (Forsyth, 1984).

The *D. zuberi* Opper-zone ranges from mid-Smithian to middle-Anisian but the absence of *Xylopteris* spp.

suggests a pre-Anisian age for the Tasmanian flora (Retallack, 1977).

Amphibian faunas include a brachiopod, *Blinasaurus townrowi* and three rhytidosteids including *Deltasaurus kimberleyensis* (also present in the Blina Shale) *Chomatobatrachus halei* and *Derwentia warreni* (Cosgriff, 1974; Jupp and Warren, 1986). Bone fragments occur from the base of the sequence into the interval with the younger microflora but the ranges of individual taxa are poorly known. Three taxa occur in assemblages from Coningham and Old Beach and all four occur together at Midway Point. Cosgriff (1974) considered the fauna younger than the *Lystrosaurus* Zone and older than the *Cynognathus* Zone of South Africa whereas faunas from the Gosford Subgroup were correlated with the *Cynognathus* Zone. This suggests the composite Tasmanian assemblage may be older than the *A. tenuispinosus* Assemblage-zone. *D. kimberleyensis* was recorded from the Cluan Formation at Poatina, (Cosgriff, 1974) but the specimen is almost certainly from the Ross Formation. The specimen locality occurs between strata with the older microflora below and the younger microflora above. The presence of lycopsid remains at the Old Beach and Midway Point localities (Banks *et al.*, 1978) may suggest these localities lie within the *D. zuberi* Opper-zone. This is certainly the case at Lime Bay (M.R. Banks pers. comm.) and for part of the succession in the Poets Road Member where *Chomatobatrachus halei*, a proterosuchian reptile *Tasmaniosaurus triassicus* Camp and Banks 1978) and *B. townrowi* occur in ascending order. Camp and Banks (1978) considered that the reptile was most closely related to a form in the *Lystrosaurus* Zone but was more advanced and favoured correlation of the reptile-bearing strata with the *Cynognathus* Zone, the Blina Shale and the Gosford Subgroup.

Conchostracans include three subgenera, *Palaeolimnadia* (*Palaeolimnadia*), *P. (Grandilimnadia)* and *Cyzicus (Lioestheria)* found also in the Blina Shale; *C. (Lioestheria)* is also found in a *Lystrosaurus* Zone correlate in India (Tasch, 1975). *P. (Palaeolimnadia)* spp. occur in the Ross Formation. In the Knocklofty Formation, *P. (Palaeolimnadia)* and *P. (Grandilimnadia)* occur together and *C. (Lioestheria)* spp. occur near the Poets Road Member. *P. (Grandilimnadia)*, and *Palaeolimnadiopsis* and *C. (Lioestheria)* respectively, occur at the vertebrate localities at Old Beach and Tinder Box. *Cyzicus* has also been recorded from Micekeys Bay on Bruny Island (Rigg, 1969). The richest fossil fish faunas occur with the temnospondyls at Coningham and include *Ceratodus gypsatus*, *Cleithrolepis granulata* and *Saurichthys sp.* *Acrolepis* and a coelacanthid respectively occur with *Ceratodus gypsatus* and temnospondyls at Old Beach and Midway Point. *Acrolepis hamilton* and *A. tasmanicus* occur elsewhere (Dziewa, 1980).

UNIT 3: Sequence with quartz and lithic sandstone (Pre-Anisian? to Ladinian)

Introduction

The broad change in sandstone composition from the Lower Triassic quartz sandstone to overlying sequences with lithic sandstone and some coal measures is punctuated by intervals with interbedded quartz sandstone and by hiatuses in some areas. The occurrence of these younger quartz sandstone intervals overlying or associated with lithic sandstone or with coal measures was commented upon by Gould (1869), Nye (1921), Hills *et al.* (1922), Hale (1962) and Banks and Clarke (1973). The association of quartz and lithic sandstone forms a useful mapping unit (Leaman, 1976, 1977; Forsyth, 1984, 1989).

The quartz sandstone has been found in two intervals; a basal interval from which it may be absent in places and

a younger interval where on a sub-regional scale the quartz sandstone is lenticular and diachronous. Because of the hiatuses the upper interval with quartz sandstone occupies a basal stratigraphic position in north-eastern Tasmania resting on Lower Triassic sandstone, Lower Permian Supergroup strata and older rocks. The stratigraphic framework of the sequence is based on its occurrence in the southern Midlands (Forsyth, 1984) and elsewhere it is known mainly from scattered drill holes and surface outcrops.

Basal interval with quartz sandstone

STRATIGRAPHY

MIDLANDS

North of Melton Mowbray, Forsyth (1984) utilised a convenient mapping horizon at the base of a granule feldspathic, quartz sandstone unit to delimit the base of the sequence containing both quartz and lithic sandstone. The granule sandstone unit (5 m) changes laterally into finer-grained sandstone without granules and is discontinuous. Palaeocurrents were towards the NNW.

Locally the granule sandstone unit is overlain by an interval containing sandstones of only lithic composition, but more generally an interval (up to 20 m) is present that contains up to three quartz sandstone units separated by lutite dominated units. Much of the quartz sandstone is especially mature, white, with sharply defined lamination and contains thin silicified layers. Lateral accretion structures are present. Scant palaeocurrent data suggest currents were towards the north-west. The proportion of quartz sandstone varies laterally, so that in places, only a few thin units (<2 m) of quartz sandstone occur, interbedded with either dominantly lutite or dominantly lithic sandstone. The lutite includes pale blue grey lithologies that rapidly develop an orange weathering hue, and subordinate but characteristic dark grey mudstone banded with white sandstone.

Eight kilometres to the north near Jericho, the basal sandstone contains white, pink and red quartz granules and both the basal granule sandstone unit and the overlying quartz sandstone units indicated north westerly directed palaeocurrents (Forsyth, 1984). In what may approximate the down-current direction, granule sandstone occurs 20 km away at Table Mountain (Forsyth, 1984). At Constitution Hill 13 km south of Melton Mowbray, a granule sandstone unit with pink quartz grains indicates northerly directed palaeocurrent. West of Ross, the basal sandstone unit contains pink and red quartz granules and small pebbles and polycrystalline quartz grains that exhibit evidence of haematite impregnation prior to deposition (Forsyth, 1989).

POATINA

A correlate of the basal interval with quartz sandstone occurs in the Cluan Formation. Hydro Electric commission drill holes that intersected the lower 90 m of the Cluan Formation reveal two sandstone units 40-50 m above the base of the Cluan Formation. Each unit reaches a maximum thickness of about 10 m and contains beds of very coarse- to coarse-grained sandstone and some granules and pebbles of quartz. Labile grains are prominent in the sandstone and some beds contain only 50% quartz. Interbedded sandstone and lutite beds occur between these two main sandstone units and include pale blue grey lutite and black and white banded rocks very similar to the rocks near Melton Mowbray. Some sandstone beds consist of 35-50% quartz grains in a homogeneous matrix. Coarse-grained sandstone is not evident in road cuttings along the Poatina Highway or access portal road, about one kilometre north of the

boreholes. Instead, the interval base occurs at a unit of lithic sandstone (30-40% quartz) that contains prominent altered biotite and muscovite. The lithic sandstone indicates north-westerly directed palaeocurrents. The overlying beds that crop out consist predominantly of shale with some interbedded sandstone including very mature quartz sandstone. These quartz sandstone beds are associated primarily with dark grey carbonaceous shale in H.E.C. bores 5019, 5020 and were considered by McKellar (1957) to occur near the top of the Cluan Formation. Eggert (1983) noted the more mature quartz sandstone beds contained up to 95% quartz (proportion of grains) and a very low plagioclase to total feldspar ratio.

POSSIBLE CORRELATES IN SOUTHERN TASMANIA

In southern Tasmania, the basal interval with quartz sandstone may be represented by laminated quartz sandstone near Pelterata (Farmer, 1985) and also east of Hamilton in the Derwent Valley. Various outcrops of granule sandstone, for instance near Collins Bonnet and in the Kingborough Quadrangle may be in the interval. The most striking probable correlatives are a siliceous sandstone unit at Dalys Hill that contains pebble sandstone and conglomerate with quartz clasts up to 100 mm size (Farmer, 1985) and its probable correlative of white and pink quartz pebbly sandstone at Raminea Plain (Hale, 1953). A possible correlative is the pebbly coarse-grained 'anomalous' sandstone south of Big Blue Hill near Dunalley (Gulline, 1984).

INTERPRETATION

Near Melton Mowbray, the granule sandstone unit (≤5 m) is probably the shoe-string deposit of an erosive low sinuosity river that flowed NNW. Palaeocurrents at Jericho and Constitution Hill were also between north and north-west. Similarly directed palaeocurrents are known from basal lithic sandstone at Poatina (J. W. Collinson pers. comm.) and in some higher quartz sandstone units, some with lateral accretion structures, in the southern Midlands. Palaeocurrent directions, ferruginous grains and the very mature composition of some sandstone are consistent with possible recycling of older (Upper Permian?) rocks.

PALAEONTOLOGY AND AGE

The macroflora of the basal interval with quartz sandstone may include *Dicroidium odontopteroides*, thus perhaps indicating a late Anisian maximum age based on Retallack (1977). The microflora (fig.7) includes common *Cycadopites follicularis* and *C. crassimarginis*, *Aratrisporites* spp. and *Protohaploxypinus* sp. suggesting approximate correlation with the *Aratrisporites tenuispinosus* - *A. parvispinosus* Assemblage Zone boundary (Forsyth, 1984; Helby, 1973). *Cycadopites* sp., *Guttatisporites* sp. and *Aratrisporites wollariensis* occur in the interval at Poatina (H.E.C. bore 5020).

Interval with lithic sandstone and lutite

STRATIGRAPHY

Southern Midlands

The basal interval with quartz sandstone is succeeded in the southern Midlands by an interval (~80 m) of interbedded quartz-rich lithic sandstone and mainly light to medium grey and grey green lutite. These rocks tend to weather to subdued buff, tan and grey green colours and in contrast to some rocks of the older Lower Triassic Quartz Sandstone Sequence (Unit 2) they do not exhibit bright orange, red, brown or purple colours. The sandstone usually consists of quartz (25-45%), feldspar, chert and other quartzose lithic grains, some fine-grained felsic

igneous grains and rarely basaltic grains. At places, the interval consists mainly of fining-upward, lutite-dominated cycles with basal fine- to medium-grained sandstone (0.1–1 m) that is overlain by lutite. Units a few metres thick, of cross-bedded sandstone overlie eroded scour surfaces and contain mud pellets, multistoreyed sandstone units up to 10 m thick are rare. Some carbonate concretions, and coalfield logs occur, but dark grey carbonaceous lutite is not common and coal seams are absent. Bioturbated horizons are visible in drill core and some horizons may be palaeosols. Such horizons are associated with slight purple mottling, possible roots and occasionally irregular wood fragments dispersed in mudstone. Short, vertical sand filled tubes are more commonly observed in surface exposures of finer-grained rocks. Water-escape structures are common but desiccation cracks have not been observed and the interval was probably deposited in a continuously humid environment (Forsyth, 1984).

Poatina

The litho- and palynocorrelate of the interval at Poatina is the Tiers Formation and the uppermost part of the Cluan Formation above the top quartz sandstone in H.E.C. bores 5019 and 5020. The uppermost part of the Cluan Formation differs from the overlying Tiers Formation primarily in the greater proportion of dark grey lutite present in the former (McKellar, 1957) and not in sandstone composition. The sandstone is less quartzose than in the Midlands (fig. 6) with quartz (about 10%), feldspar (30%) and lithic grains (about 60%) of mostly volcanic type (Eggert, 1983). Lutite of grey green colour is more prominent in the Tiers Formation at Poatina than in the Midlands, but some grey lutite is present in the Tiers Formation. Similarly to the Midlands coalfield logs are present (in the Tiers Formation) but coal seams are absent and dark grey lutite is not prominent except in the Cluan Formation. The scarcity of thick sandstone units is common to both areas and only three sandstone units (~5 m thick) occur at Poatina.

Correlated strata

Other palyno- and lithocorrelates (fig. 8) include an interval (17 m) passed through in an Investigation Coal Exploration Pty Ltd bore RG1 (Sangster, 1979) the basal interval (28 m) penetrated in Department of Mines bore MtLloyd 2 (Burns, 1959) (see fig. 9, 10), beds at Dunrobin Bridge in the Derwent Valley and beds west of Table Mountain with pebbles of metamorphic rock unlike rock found in eastern Tasmania (Forsyth, 1989). Lithocorrelates occur near Tunbridge, at Table Mountain (Forsyth, 1989) and in the Hobart and Brighton areas included in Assemblage 5 of Leaman (1976, 1977) especially at Constitution Hill, St Virgils school oval at Austins Ferry, Lowestoft Bay and west of Mt Direction, on the eastern side of Spring Bay (Triabunna), near the Convict Gaol Mines on Tasman Peninsula (Bacon, 1985a) where beds with roots occur, and possibly included in the 'Feldspathic Sandstone' near Wayatinah (Jennings, 1955). An interval (45 m) of feldspathic sandstone and dark grey-green shaly mudstone near Walls of Jerusalem may correspond to the Tiers Formation (MacLeod *et al.*, 1961).

The interval is represented by a hiatus near St.Marys, Apslawn and on Schouten Island.

Palaeontology and age

Fossil fauna may include a fish from Granton (Dziewa, 1980). Macrofloras include *Macrotaeniopteris*, *Equisetites*, and *Dicroidium* sp. cf. *D. dubium* var. *australe*. *D. odontopteroides*, indicative of a post-middle Anisian age, was recorded about 40 m below the top of

the interval (Forsyth, 1984; Retallack, 1977). Microfloras near the base contain *Horriditriletes* but otherwise resemble those in the interval with quartz sandstone. Species that appear in the upper half of the interval with lithic sandstone include *Neoraistrickia pickettii* Helby, 1970. *Equisetosporites* spp. including *E. steevesii*, *Aratrisporites paenulatus*, *Chordasporites australiensis* and *Pilasporites crateriformis* and those indicated in Figure 2. They occur with species recorded or possibly recorded from older horizons, including *Converruco-sisporites cameronii*, *Lundbladispora*, *Aratrisporites strigosus* and *Protohaploxypinus* cf. *jacobiae*. *Rugulatisporites trisinus* is present near the top of the interval at Mount Lloyd. The microfloras from the upper half of the interval strongly suggest correlation with the *Asseretospora gyrata* Microflora of the Esk Formation (de Jersey, 1975; Playford *et al.*, 1982) and the *Aratrisporites parvispinosus* Assemblage Zone in the Sydney Basin (Helby, 1973). *C. senectus* is confined to the higher part of the *A. parvispinosus* Assemblage Zone and occurs in the Midlands, at Mount Lloyd, and at Poatina almost to the top (within 13 m) of the Tiers Formation. An unusual feature of some assemblages is the local abundance of *Circulisporites* sp. This species occurs persistently through some intervals and may prove to be environmentally significant. The occasional presence of *Quadrissporites horridus* may be controlled by environmental conditions.

Interpretation

The lack of mudcracks suggests deposition probably took place in a more or less continuously humid environment such as a swamp complex. However, the presence of ephedroid and taeniate pollen may indicate that some areas were subject to aridity (Foster, 1979). Major channels that transported sand either were not common, or seldom migrated far from the flood plain, or both. The basal thinly bedded sandstone layers of the lutite-dominated cycles tend to be non-erosive and to contain muddy partings and only small-scale bedforms such as ripples. These cycles were interpreted as having been deposited from sluggish water moving through swamps (Forsyth, 1984). Palaeosols may have developed from time to time.

Younger interval with quartz sandstone

INTRODUCTION

The lithic sandstone and lutite interval is overlain by an interval showing considerable variation but including in many areas clean white quartz sandstone, associated with dark grey to black lutite or grey and green lutite in the St Marys area (Calver *in* Turner and Calver, 1987). Thin coal seams occur in some areas. The quartz sandstone and dark grey lutite association is prominent in the southern Midlands (Forsyth, 1984) reaching a thickness of 100 m, but it is thinner at Mt Lloyd, Poatina and St Marys. Nevertheless, microfloral changes are separated by about equal intervals of strata at Mt Lloyd and in the southern Midlands, suggesting that the quartz sandstone association is diachronous, lenticular, or both. Sandstone composition varies laterally from quartzose to lithic or feldspathic. The lithic sandstone is in places quartz- or chert-rich and often contains biotite.

STRATIGRAPHY

Near St Marys and Apslawn, the quartz sandstone association (Sisters Granule Conglomerate, Walker, 1957; Rq, Calver, *op.cit.*; Threader and Bacon, 1983) forms the base of the Upper Parmeener Supergroup. A low angle (0.3°) erosive discordance between the Upper and Lower Parmeener Supergroup occurs near St Marys. Calver *op.cit.*). The discordance has been indicated by the

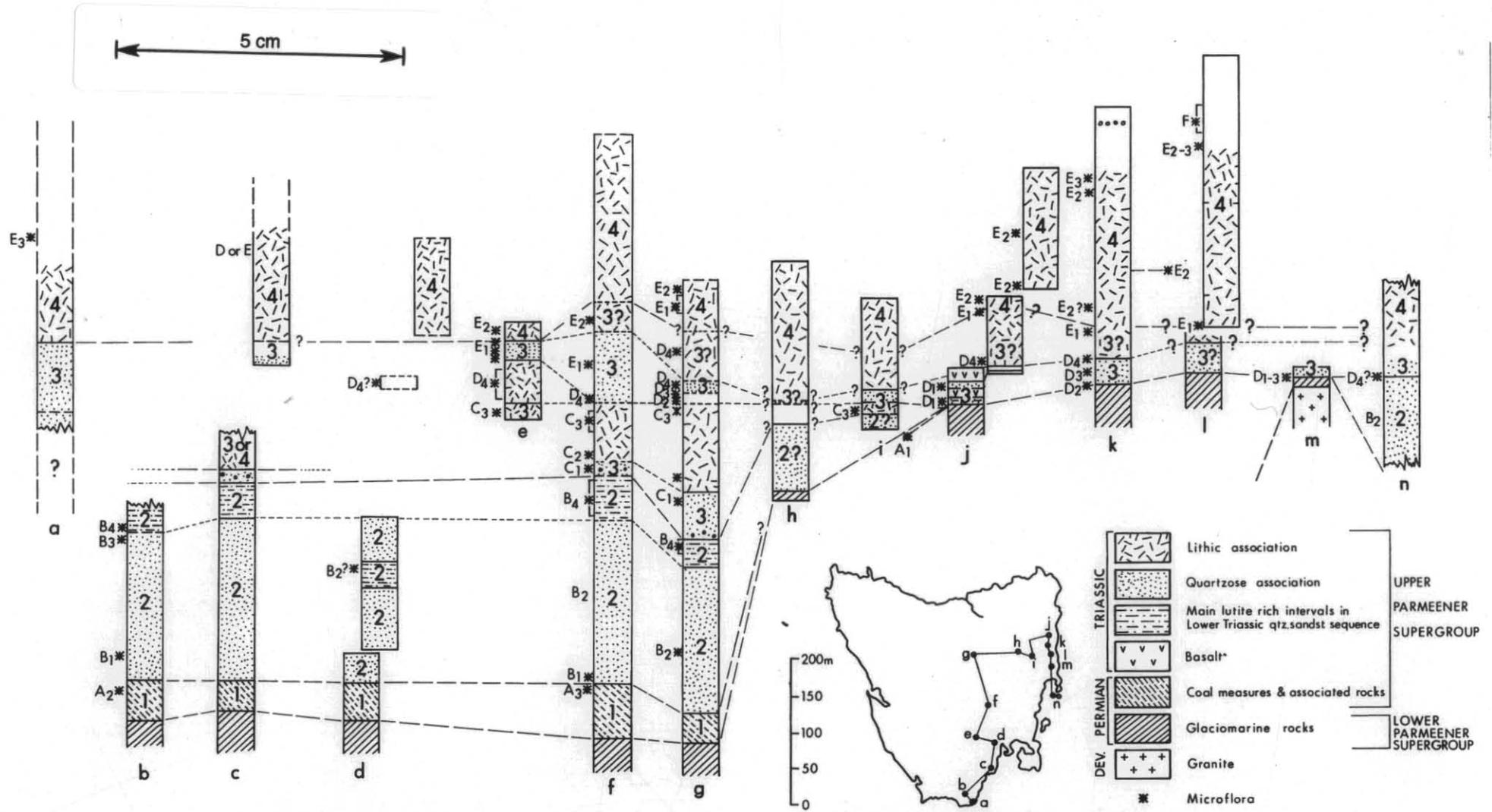


Figure 8. Stratigraphic columns of Upper Parmeener Supergroup showing palyno-correlation and litho-correlation of main rock units. [From *Spec. Publ. geol. Soc. Aust.* 15 (1989)].
 Data sources: a – Catamaran area (Perkins, 1982, 1983); b – Mt La Perouse (Davidson, 1969; c – Kingborough area (Farmer, 1985); d – Hobart area (Banks and Naqvi, 1967; Camp and Banks, 1978; Forsyth, 1987; Leaman, 1976); e – Mt Lloyd (Burns, 1959; Forsyth, 1987); f – Oatlands area (Forsyth, 1984); g – Poatina (Forsyth, 1987; McKellar, 1957; Playford, 1965); h – Avoca DDH AV12 (Borrmann and Murphy, 1981); i – Royal George DDH ICE1 (Anon., 1979a); j – Nicholas Range (Calver and Castleden, 1981; Forsyth, 1987; Hale in Spry and Banks, 1962; Playford in Threader, 1968); k – Fingal Tier (Playford in Threader, 1968; Threader and Bacon, 1983); l – Douglas River DDH GY27, DDH 10 (Bacon, 1984; Sansom, 1980); m – Apslawn DDH 963/546 (Leaman and Richardson, 1981); n – Schouten Island (K. D. Corbett, pers. comm.; Forsyth, unpublished data). 1–4 – Main informal rock units: Unit 1 – Coal Measures and associated rocks (upper Permian); Unit 2 – Quartz sandstone sequence and associated rocks (Griesbachian to pre-Anisian?); Unit 3 – Sequence with quartz and lithic sandstone (?pre-Anisian to Ladinian); Unit 4 – Volcanic lithic sandstone and coal measure sequence (Carnian).

27/43

	Microfloras						
	C3	D1	D2	D3	D4	E1	E2
1 <i>Cadargasporites senectus</i>	—						
2 <i>Equisetosporites spA</i>	—						
3 <i>Equisetosporites spB</i>	—						
4 <i>Limatulasporites limatulus</i>	—	—	—	—	—		
5 <i>Lophotriletes bauhinae</i>	—	—	—	—	—		
6 <i>Triplexisporites playfordii</i>	—	—	—	—	—		
7 <i>Aratrisporites strigosus</i>	—	—	—	—	—		
8 <i>Rugulatisporites denmeadii</i>		—	—	—	—		
9 <i>Dictyophyllidites mortonii</i>	—	—	—	—		
10 <i>Kraeuselisporites verrucifer</i>		—	—	?			
11 <i>Indospora clara</i>		—	—	—	—		
12 <i>Foveosporites moretonensis</i>			←	cf	→		
13 <i>aff. Kraeuselisporites verrucifer-Semiretisporis denmeadii</i>				—	—		
14 <i>Apiculatisporis clematisi</i>				—	—		
15 <i>Aratrisporites parvispinosus</i>					—	—	
16 <i>Semiretisporis denmeadii</i>					—	—	
17 <i>Annulispora folliculosa</i>						—	—
18 <i>Rogalskaisporites cicatricosus</i>							—
19 <i>Cyathidites sp.</i>							—
20 <i>Annulispora microannulata</i>							—
21 <i>Circulisporites parvus</i>							—

Figure 9. Index to species and generalised ranges.

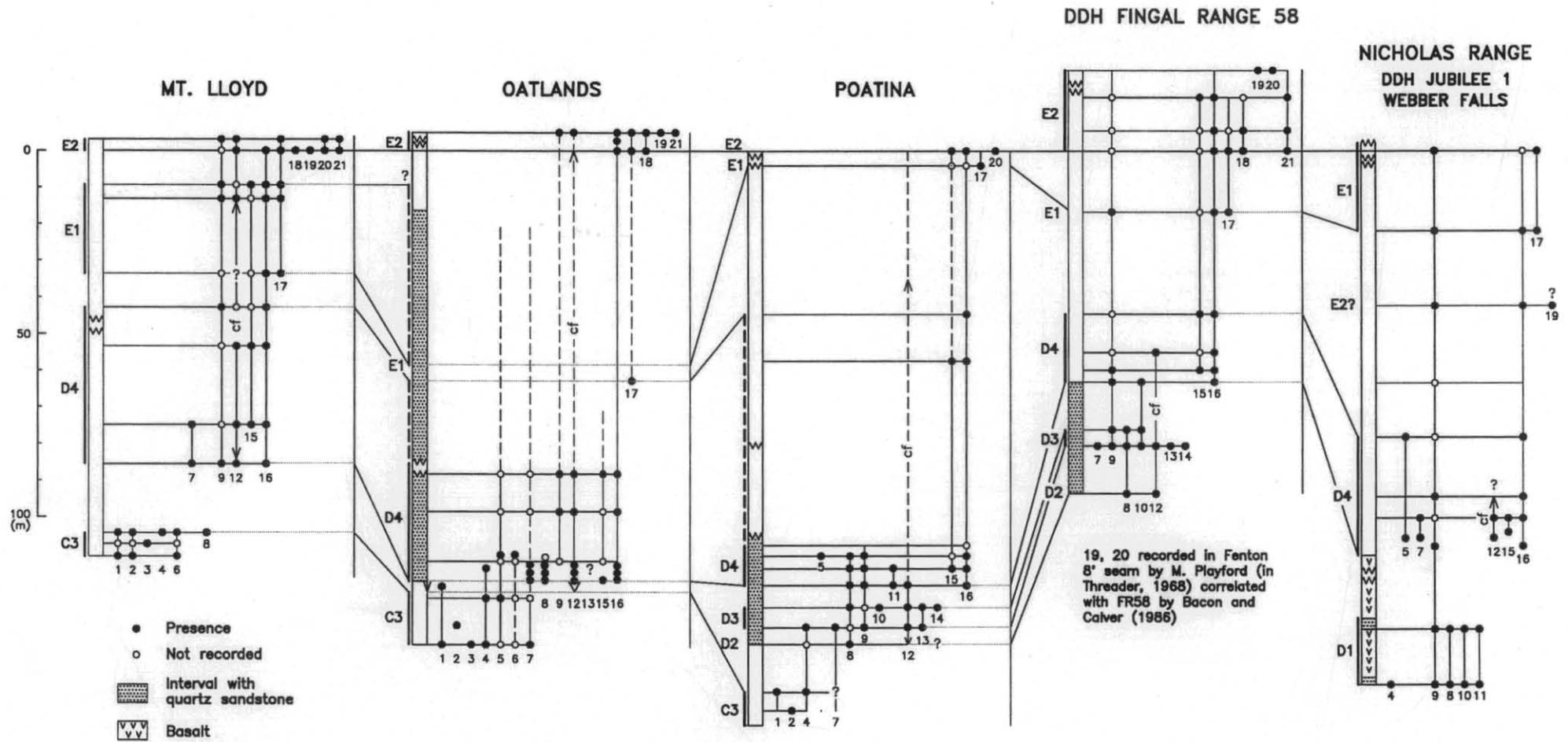


Figure 10. Seam correlation chart. Numbers 1–21 correspond to microflora species listed in Figure 9.

progressive erosion in an easterly or north-easterly direction of underlying strata by reference to the regional dip of marker beds and by the presence of Lower Parmeener derived lag deposits at the discordance (Calver *op cit.*). The interpretation of erosion at the discordance is supported by the presence of recycled Permian spores above the discordance and the excellent state of preservation of the microfungal assemblages immediately below the discordance. These assemblages show no sign of *in situ* weathering. Isopachs of the interval between the discordance and overlying correlated coal seams (based on the data of Threader and Bacon, 1983) indicate that the discordance is irregular beneath Fingal Tier. Threader and Bacon (*op cit.*) tabulate the thickness of Upper Parmeener quartz sandstone intersected in boreholes at Fingal Tier. This data has been revised to conform to the concept of the quartz association used herein. These revised data indicates that the thickness variations of the quartz sandstone association (0–60 m), approximately correspond to irregularities (palaeo- valleys?) in the discordant surface and SSW palaeocurrents at one locality (Calver, *op.cit.*) are consistent with this interpretation. South-west of St Marys, the deepest depressions contain thicker lutite lenses near the base. Two conformable units of very shallowly intrusive to extrusive basalt occur in the quartz sandstone north of St Marys (Calver and Castleden, 1981; Calver, *op. cit.*). The basalt may have occupied a depressed area on the old surface.

South of St Marys near Apslawn, Lower Parmeener rocks either were not deposited or were stripped prior to deposition of the quartz sandstone association which occurs 10 m above Devonian granite in DDH Bicheno 8. Farther south on Schouten Island, the quartz sandstone association rests on Lower Triassic quartz sandstone but is readily distinguished by its rich *Dicroidium* flora, microflora and associated carbonaceous beds. South-west from St Marys, the quartz sandstone association overlies an attenuated interval of the lithic sandstone and lutite part of the sequence near Royal George.

In the southern Midlands, (Forsyth, 1984, p. 75) chose the base of a unit of medium to dark grey carbonaceous mudstone as the base of the quartz sandstone association (Rsq'). Herein the base of the association is revised downward 4 m to include a discontinuous underlying unit of feldspathic quartz granule sandstone with some pink quartz possibly of granitic provenance. This granule sandstone was described by Forsyth (1984, p. 171) in measured surface section 3 at depth 7.49–9.49 m. In this area, current directions of channel deposits are unimodal at outcrop scale but may be polymodal on a regional scale. Lack of currents towards the east and a possible predominance of currents towards the south-west (Forsyth, 1984) is consistent with flow away from St Marys. However, this is not the case north of Colebrook at the old Jerusalem Coal Pits, where flow is easterly directed.

Litho- and palynocorrelates of the association also occur at Constitution Hill (Forsyth, 1984), in the basal part of the Brady Formation at Poatina and at Mount Lloyd. Litho- correlates occur at various places in the Coal River Valley (Townrow, 1966), near Claremont, Mt Hobbs? and Triabunna, in the Sorell Quadrangle (Forsyth, 1984), at Prices Bay on Tasman Peninsula and at Coal Head on the south coast, and possibly at Kaoota (Farmer, 1985) and near Dover (Hale, 1953). The association is probably present east of Wayatinah (BHPDDH10, Anon. 1983) and near Hollow Tree. Traces of quartz sandstone at Table Mountain, Mike Howes Marsh, Tunbridge and possibly at Woods Lake where palaeocurrents are directed towards the south west, may belong to the association (Forsyth, 1989).

Sedimentary features

Sandstone- and lutite-dominated intervals occur in about equal proportions. The thicker sandstone units show cross-bedded layers, troughs often with large-scale primary current lineation? rare bars one metre in height, and slumps, but overturned cross-bedding is extremely rare (Forsyth, 1984; Calver, *op.cit.*). Some beds (1–2 m) consist almost entirely of linguoid-rippled sandstone. Basal beds in the Midlands and near St Marys are granule- to very coarse sand-grade in places and in higher beds fine- to medium-grained sandstone predominates. Sandstone- and lutite-dominated intervals occur in about equal proportions. The dark-coloured rarely pyritic lutite usually occurs interbedded to laminated with sandstone, but some intervals up to 8 m thick consist entirely of mudstone. Mudstone drapes and partings occur over some bar laminae and in some main sandstone units. Carbonaceous matter is interlaminated with some toe-sets of cross-bedding, particularly where they overlie lutite.

Depositional environment

Forsyth (1984) suggested some lutite units were channel-fill or flood-basin deposits. The prevalence of dark lutite and only rare occurrence of desiccation cracks (Calver, *op.cit.*) may indicate deposition was deltaic into a freshwater lake or swamp complex. Some of the sedimentary features are similar to the deposits of tidally influenced estuaries. Toe-set laminae may show spring tidal periodicity (R. Rahmani pers. comm.).

Some similarity with the Upper Permian coal measure facies is shown and in this respect the occurrence of the unusual palynomorph *Quadrisporites horridus* at both horizons may be significant. Zygosporites may indicate warm shallow water. Some plants (*Johnstonia*, *Xylopteris*) of probable xerophytic habit (Retallack, 1977) may have grown on well-drained areas.

Relationship of biostratigraphy to lithostratigraphy

The degree to which facies control influenced the microfungal changes in the interval with quartz sandstone is unknown, but parallel changes in different areas shown by incomplete study are utilised to subdivide the interval. The preservation of acid-insoluble residues is very different from that of older intervals.

Based on composite sequences the successive microfungal changes are indicated in Figures 7–10. Associated megaspores include *Horstisporites microlumenus* and *Hughesisporites variabilis* (Dettmann, 1961). In contrast *S. denmeadii*, *A. parvispinosus*, *A. strigosus* and *Foveosporites cf. moretonensis* occur 60 m below the quartz sandstone association at Mount Lloyd in an interval with black shale and quartz-rich lithic sandstone. This interval is distinguishable from the older lithic sandstone and lutite interval by the change from grey-green lutite, by an increase in sandstone grain size and a fourfold increase in the proportion of sandstone (Burns, 1959).

Thus the deposition of quartz sand is considered to have commenced synchronously near St Marys, at Poatina and in the Midlands, but notably later at Mt Lloyd.

The next significant microflora datum is the introduction of *Annulispora folliculosa*. This species appears as a rare element about midway through the quartz sandstone association in the southern Midlands and more frequently through most of the quartz sandstone association at Mt Lloyd. Possibly because of the rarity of the species, it has not been found until about 87 m above the basalt north of St Marys and about 46 m above the quartz association beneath Fingal Tier. At Poatina, it has not yet been found in the interval exceeding 100 m that overlies the quartz sandstone association. The oldest known occurrence of *A.*

folliculosa at Poatina is in DDH HEC 5018 at a depth of 88 m. This horizon was indicated by correlation to be 130 m above the base of the Brady Formation (McKellar, 1957). Elements of a younger microflora, *A. microannulata* and *Circulisporites parvus*, are present at a slightly higher horizon at Poatina. Elsewhere the younger microflora is recognised by the almost synchronous introduction of *A. microannulata*, *Circulisporites parvus*, *Cyathidites* sp. and *Rogalskai-sporites cicatricosus* and is generally confined to the younger volcanic lithic sandstone and coal measure sequence. For example at Mt Lloyd all four elements listed above are present 35 m above the introduction of *A. folliculosa*. At Fingal Tier in DDH FR58, *R. cicatricosus* and *Circulisporites parvus* are present 220 m above the introduction of *A. folliculosa*.

In the Fenton coal seam near St Marys *A. microannulata* and *Cyathidites* sp. are present (M.E. Playford in Threader, 1968). The correlative of this horizon at Fingal Tier in DDH FR58 (Bacon and Calver, 1986) occurs about 40 m above the introduction of *A. folliculosa* and about 20 m above the introduction of *R. cicatricosus* and *Circulisporites parvus*.

Some beds of lithic sandstone occur in the interval between the locally youngest quartz sandstone bed and the horizon biostratigraphically equivalent to the regionally youngest quartz sandstone. The composition of these lithic sandstone beds is too poorly known to determine whether such intervals can be lithologically distinguished from the overlying volcanic lithic sandstone sequence containing the younger microflora. Sandstone at Poatina and near St Marys tends to be more feldspathic than in the overlying sequence and the grain composition ranges quartz (9–33%), feldspar (19–46%), and lithics (21–63%) (Eggert, 1983). Intermediate and acid volcanic grains and biotite are present just above the basalt north of St Marys (Baillie, 1980). Many sandstone layers at Poatina contain abundant volcanic grains (Eggert, 1983), but some layers instead contain abundant chert and notable biotite.

There appears to be a general tendency for the interval between the quartz association and the volcanic lithic sandstone sequence to contain a greater proportion of lutite or very fine-grained sandstone, to be thinner-bedded and to show a gradual upward increase in coal seam thickness from a few tens of millimetres to a about one metre (Threader and Bacon, 1983; Forsyth, 1984; Summons, 1984). An apparent increase in dark igneous grains from this interval to the volcanic lithic sandstone sequence may be related to grain-size rather than provenance.

The general tendency towards a greater proportion of lutite is manifested, for example at Poatina, by approximately equal proportions of channel sandstone units and lutite dominated units, and at Spring Hill in the Midlands, by an interval (40 m) almost entirely lacking channel sandstone units (Rsfu-Forsyth, 1984). A few kilometres away from Spring Hill in the Mount Vernon bore, the upper part of this lutite dominated interval is replaced by sandstone.

MACROFLORAS

Macrofloras from the quartz sandstone association include the lost lectotype and neotype (Townrow, 1966) of *Dicroidium odontopteroides*, and type specimens of *Johnstonia trilobata*, *Cladophlebis australis* and *Heidiphyllum elongatum* and elements of floras described by Morris (in Strzelecki 1845), Johnston (1887, 1894, 1896), Walkom (1925, 1926) and Townrow (1962) from Spring Hill, Triabunna? and probably Lords Hill in Hobart. Other typical genera include *Xylopteris*, *Philophorosperma*, *Sphenobaeria*, *Taeniopteris*, *Linguifolium*, *?Ginkophytopsis*, *?Chiropteris*, cf.

Dicroidiopsis and *?Neocalamites*. Species have been listed by Forsyth (1984) and Calver (in Turner and Calver, 1987) and include a form close to *Dicroidium odontopteroides* var. *remotum* for which a late Anisian to Ladinian age has been indicated (Retallack, 1977). Illustrations of fossil leaves from an unknown locality(s) near Dunalley (Johnston, 1896) suggest forms like *Dicroidium dubium* var. *australe* (Smithian–Middle Anisian) and *D. eskense* (Late Anisian–Ladinian) may be present (Retallack, 1977). If associated these species may have a possible quartz sandstone association provenance.

AGE

The microfloras from the quartz sandstone association lack some species that occur in the microflora from the underlying lithic sandstone and lutite interval. The local ranges of *Kraeuselisporites verrucifer* (= *K. differens*), *Rugulatisporites trisinus* and *Polypodiaceosporites* sp. (fig. 7), and other features, further distinguish the microfloras from the two intervals. Whereas the microflora from the lithic sandstone and lutite interval can be confidently correlated with the *Aratrisporites parvispinosus* Assemblage Zone of Helby (1973) and the *Asseretospora gyrata* Microflora of De Jersey (1975; Playford *et al.*, 1982), the microfloras from successive horizons up the interval with quartz sandstone show less and less affinity with those zones. Indeed, the progressive upward reduction of species characteristic of the *Aratrisporites parvispinosus* Zone, and the appearance of *Semiretisporis denmeadii*, suggest microfloras above that horizon are younger than the *Aratrisporites parvispinosus* Assemblage Zone. This is despite the appearance in the interval of *Aratrisporites parvispinosus*, as this species appears to be distinct from species in the Sydney Basin included in Helby's (1973) extended concept of *Aratrisporites parvispinosus*. Microfloras from above the appearance of *Annulispora folliculosa* are probably younger than the *Asseretospora gyrata* Microflora. In the Canning Basin *S.denmeadii* appears in the *Staurosaccites quadrifidus* Zone (Dolby and Balme, 1976). Correlates of the *Staurosaccites quadrifidus* Zone have been recognised in eastern Australia. These occur at horizons equivalent to the lower part of the Moolayember Formation, and in the upper part of the Moolayember Formation in the Mimosa Syncline within the range of *Kraeuselisporites verrucifer* and associated with *Semiretisporis denmeadii* (de Jersey and McKellar 1980; de Jersey and Hamilton 1967; J. L. McKellar, 1977).

In New Zealand, *Annulispora folliculosa* appears in the Kaihikuan Stage (Ladinian) preceding *A. microannulata* in the Oretian Stage (Carnian) (N. J. de Jersey, pers. comm.). In the Carnarvon Basin, *A. folliculosa* appears in the *Samaropollenites speciosus* Zone (probably upper Carnian) (Dolby and Balme, 1976). Its first appearance in Tasmania is believed to be in the time interval occupied by the hiatus in Queensland, between the *Asseretospora gyrata* Microflora and the *Craterisporites rotundus* Zone of de Jersey (1975).

In Tasmania, the introduction of *Annulispora microannulata* or *Rogalskai-sporites cicatricosus* is equated with the base of the *C. rotundus* Zone. However, although the succeeding microflora shows much similarity with *C. rotundus* Zone assemblages in Queensland, the nominate species is not found until much higher in the succession. The palaeontological data suggest the younger quartz sandstone association ranges in age from late Anisian-Ladinian to Ladinian. This is supported by the minimum radiometric age of 233 ± 5 Ma for the lower basalt in the base of the association (Calver and Castleden, 1981; Webb, 1981).

UNIT 4: Volcanic lithic sandstone and coal measure sequence (Carnian)

Introduction

The sequence consists predominantly of volcanic lithic sandstone, lutite, coal seams and rare tuff and conglomerate beds. The economic value of some of the coal seams has led to a long history of investigation and observation dating from even before the first settlement in Tasmania (Bacon, 1986). Coal production has been intermittent. The local geology of many of the coal occurrences was described by Hills *et al.* (1922). An increase in the economic viability of coal in part related to the potential use of Tasmanian coal as fuel for a thermal power station led to surge in private and government coal exploration during the 1970s extending into the 1980s. Much drilling has been undertaken particularly in north-eastern Tasmania to locate new coal occurrences, to extend known occurrences and to quantify reserves in terms of quantity, quality and feasibility of mining. This has provided much new stratigraphic information and detailed descriptions of the coal seams. Private company reports pertaining to Triassic coal measures, that are currently on open file are listed in appendix 1. The early account of Hills *et al.* (*op cit.*) has been updated as a collection of unpublished reports largely by C. A. Bacon, V. M. Threader and R. H. Castleden and including geophysical data (D. E. Leaman) (see also Leaman and Richardson, 1981).

The distribution of the sequence (fig. 5c) is encircled by commonly isolated occurrences; from near St Marys along the northern side of the South Esk Valley (Mt Nicholas, Tower Hill) to the defunct Norwich Colliery near Longford, a possible occurrence in the Tamar Estuary (Johnston, 1888), an occurrence at Poatina (Brady Formation in part) and a probable occurrence near Bronte, occurrences along the Derwent River valley for example at Wayatinah, Langloh Colliery, Plenty, Mt Lloyd at Newtown ('Newtown Coal Measures') and other localities near Hobart, at Kaoota (Kaoota Coal Measures in part) and possibly at Glendevie, occurrences at Strathblane and Catamaran and nearby areas through to the southern coast at South Cape Bay, at the Convict Coal Mines on Tasman Peninsula, possibly at Kellevie Tier and through to Schouten Island on the east coast. Locally derived material is recycled into Cretaceous deposits near Boobyalla (Moore *et al.* 1984) and further west, coal washed ashore onto beaches may be from the sequence (Gould, 1865).

The sequence usually is preserved beneath Jurassic or Tertiary igneous rocks or in grabens, but near the Douglas River younger beds of Norian age (for convenience dealt with here) occur about 250 m above the sequence base. Sequences in the Midlands are about 270 m thick (Forsyth, 1984).

Stratigraphy

No effective regional stratigraphic subdivision of the main coal-bearing interval has been achieved, but locally near St Marys correlation between coal exploration bores about one kilometre apart usually enables individual coal seam groups to be recognised. The coal seam stratigraphy used by the Geological Survey (Threader and Bacon, 1983; Calver *in* Turner and Calver, 1987) is based on the occurrence of eight seams or groups of seams distributed over an interval of about 220 m. These seams are present in most bores and named seam A to H from top to bottom. Thinner, less continuous seams occur outside of this interval in some bore holes. An interval of about 40–50 m of strata separates H seam from underlying quartz sandstone. Part of this interval is probably of the same age as the quartz sandstone association elsewhere. In bores

studied by Bacon (1979) that can be related to the coal seam stratigraphy, there is a pronounced quartz enrichment in sandstone layers just above seam D and apparently at a similar horizon elsewhere (field 4.3 in fig. 6). Because Jurassic dolerite truncates the sequence, the youngest horizon known from Fingal Tier is a conglomerate layer (1–5 m) known informally as the Dalmyne Conglomerate, but further south and east, up to 100?m of strata overlie the conglomerate. Near the Douglas River these higher strata are predominantly dark grey and black lutite with some red and green mudstone. They contain a distinctive microflora.

Calver (*in* Turner and Calver 1987), suggests extrabasinal cobbles and boulders are absent in the lower 150 m interval above the quartz sandstone, i.e. in the interval up to about E seam. Tuff beds appear to be confined to above B seam. Tuffs also occur in the Midlands near Bothwell and associated with silicified wood and extrabasinal clasts at Woodbury (Forsyth, 1984, 1989).

Lithology

SANDSTONE

On average, the sandstone composition is less quartzose or less feldspathic and contains a higher proportion of very fine-grained igneous grains than sandstone of older sequences. Chloritisation or sericitisation of labile grains and part replacement by calcite cement or the formation of calcite concretions is common. Quartz is usually 5–35% but may be 50%, generally subangular, less commonly rounded and usually strained (Bacon, 1979) or may be unstrained and include embayed grains (Forsyth, 1984). Feldspar usually forms <10% and ranges 6–18%. Sandstone with up to 80% feldspar (Nye, 1921) may be from the sequence. At St Marys and Poatina, the basal beds are more feldspathic (Eggert, 1983). In core from low, or in some cases perhaps below the sequence at Poatina, Eggert (1983) indicated detrital grains as feldspar 18%, quartz 12% and lithics 70%, and similarly for more widely distributed surface samples biased towards low stratigraphic horizons (fig. 6). Either K-feldspar or more usually plagioclase may dominate the feldspar fraction and orthoclase, microcline, rare perthite, oligoclase, andesine? and less commonly albite and labradorite occur. From north-eastern Tasmania, Bacon (1979) reported plagioclase as <7% and K-feldspar generally 0–1% but up to 4%. The feldspar grains tend to be subangular and altered, but some grains are optically clear. Biotite is the dominant mica (up to 5%), but muscovite also occurs. Of the lithic grains, Bacon (1979) indicated mudstone and siltstone were often very prominent (16–35%) and that rounded chert formed 4–13%. Calver (*in* Turner and Calver, 1987) considered volcanic grains to be conceivably the most common lithic component but often difficult to identify, Bacon (1979) indicating 1–10% and Eggert (1983) indicating about 50%. Except for minor granitic grains, the igneous and tuffaceous grains are very fine-grained to cryptocrystalline or devitrified glassy material. The igneous grains are often trachytic, some are flow-banded and some have a spherulitic fabric; they range from acid to basic with grains of intermediate composition probably most common. Dacite and alaskite occur. Other rock fragments include schist, slate, phyllite, chalcedony and coal. Heavy minerals include zircon, garnet, tourmaline, hornblende, ilmenite, topaz, rutile, epidote, apatite and sphene. (Lewis and Voisey, 1938; Hale, 1953, 1962; McNeil, 1965; Whitehead, 1963; Everard, 1970; Bacon, 1979; Eggert, 1983; Forsyth, 1984; Calver *in* Turner and Calver, 1987).

LUTITE

Lutite is usually light grey to black with lesser grey-green and brown types. Lutite occurs interbedded to laminated with sandstone.

LARGE EXTRABASINAL CLASTS

Many types of extrabasinal clasts occur in channel lags as scattered pebbles and cobbles, as thin conglomerate or as thicker 'Dalmayne Conglomerate'. Clasts are known throughout the north-eastern coal field from Stanhope to Apslawn and at various localities in the Midlands where boulders up to 400 mm occur (Nye, 1921; Blissett, 1959; Bacon and Everard, 1981; Forsyth, 1984, 1989; Calver, *op.cit.*). A record of volcanic bombs at South Cape Bay (Twelvetrees, 1915) may misidentify clasts. Clasts were probably rafted by trees and clast size may not reflect nearness to source (Forsyth, 1984). Less common clasts include granitic rocks, pink garnetiferous and white quartzite, vein quartz, chert, metamorphosed silicified conglomerate and Lower Parmeener Supergroup lithologies. Clasts with Permian fossils include silicified limestone, greywacke and conglomerate of volcanic constituents. Quartz feldspar porphyry clasts are more common and range from medium-grained to rocks with devitrified glassy groundmass and show a variety of textures similar to andesites, dacites and rhyolites. Tuffaceous clasts include ignimbrite of densely welded glass shards, other shard rich vitric types, coarse lithic crystal tuff with trachyte fragments, probably accretionary lapilli tuff and tuff with sodic plagioclase. Some clasts show a development of secondary spherulitic texture, whereas others are totally spherulitic or of myrmerkitic texture. Bipyrarnidal quartz phenocrysts are common in some porphyries including probable rhyolite. A number of porphyry clasts contain abundant chlorite-epidote. Some clasts may be dropstones eroded from the Lower Parmeener. Clast lithologies can be matched with Lower Palaeozoic rocks in western Tasmania, rock units in eastern Tasmania such as the Mathinna Beds and Devonian dykes and contemporaneous Triassic tuffs, but many of the unshered igneous rocks have no known source. Triassic tuffs and rhyolite clasts are chemically similar (Bacon and Everard, 1981).

Sedimentary features and architecture

The proportion of sandstone varies (Bacon 1979; Hale 1962), but where the sequence is reasonably complete sandstone generally predominates over lutite and coal measures and averages about 70% of the sequence (Kind 1980; Forsyth 1984; Summons 1984; Farmer 1985; Calver *in* Turner and Calver 1987). Mudstone beds and mudstone-dominated intervals occur up to 5-10 m thick or rarely at Poatina up to 27 m thick. Lutite is generally most common near the top and near the base of the sequence, forming transitional boundaries with older sequences. The sandstone occurs predominantly as parts of fining-up fluvial cycles. Near St Marys, sandstone forms uninterrupted units 15 m thick and there are intervals mainly of sandstone up to 40 m thick (Threader, 1968; Bacon, 1979; Threader and Bacon, 1983; Forsyth, 1984; Calver *in* Turner and Calver, 1987).

Commonly major fluvial cycles begin with erosive basal very coarse-grained sandstone beds that contain mud clasts, or high in the sequence, extrabasinal pebbles, cobbles or small boulders. Mud-clast breccia occur as lenses up to many tens of metres broad that probably formed in the deepest parts of channels. In the Midlands the basal cosets have a set amplitude of one metre. They rapidly pass up into small-scale festoon cross-bedded sandstone and eventually into rippled fine-grained sandstone and lutite in complete cycles. Occasionally somewhat thicker cosets up to 1.5 m thick fill troughs near

St Marys. The troughs are several metres broad and up to 40 m long. Under appropriate weathering conditions most sandstone beds near St Marys show festoon cross-bedding. Outcrops that clearly reveal sedimentary structures tend to be uncommon throughout Tasmania. Some beds contain coal and coalified wood. Large fossil logs up to one metre across occur in sandstone, usually as uncompressed silicified wood but in places as coal, ferruginous replacements as moulds, or as a combination of the above. The fossil logs commonly occur parallel to bedding and either parallel to or across the palaeocurrent direction or rarely they may occur in upright position. *In situ* tree roots occur in the Duncan Colliery. (Townrow in Spry and Banks, 1962; Bacon, 1979; Kind 1980; Forsyth, 1984; Calver *op. cit.*).

Using statistical methods Bacon (1979) showed that mudstone or siltstone, in places interbedded with sandstone, often separates major sandstone units. She showed further that the cycles that pass from sandstone into mudstone, or less commonly, mudstone interbedded with sandstone in most cases pass up into coal measures, often with a mudstone capping. Coal seams are often associated with claystone. In places the seat earths are the most kaolinitic horizon and the supra-coal claystones are chiefly composed of Ca-montmorillonite with lesser kaolinite and illite, whereas the montmorillonite of interseam claystone is often aluminous or sodic. The claystone components of other lithologies throughout the sequence are of these types (Bacon, 1979).

Provenance

A major hiatus between the Upper and Lower Parmeener Supergroup occurs in north-eastern Tasmania. This, and the presence of fossiliferous Lower Parmeener clasts in the upper part of the volcanic lithic sandstone sequence, and supportive palaeocurrent evidence (fig. 5c), suggests that the provenance probably was to the east of the present distribution limit of the sequence. The exact nature of the source-rock composition is probably clouded by second cycle detritus from the Lower Parmeener. Eggert (1983) considered the provenance of Upper Parmeener lithic sandstone in general, to have been calcalkaline volcanic and plutonic rocks and speculated a magmatic arc source. Tuff beds were derived from rhyolitic and rhyodacitic volcanoes.

Depositional environment

Based on the data of Threader and Bacon (1983), the cycles of the main coal-bearing interval south of St Marys show much uniformity: channel deposits were interpreted to form continuous sheets of sandstone over areas of many tens, perhaps hundreds of square kilometres. In places the channel sandstone contains isolated areas of finer-grained deposits that include couplets of coarse-grained sandstone and mudstone and these deposits may be channel fills. The main sandstone sheets are punctuated by intervals of finer-grained rocks with coal seams that are continuous over areas of tens of square kilometres. Apart from some root? bioturbated mudstone and rare mudcracks, there is little evidence for subaerial exposure or thick palaeosols in these fine-grained rocks. The latter were probably usually subaqueous until the basins were sufficiently isolated from the main channels and infilled for peat swamps to develop. Coals examined by Bacon (1986) were deposited in dry forest moor environments affected by fluctuating watertable conditions. Occasionally the finer-grained rock includes thin sandy wedges that may be crevasse splay deposits, and thicker (5 m) distributary? channel sandstone. Peat-forming conditions were often terminated by the introduction of thicker sand deposits in mud and silt, heralding the reappearance of major channels that not infrequently stripped sediments down to

cohesive peat layers that themselves were sometimes eroded or breached (Kind, 1980).

Townrow (1964) considered the climate to have been cool temperate. Conditions very favourable to seasonal growth are indicated (Morrison and Bacon, 1985).

The rocks are probably the deposits of high sinuosity rivers (Bacon, 1979; Eggert, 1983; Forsyth, 1984; Calver in Turner and Calver, 1987). Palaeocurrent azimuths are widely dispersed and locally the directions of different channel reaches may be polymodal or even bimodal. In some sub-regions no preferred current direction has been detected (N = 49, Calver in Turner and Calver, 1987). Amassed data from north-eastern Tasmania and the northern Midlands (Eggert, 1983; Forsyth, 1989; Castleden pers.comm.) suggests currents to the ENE quadrant occurred less commonly and this may have been the source direction. Near Oatlands, an average palaeocurrent to north-west has been determined (Forsyth, 1984). At Catamaran, slightly arcuate lateral accretion surfaces with northerly directed festoons may be part of a meander. The Duncan seam near Fingal is scoured by channels of linear, braided and less commonly meandrine tracts generally indicating flow towards the north-east or NNE (Kind, 1980), but these may not be the channels of the main rivers.

Palaeontology and age

There is only rudimentary knowledge linking palynomorph ranges to the coal seam stratigraphy (fig. 7). An horizon at Mount Nicholas with *Circulisporites parvus*, *Rogalskisporites cicatricosus*, *Annulispora microannulata*, *Punctatisporites leighensis*, *Cyathidites* sp. and *Aratrisporites flexibilis* (M. Playford in Threader, 1968) has been correlated lithostratigraphically with G seam (Calver and Bacon in Turner and Calver, 1987). *Annulispora microannulata* is certainly present in F seam at the Duncan Mine (M. Playford *op cit.*). Higher microfloras are poorly known at Fingal Tier, but *Aratrisporites parvispinosus* is present at seam C and *A. banksii*, *Semiretisporis denmeadii*, *Craterisporites rotundus* and *Polycingulatisporites densatus* are present below a coal seam correlated with seam A in DDH Fingal Range 58. A similar assemblage in DDH Fingal Range 83 occurs probably above seam A but below the 'Dalmayne Conglomerate'. This assemblage contains *A. banksii*, *S. denmeadii*, *P. densatus* and possibly *A. parvispinosus*. The Mount Nicholas horizon, and the interval from G seam to A seam and possibly the broader interval below the 'Dalmayne Conglomerate' from H seam to above A seam, may be correlated with the *Craterisporites rotundus* Zone (Carnian) of de Jersey (1975). In the Denison Rivulet, *Semiretisporis denmeadii* occurs immediately below a tuff (isotopic age 214±1 Ma; Bacon and Green, 1984) and associated coal. The lithostratigraphic correlative of the coal in borehole GRAY 27 C. A. Bacon (pers. comm) contains *A. parvispinosus*. Twenty metres higher in the bore the microflora of the *C. rotundus* Zone correlative is overlain by a younger microflora (F in fig. 2) containing *Camarozonosporites rudis*, *Discisporites psilatus* and *Cyathidites* spp. This microflora is correlated with the lower *P. crenulatus* Zone of Norian age (De Jersey, 1975, 1976; Stevens, 1981; Tozer, 1984). The isotopic age is close to the 215 Ma age proposed by Webb (1981) for the Carnian-Norian boundary.

Other correlatives of the *C. rotundus* Zone include coal measures near Longford (Playford, 1965) and correlatives indicated in Figure 8. Probable correlatives occur in the coal measures at Langloh (Morrison and Bacon, 1985) and at South Cape Bay (Forsyth, 1977).

Megaspores recorded by Dettmann (1961) from low in the coal measures on the Mount Nicholas Range include *Banksisporites pinguis*, *B. sinuosus*, *Nathorstisporites*

flagellatus and *N. reticulatus* and the older forms *Horstisporites microlumenus* and *Hughesisporites variabilis*. *N. reticulatus* and *H. variabilis* were only recorded from this basal interval which lies within the *C. rotundus* Zone correlative. The megaspores support correlation with the coal measures at Langloh and the Brady Formation.

The macroflora of the coal measures and some underlying rocks has been described by Johnston (1885, 1887, 1888, 1894, 1896), Walkom (1925, 1926), Townrow (1962, 1965, 1966) and Townrow and Jones (1969) and the nomenclature revised (Jain and Delevoryas, 1967; Herbst, 1977; Retallack, 1977, 1980, 1981, 1983). The macroflora of the volcanic lithic sandstone and coal measures sequence includes mosses, bryophytes, leaves (*Cladophlebis*, *Ginkophytopsis*, *Dicroidium*, *Johnstonia*, *Xylopteris*, *Pachydermophyllum*, '*Pachypteris*', *Dejerseyia*, *Heidiphyllum*, *Ginkgoites*, *Sphenobaiera*, *Linguifolium* and possible *Rissikia*), a microsporophyll (*Townrovia*), coniferous-type wood and tree ferns. Townrow (1966) suggested that two zones could be recognised based on the upward replacement of *D. odontopteroides* by *D. obtusifolium*. This now seems unlikely on absolute ranges but may reflect relative abundance of the species. Recent floral lists (Bacon, 1979; Forsyth, 1984; Calver in Turner and Calver, 1987) indicate occurrences of all varieties of *D. odontopteroides* (excluding *D. var. remotum*) and *Xylopteris elongata* recognised by Retallack (1977). Other taxa include *D. dubium* var. *dubium*, *D. cf. lancifolium*, *D. prolongatum*, *D. natalense*, *X. spinifolia*, *Johnstonia coriacea* var. *coriacea* (in places as paper coal), '*Pachypteris crassa*', *Cladophlebis australis*, *Ginkophytopsis* cf. *lacerata*, *Linguifolium tenison-woodsi*, *L. lilleanum* and *Heidiphyllum elongatum*.

Faunal remains are sparse but include conchostracans in the Brady Formation (Banks and Clarke, 1973) and a fossil cockroach *Triasoblatta tasmanica* and a heteropteran bug in the 'Newtown Coal Measures' (Riek, 1962, 1967).

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[14 December 1989]

APPENDIX A

List of Department of Mines Unpublished Reports, mainly by C. A. Bacon, in preparation for a major review of coal in Tasmania

1980/21 *Sedimentology of the Freshwater Sequence, Upper Parmeener Super-Group on Fingal Tier.* C. A. Bacon.

1981/10 *Report on the Department of Mines coal exploration programme at Fingal, Vol.1.* V. M. Threader, R. H. Castleden, C. A. Bacon.

1983/03 *Introductory notes for a survey of the coal resources of Tasmania.* C. A. Bacon.

1983/04 *The Cygnet coalfield.* C. A. Bacon.

1983/05 *The Kaoota (Sandfly) coalfield.* C. A. Bacon.

1983/06 *The Mt Lloyd coalfield.* C. A. Bacon.

1983/07 *The Merrywood coalfield.* C. A. Bacon.

1983/08 *The Strathblane, Hastings, Ida Bay, Moss Glen and Catamaran coalfields.* C. A. Bacon.

1983/22 *The Mount Christie - Stanhope coalfield.* C. A. Bacon

1983/33 *Coal intersections in a drill hole near Kempton.* C. A. Bacon

1983/34 *The Fingal coalfield.* C. A. Bacon

1983/36 *Analysis of coal from the Duncan seam, Duncan Colliery, Fingal.* C. A. Bacon.

1983/41 *The Mt Nicholas coalfield.* C. A. Bacon.

1983/46 *The Department of Mines coal exploration programme, Fingal Tier.* V. M. Threader, C. A. Bacon.

1984/10 *The Dalmayne coalfield.* C. A. Bacon, C. R. Calver.

1984/12 *The Seymour coalfield.* C. A. Bacon, C. R. Calver.

1984/14 *The Douglas River coalfield.* C. A. Bacon.

1984/17 *The Mt Paul coalfield.* C. A. Bacon.

1984/22 *The Denison Rivulet coalfield.* C. A. Bacon.

1984/37 *The Schouten Island coalfield.* C. A. Bacon, K. D. Corbett.

1984/41 *Analysis of coal from the Blue Seam, Blackwood Colliery, Mt Nicholas.* C. A. Bacon.

1984/57 *Petrographic and proximate analyses of the Merrywood Seam, Merrywood Colliery, north-east Tasmania.* C. A. Bacon.

1984/66 *Petrographic analysis of the Duncan Seam, Duncan Colliery, Fingal.* C. A. Bacon.

1985/09 *Petrographic and proximate analyses of coal from the York Plains coalfield.* C. A. Bacon.

1985/14 *The York Plains coalfield.* C. A. Bacon, S. M. Forsyth.

1985/27 *The Saltwater River coalfield.* C. A. Bacon.

1985/30 *The Bagdad - Kempton coalfield.* C. A. Bacon.

1985/31 *The Langloh (Lawrenny) coalfield.* C. A. Bacon.

1985/38 *The Mersey - Don coalfield.* C. A. Bacon.

1986/03 *The Adventure Bay coalfield.* C. A. Bacon.

1986/04 *The Llandaff coalfield.* C. A. Bacon.

1986/05 *The Longford coalfield.* C. A. Bacon.

1986/06 *The Mike Howes Marsh coalfield.* C. A. Bacon.

1986/07 *The New Town coalfield.* C. A. Bacon.

1986/08 *The George Town coalfield.* C. A. Bacon.

1986/09 *The Richmond coalfield.* C. A. Bacon.

1986/10 *The Colebrook (Jerusalem) coalfield.* C. A. Bacon, M. J. Dix.

1986/11 *Minor coal areas in southern Tasmania.* C. A. Bacon.

1986/12 *The Woodbury coalfield.* C. A. Bacon.

1986/22 *The history of coal mining in Tasmania.* C. A. Bacon.

1986/35 *Analysis of coal from the Fenhope Colliery, near Avoca.* C. A. Bacon.

1986/43 *Coal in Tasmania.* C. A. Bacon.

1986/60 *Correlation of coal seams in north-eastern Tasmania.* C. A. Bacon, C. R. Calver.

APPENDIX B
List of Open File Company Reports dealing with coal

Microfiche copies of the reports listed are available at the prices shown

TCR 12-013 (1)	\$3.00	TCR 75-1101 (5)	\$7.00
REPORT ON COAL PROPOSITION EAST OF RECHERCHE BAY. FEB 1913.		REPORT ON THE COAL OCCURRENCES AND POTENTIAL OF EL 5/61. JUNE 1975.	
* F. NOETLING.		* IMI PTY LTD	
TCR 12-014 (1)	\$3.00	TCR 75-1105 (1)	\$3.00
REPORT ON CATAMARAN COAL SEAMS. CATAMARAN. FEB 1912.		EVALUATION OF COAL OCCURRENCES AT IDA BAY WEST OF SOUTHPORT LAGOON [EL 16/74]	
* F. NOETLING.		* EARTH RESOURCES AUST. PTY. LTD.	
TCR 23-028 (1)	\$3.00	TCR 76-1166 (5)	\$7.00
EXAMINATION OF THE COAL AREA HELD BY LEPRENA C. M. CO. LEPRENA. MAR 1923.		SUMMARY REPORT ON COAL DRILLING OPERATIONS AT IDA BAY & STRATHBLANE PLAINS. JUNE 1976.	
* L. C. M. CO.		[EL 19/75]	
TCR 31-048 (1)	\$3.00	* EARTH RESOURCES AUST. PTY LTD.	
SEYMOUR COAL MINES REPORT. SEYMOUR. SEPT 1931.		TCR 77-1201 (1)	\$3.00
* W. H. CUNDY.		EL 16/76. AVOCA. REPORT FOR 6 MONTHS AUGUST 1976 TO FEBRUARY 1977.	
TCR 44-088 (1)	\$3.00	* WESTERN MINING CORPORATION PTY LTD.	
PROPOSALS FOR THE PROVISION OF WHARFAGE FOR THE RE-OPENING OF THE SEYMOUR COAL MINE. SEYMOUR. NOV 1944.		TCR 77-1206 (3)	\$5.00
* SEYMOUR COAL CO.		EL 16/76 AVOCA. TERMINAL REPORT	
TCR 59-284 (1)	\$3.00	* WESTERN MINING CORPORATION PTY LTD.	
REPORT ON THE GEOLOGY OF MOORE'S VALLEY. 9 DECEMBER TO 25 MARCH. [EL 3/59]		TCR 78-1243 (2)	\$4.00
* LYELL-E. Z. EXPLORATIONS.		PROGRESS REPORT DURING 1974 - 1977. [EL 43/70] ARTHUR RIVER.	
TCR 60-312 (2)	\$4.00	* MINERAL HOLDINGS AUST PTY LTD.	
GREAT LAKE POWER DEVELOPMENT CORNWALL COLLIERY TEST DRIVE GEOLOGICAL NOTES.		TCR 78-1278 (3)	\$5.00
* HYDRO ELECTRIC COMMISSION(TAS).		EL 16/77 ROYAL GEORGE. REPORT FOR 6 MONTHS, DECEMBER 1977 TO JUNE 1978.	
TCR 69-552 (2)	\$4.00	* INVESTIGATOR COAL EXPLORATION.	
GEOLOGICAL REPORT 1966 - 67. [EL 13/65] SOUTH WEST TASMANIA.		TCR 78-1282 (2)	\$4.00
* BHP COMPANY LTD.		EL 18/77 AVOCA. 6 MONTHLY REPORT PROGRESS REPORT FOR PERIOD ENDING JULY 1978.	
TCR 71-772 (2)	\$4.00	* SHELL COMPANY OF AUST. LTD.	
EL 42/70 & EL 12/71. JUNE 1971.		TCR 78-1285 (3)	\$5.00
* MURCHISON NICKEL LTD		EL 5/61. GRAY. 6 MONTHLY PROGRESS REPORT FOR PERIOD ENDED 23 AUGUST, 1978.	
TCR 71-778 (1)	\$3.00	* INDUSTRIAL & MINING INVESTIGATIONS.	
"FINGAL COAL" EL 14/71. JULY 1971.		TCR 79-1324 (3)	\$5.00
* GIPPSLAND MINERALS N. L		EL 16/77 ROYAL GEORGE. REPORT FOR 6 MONTHS. JUNE TO DECEMBER 1978.	
TCR 74-992 (2)	\$4.00	* INVESTIGATOR COAL EXPLORATION.	
PROGRESS REPORT. [EL 19/72] DIAL RANGE. FEB 1974.		TCR 79-1333 (5)	\$7.00
* CRA EXPLORATION PTY LTD.		PRELIMINARY PROPOSAL FOR THE EXPLOITATION OF COAL RESERVES IN THE FINGAL COALFIELD. JUNE 1979.	
TCR 74-1000 (1)	\$3.00	* ROBERTSON RESEARCH (AUST) PTY LTD	
ASSESSMENT OF COAL DEPOSITS IN SOUTH EASTERN TASMANIA. EL 16/74. MARCH 1974.		TCR 79-1334 (5)	\$7.00
* EARTH RESOURCES AUST. PTY LTD		EL 18/77 AVOCA. 6 MONTHLY PROGRESS REPORT FOR PERIOD ENDING JANUARY 1979.	
TCR 74-1057 (1)	\$3.00	* SHELL COMPANY OF AUSTRALIA LTD	
STAGE 1 INVESTIGATIONS. COAL DEPOSITS. SOUTH EASTERN TASMANIA. NOV 1974.		TCR 79-1338 (31)	\$33.00
* A. P. M. LTD.		SIX MONTHLY PROGRESS REPORT ON EXPLORATION. [EL 5/61] GRAY. FEB 1979.	
TCR 75-1090 (2)	\$4.00	* SHELL COMPANY OF AUSTRALIA LTD.	
CATAMARAN COAL PROSPECT. EL 16/74. MAY 1975.			
* APM LTD			

TCR 79-1339 (3) \$5.00
 EL 18/73 & 2/63. DRILL LOGS.
 * RENISON LTD

TCR 79-1372 (1) \$3-00
 PROGRESS REPORT FOR AUGUST 1979.
 [EL 7/79]. MT. DURHAM.
 * MCELROY BRYAN & ASSOC. PTY. LTD.

TCR 80-1442 (3) \$5.00
 REPORT ON FIELD INVESTIGATIONS OF
 THE HALL CREEK - SPECIMEN CREEK AREA
 EL 4/61, 5 JUNE 1980.
 * INDUSTRIAL & MINING INVESTIGATONS.

TCR 80-1449 (3) \$5.00
 TASMANIAN OIL-SHALE PROSPECTS. FINAL
 BY GENERAL GEOLOGICAL SERVICES. [EL
 17/79, 18/79, 19/79, 21/79]
 * PETRO QUEST PTY LTD.

TCR 80-1458 (1) \$3.00
 REPORT FOR THE YEAR ENDED AUGUST
 1980.
 [EL 19/78]. WELDBOROUGH.
 * ABERFOYLE EXPLORATION PTY LTD.

TCR 80-1461 (7) \$9.00
 PROGRESS REPORT. [EL 12/72].
 BULGOBAC. JULY 1980.
 * ELECTROLYTIC ZINC CO OF A'ASIA LTD.

TCR 80-1463 (2) \$4.00
 TASMANIAN COAL PROSPECTS QUARTERLY
 INTERIM REPORT. JUNE 1980.
 [EL 26/79-27/79-28/79 & 29/79]
 * CAPRICORN MINING LTD.

TCR 80-1493 (2) \$4.00
 FIRST SIX MONTHLY REPORT ON EL 6/79
 (CATAMARAN) FOR PERIOD 16-5-1980 TO
 15-11-1980.
 * MARATHON PETROLEUM AUST. LTD.

TCR 81-1512 (3) \$5.00
 EL 18/77. AVOCA. PROGRESS REPORT
 * SHELL COMPANY OF AUSTRALIA LTD.

TCR 81-1513 (3) \$5.00
 FINAL REPORT OF SOUTHEASTERN
 TASMANIAN COAL PROSPECTS.
 [EL 26/79-27/79-28/79 & 29/79]
 * CAPRICORN MINING LTD.

TCR 81-1518 (3) \$5.00
 THIRD QUARTERLY REPORT [EL.6/79.]
 CATAMARAN. NOV 1980 TO FEB 1981.
 * MARATHON PETROLEUM AUST LTD.

TCR 81-1522 (5) \$7.00
 PROGRESS REPORT ON EXPLORATION IN
 THE PERIOD NOV 1979 TO JULY 1980.
 [EL.5/61.] GREAT OYSTER BAY.
 * THE SHELL COMPANY OF AUST LTD.

TCR 81-1559 (1) \$3.00
 THREE MONTHLY REPORT. [EL 25/78].
 MOULTING LAGOON. NOVEMBER 1980.
 * MEEKATHARRA MINERALS LTD.

TCR 81-1562 (8) \$10.00
 RENEWAL & PROGRESS REPORT TO MAY 21,
 1981. EL 31/80. BELLS LAGOON AREA.
 * VICTOR PETROLEUM & RESOURCES LTD.

TCR 81-1570 (3) \$5.00
 EL 18/77. AVOCA. A REVIEW OF THE
 COAL RESOURCES AND PROSPECTIVITY.
 MAY 1981.
 * SHELL COMPANY OF AUSTRALIA LTD.

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