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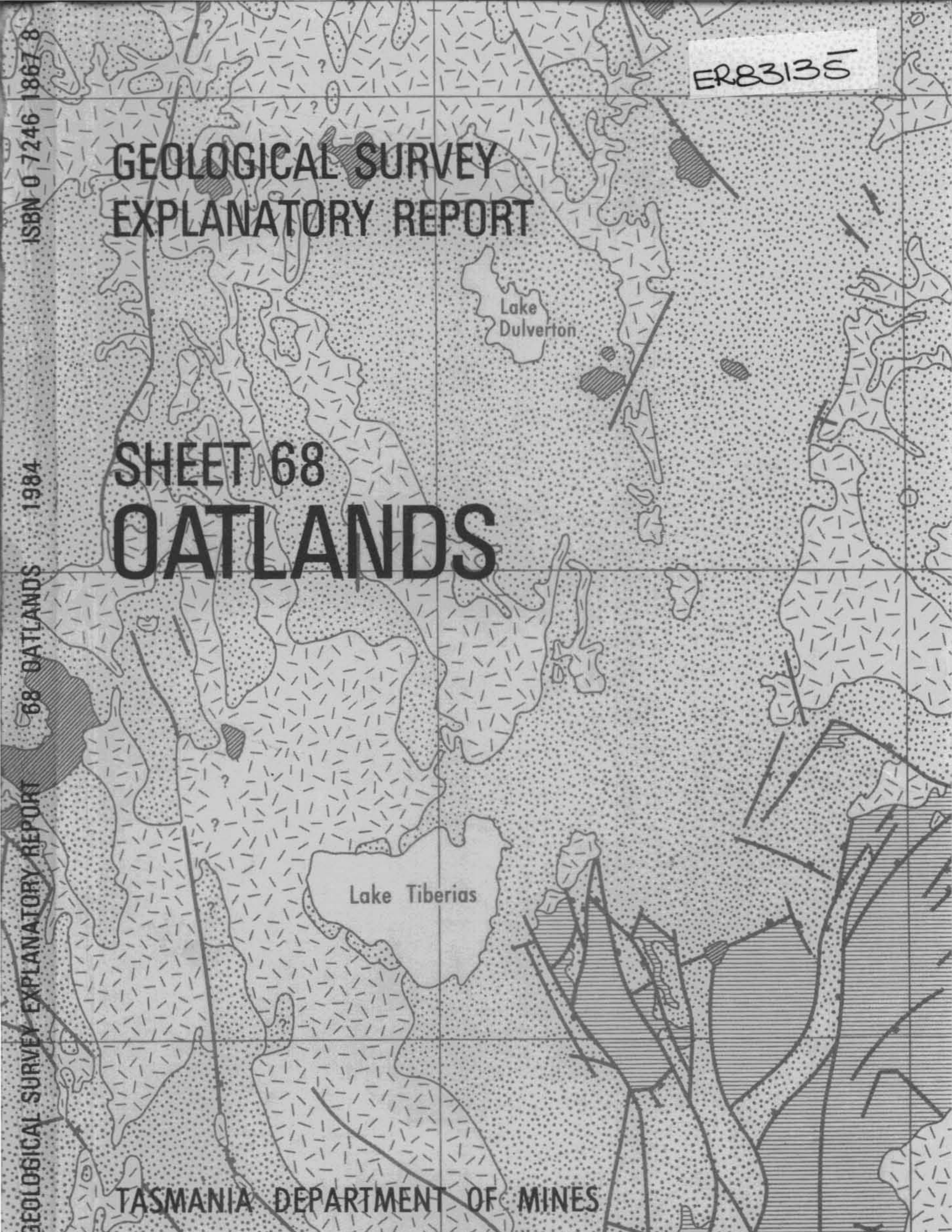
# GEOLOGICAL SURVEY EXPLANATORY REPORT

# SHEET 68
# OATLANDS




TASMANIA DEPARTMENT OF MINES

GEOLOGICAL SURVEY EXPLANATORY REPORT 68 OATLANDS 1984

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1984

# GEOLOGICAL SURVEY EXPLANATORY REPORT

GEOLOGICAL ATLAS 1:50000 SERIES

SHEET 68 (8313S)

# OATLANDS

*by S.M.FORSYTH, B.Sc.*

*with contributions by F.L. SUTHERLAND, B.Sc.(Hons.), M.Sc., Ph.D., and A.V. BROWN, B.Sc.(Hons.).*

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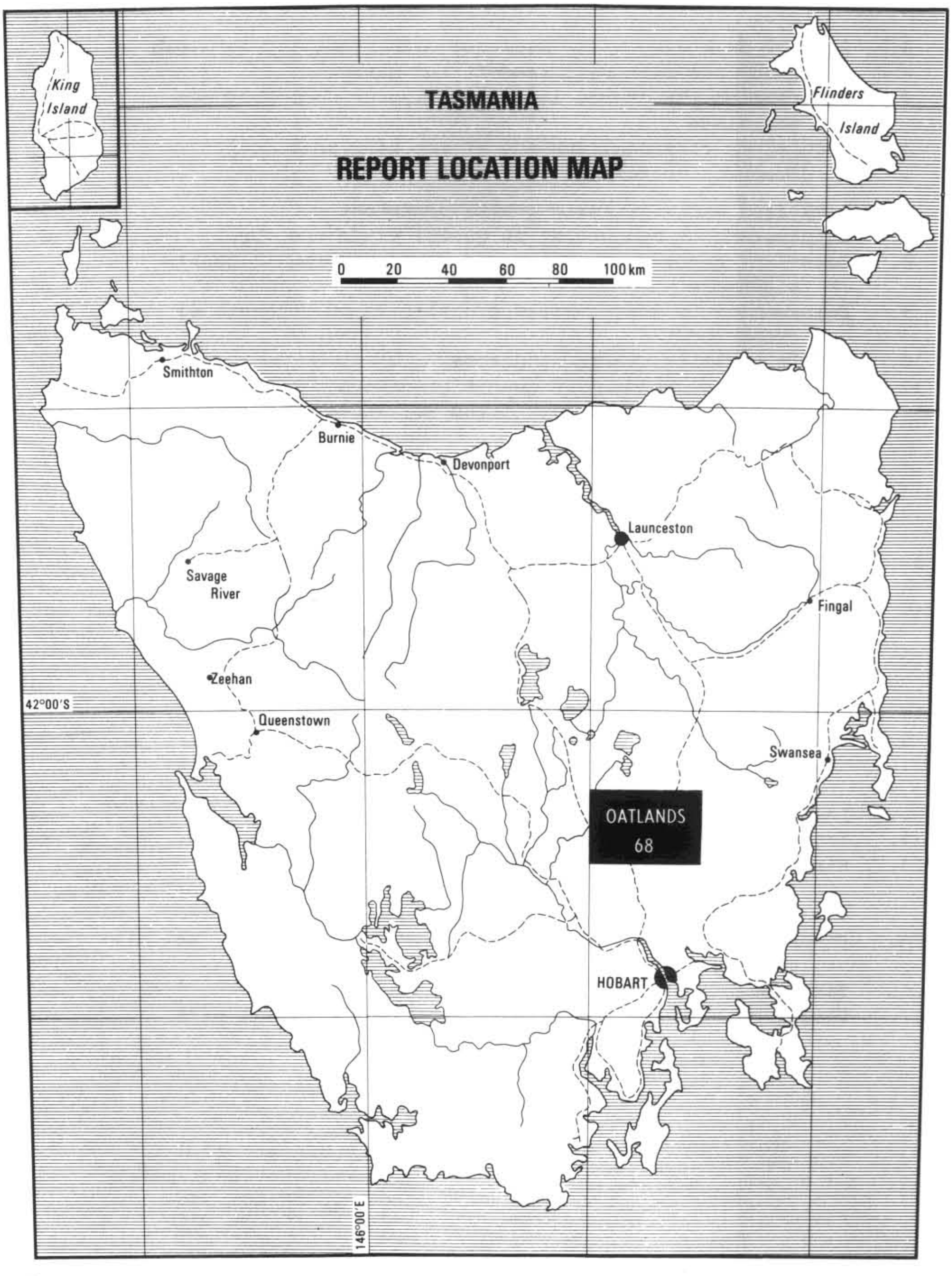


Figure 1. *Location of Oatlands Quadrangle.*

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# INTRODUCTION

The Oatlands Quadrangle (fig. 1) is situated about 50 km north of Hobart in the lower Midlands area and is crossed by both the railway and Midland Highway linking Hobart and Launceston. The largest town is Oatlands [EP305165], which has a population of about 600 and is situated on the Midland Highway. The Lake Highway junctions with the Midland Highway at Melton Mowbray [EN147978] and passes through the second largest town, Bothwell [EP005074], situated on the River Clyde on the western margin of the quadrangle. Numerous villages and settlements occur south-east of Oatlands, the largest of these being Parattah [EP334110] and Tunnack [EN378996]. A network of secondary roads enables all areas within the quadrangle to be reached by walking in less than half a day.

Much of the area has been cleared for pastoral use resulting in sparsely wooded, rolling hills or open plains running back into higher and usually steeper, lightly forested dolerite terrain or deeply dissected sandstone terrain. It is only in the Woods Quoin area [EP075180] in the north-western corner of the map, the Den Hill [EP070010] area, and deep gullies south of Tunnack [EN378995] that extensive forested areas occur. Pastoral activity is most intense on the plains along the Clyde, Jordan, and Coal Rivers, often with irrigation during summer. Logging occurs intermittently and Parattah is a major railway depot for log transport. Very small quantities of coal have been mined from York Plains [EP361189] and building stone has been quarried at various localities from time to time.

Because of the low rainfall over much of the quadrangle, the first regional scale geological sketch mapping was undertaken in an attempt to locate underground water reserves (Nye, 1921). Several hundred water bores have been drilled, mostly in the eastern half of the quadrangle, particularly following recent dry winters.

Mapping for this project was commenced by B.F. Abtmaier in the Oatlands area about 1970, with Nye's map, a soil map of the quadrangle (Cowie, 1959), and maps by Hughes (1950*a*), Moore (1968*a-d*), Butters (1970), and Matthews (1959) the main indicators of regional rock distribution. Leaman (1971) had already mapped the Tunnack area as an extension of the Brighton Quadrangle for an underground water assessment of the Coal River basin. The initial mapping by Abtmaier was hampered by a lack of suitable topographic maps and subdued topography leading to a lack of exposed geological sections. Consequently no stratigraphy of the Upper Parmeener Super-Group was determined by Abtmaier and it has been necessary to depict this area of the quadrangle as largely undifferentiated Upper Parmeener Super-Group on the map and to add all of Abtmaier's field data on these rocks in symbolic form. Abtmaier deduced a fault pattern based rarely on fault exposures, but mostly on topographical variation of dolerite outcrops and occasionally on lithological change. Because of the unpredictable variability of dolerite intrusions, the method of deducing structure based on dolerite altitude is regarded by the writer as unreliable and these faults have been omitted from the map but are instead presented in Appendix 2. Where investigated, faults based on lithological change have been found to be formation boundaries. Subsequent to Abtmaier ceasing mapping, the writer mapped the remainder of the quadrangle, including some remapping of Leaman's Tunnack area, in particular remapping most outcrops of the basal Upper Parmeener Super-Group rocks. Leaman has revised his contribution to the Oatlands 1:50 000 map based on this remapping. In compiling the final map the writer has transferred Abtmaier's aerial photo map to the topographic map with some revisions and additions, and with reference to a collection of rock samples made by Abtmaier and limited remapping.

These explanatory notes incorporate all new data which has become available since map publication in 1976, including drilling results and new sections exposed on the realigned Midland Highway, revisions required by mapping along the Oatlands-Interlaken Quadrangle boundary, and visits to the Oatlands Quadrangle during preparation of these notes.

Invertebrate palaeontology largely follows the nomenclature of Clarke and Farmer (1976) and the nomenclature of *Dicroidium* and related genera follows Retallack (1977).

ACKNOWLEDGEMENTS

The writer wishes to acknowledge the assistance and express thanks to a number of people. In particular numerous field visits by Dr E. Williams and Dr N. Farmer have led to many useful suggestions and discussions and critical examination of field mapping. M.J. Clarke similarly assisted with Lower Parmeener Super-Group stratigraphy and palaeontology and checked and revised all identifications of Permian invertebrates. Dr M.R. Banks (University of Tasmania) has maintained an encouraging interest in the geology of the area and has made available a useful manuscript on the stratigraphy of Triassic rocks in Tasmania. Dr P.R. Williams assisted with Markovian analyses and discussed sedimentological concepts. W.L. Matthews and P. Ruzicka assisted in locating underground water bore records and site locations. Other colleagues too numerous to list have assisted from time to time, particularly in petrographical matters.

Several people external to this Department have also contributed in a variety of ways. The writer has been stimulated by the enthusiasm of Dr J.M. Anderson (Botanical Research Institute, Pretoria) and W.B.K. Holmes during their visits to observe Tasmanian fossil floras and benefited from discussions with Dr J. Collinson (Institute of Polar Studies, Ohio State University) concerning palaeocurrent analysis. B. Weldon (Department of Main Roads) drew attention to several fully cored holes drilled along the realigned route of the Midland Highway and made the core available for inspection. Dr N.J. de Jersey and J.L. McKellar (Geological Survey of Queensland) have given the writer basic training in palynological processing. R. Smithhurst and G. Hodge assisted in the field.

Special thanks must go to Dr F.L. Sutherland (Australian Museum, Sydney) who has agreed to write the section on Tertiary volcanic rocks, the Bedford family who made my stay at the Castle Hotel, Bothwell a pleasant one, and to my wife, not only for considerable patience during the completion of this work but also for assisting in the field.

The co-operation of land owners throughout the Oatlands Quadrangle is gratefully acknowledged.

PREVIOUS WORK

Strzelecki visited the area in the early 1840's and later published a description of a section in Middle Triassic rocks and a list of identifications by J. Morris of the associated fossil flora at the Guard House Well [EP212023] (Strzelecki, 1845). Strzelecki also collected new species of Permian invertebrates from an unknown locality west of Spring Hill which were also described by Morris in the same publication. Gould (1869) listed several coal outcrops and the distribution of potential coal-bearing strata along the proposed railway route and near Jericho [EP234074].

Gould considered that the coal measures underlay quartz sandstone and that the dolerite was extrusive.

Johnston (1888) more fully described Upper Parmeener Super-Group sections along the Midland Highway, recognised that some dolerite was intrusive, and added to the lists of fossil flora.

Nye (1921, 1922) produced sketch maps on a scale of about 1:83 000 of parts of the quadrangle and described the stratigraphy and lithology of the major rock types. Nye's mapping was not sufficiently detailed to locate faults, except at York Plains and along the Coal River. Nye recognised that the dolerite was fully intrusive, placed the "Trias-Jura" coal measures correctly above the Early Triassic quartz sandstone, and maintained Gould's concept of further quartz sandstone occurring above the coal measures. Nye's belief that the Permian marine rocks belonged to the Lower Marine series is now known to be incorrect.

Additional faults near York Plains were indicated by Nye (*in* Hills *et al.*, 1922).

Localised investigations were carried out for engineering purposes, petrology, coal prospects, underground water, and limestone by various geologists including Nye (1928), Blake (1936*a*, *b*), Lewis and Voisey (1938) and Hughes (1950*a*, *b*, 1952, 1957).

Hughes (1950*a*) produced a geological map of the Bothwell district. A reconnaissance soil map by Cowie (1959) gave the best indication of rock distribution for the entire quadrangle and was partly used for compiling the Oatlands 1:250 000 map (Gulline and Forsyth, 1976). The Tunnack area was mapped by Matthews (1959). Dam site investigations during the 1960's by MacLeod (1962*a*, *b*), Stevenson (1968*a*, *b*), and Moore (1968*a*, *b*, *c*) produced detailed local geological maps and a regional map of part of the River Jordan (Moore, 1968*d*). Geological and underground water investigations of Lake Tiberias [EP300030] and the Coal River Basin are presented in Leaman (1968; 1971). The latter publication includes a 1:63 360 scale coloured geological map which has been used with some revisions for part of the south-east corner of the 1:50 000 map of Forsyth *et al.* (1976). Spry and Solomon (1964) described in detail the contact metamorphic rocks around basalt necks [EP095054] near Apsley. A nearby tuff [EP112037] was petrologically described by Everard (1968). Butters (1970) further described the tuff deposit, produced total magnetic intensity maps around some of the basalt necks, and geological and gravity maps of the Apsley area. Results of underground water boring were listed by Matthews (1961, 1963) and road building materials were listed for the Oatlands Municipality by Threader (1968*a*). Subsequent to the 1:50 000 map being published (Forsyth *et al.*, 1976), Ruswandi (1977) conducted a gravity survey leading to structural interpretations and the location of dolerite feeders in the south-western part of the area. Geochemical surveys and coal exploration have been carried out by private companies.

## PHYSIOGRAPHY

The physiography of the Oatlands Quadrangle is largely controlled by the distribution of rock types (particularly dolerite) and the effect of this distribution, and of faulting, on the drainage pattern. There are two main areas where the height is due to the occurrence of major dolerite intrusions. In the south-western corner of the quadrangle 30 $km^2$ of mountainous dolerite terrain occurs over 600 m above sea level, rising to 840 m on Den Hill [EP070010]. High country also occurs on the periphery

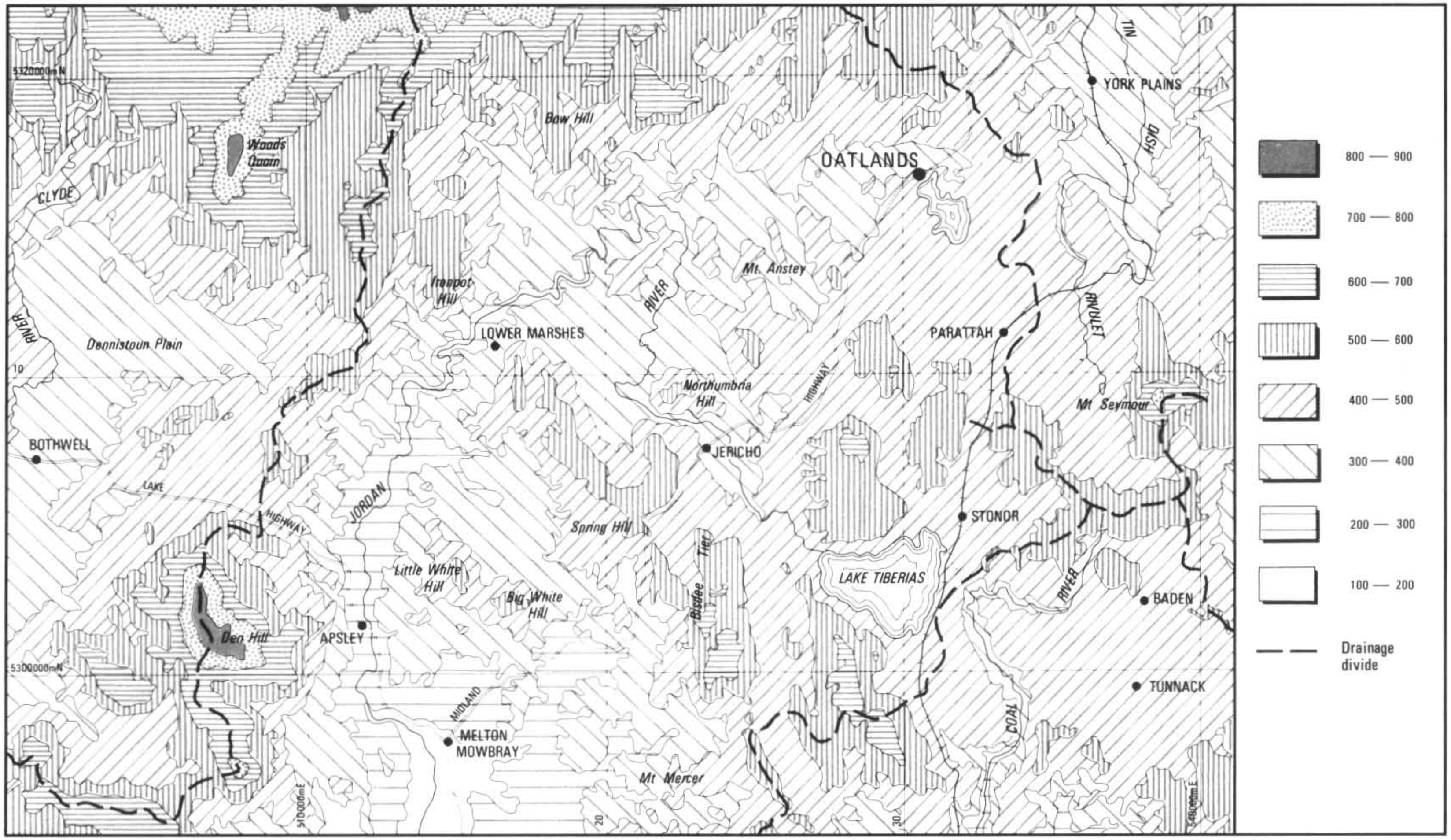



Figure 2. *Generalised relief of Oatlands Quadrangle (metres above sea level) and drainage divides.*

5 cm

of the dolerite country of the Central Plateau along the north-western margin of the quadrangle. At Woods Quoin [EP077178] (923 m) the remnants of a higher level dolerite intrusion caps a thick Triassic sequence of sedimentary rocks that rise above the general level of the Central Plateau intrusion.

Areas of more mature landscape development are found on the plains near Bothwell and elsewhere on an apparent surface 400-500 m above sea level, with lesser areas between 500 and 600 m above sea level. Rising from this surface are several dolerite hills which exceed 600 m above sea level (see fig. 2). Dissection of this surface to below 200 m above sea level, principally by the Jordan and Coal Rivers, has resulted in an increasing markedness of youthfull landscape features downstream along these rivers. On a smaller scale the valleys of the Jordan River and Tin Dish Rivulet have developed more mature reaches upstream of local base level barriers.

In the areas of more mature landscape broad shallow basins developed in sedimentary rocks are separated by ridges and massifs of dolerite. A series of such basins separated by NNW trending dolerite ridges is crossed by the Midland Highway north of Spring Hill [EP208049]. The basins contain plains and rolling hills with occasional benches of Triassic sandstone. Steeper slopes are developed where sedimentary rocks abut against, or are capped by igneous rocks. Conical hills at York Plains are notable examples.

Five drainage systems influence the area (fig. 2). The Clyde, Jordan, and Coal Rivers flow to the south. Blue Hills [EP393059] forms the watershed that separates the Coal River from the north-flowing Tin Dish Rivulet, while a small area of 12 $km^2$ east of Blue Hills is drained by several short steep creeks which flow into the Little Swanport River.

Tin Dish Rivulet drains an area of about 125 square kilometres. Near Andover [EP368133] the rivulet flows through a slightly incised valley cut into sandstone terrain before the broader York Plains basin is reached. Surrounding the York Plains basin are hills capped with dolerite or basalt, some of which show remarkable conical form.

The Coal River and some of its tributaries have cut back deep gorges into the flat country near Tunnack. The gorges are up to 200 m deep, in places strongly fault controlled, and exhibit numerous cliff faces bounding Triassic sandstone benches. The Coal River gorge east of Lake Tiberias is cut very close to the water divide between the Coal River and Jordan River systems. The upper reaches of the Coal River may have once continued in their westward direction to flow into Lake Tiberias but the river now swings abruptly to flow south-easterly near Tunnack.

The River Clyde follows a meandering gorge cut into the Central Plateau before entering the extensive plains north of Bothwell. An area of 260 $km^2$ is drained by the Clyde including the upland basins accompanying Fordell [EP115180] and Bryans Creeks [EP076205] and the western slopes of the Den Hill area.

Between Melton Mowbray and Lower Marshes [EP162114] the valley of the Jordan River follows a major fault system. The Jordan flows in a marsh-floored broad valley below the 200 m contour near Melton Mowbray, but south of Apsley the valley is constricted and the river has cut a meandering gorge through dolerite and lithic sandstone. A tributary, Quoin Rivulet, has deeply dissected the sandstone terrain east and north-east of Melton Mowbray. Upstream from Apsley [EP120015] the valley is again floored by a series of broad marsh flats. West of these marshes several short streams have cut valleys into Permian mudstone, while to the east several cuestas dip east at up to 20° and the streams have cut sandstone-bench lined valleys back towards Rose Hill [EP180091] and the flat-topped basalt hills, Little White Hill [EP150034] and Big White Hill [EP168023].

A further narrow constriction of the Jordan Valley occurs at Sandy Toms Rocks [EP146096] where the river has penetrated the spur of dolerite that runs north-west from Spring Hill Tier [EP219035]. Immediately downstream [EP135095] alluvial deposits occur over 20 m above the present river and may indicate recent incision. Upstream the 400 m contour defines a rapid broadening of the valley, although the river itself meanders deeply incised in sandstone at Toms Hill [EP150103] and Burnt Log Gully [EP212152]. Higher level alluvial deposits [EP180141] north of Red Sugarloaf may indicate the location of a former river course.

The Jordan River flows out of Lake Tiberias in a north-westerly direction towards Lower Marshes. Two kilometres west of Northumbria Hill [EP203096] the river swings abruptly to the NNE for six kilometres to where it is joined by the Dulverton Rivulet [EP224156] before returning towards Lower Marshes. Along this departure the Jordan passes through country that is topographically higher than along the direct course to Lower Marshes and it is probable that the upper reaches of the Jordan have been captured by the Dulverton Rivulet.

The majority of the Tertiary basalt flows lie on rocks whose maximum altitudes range from 460 to 560 m regardless of whether they occur in mature or dissected areas. Exceptions to this occur north of Bow Hill [EP183185] where the basalt occurs at higher elevations, and along the Clyde and Jordan River Valleys (see page 104). Where the physiography is more mature, the basalts are only slightly higher than the general topography and indicate little erosion of these areas since pre-basalt times. If a uniform surface once existed over much of the mapped area its dissection had commenced before basalt extrusion had ceased.

## STRATIGRAPHY

### Lower Parmeener Super-Group

The main Lower Parmeener Super-Group outcrops occur in two uplifted areas 20 km apart; one near Tunnack [EP390000], the other west of the Jordan River [EP110070]. The basal beds are not exposed. All of the exposed beds belong to the Upper Marine sequence.

#### UPPER MARINE SEQUENCE

#### *CALCAREOUS BEDS (P1)*

*Lithostratigraphy*

The oldest exposed Permian rocks belong to a richly fossiliferous calcareous sequence. In the vicinity of Limekiln Spur [EP108082] 70 m of this sequence is exposed between an intruded dolerite sheet and overlying sandstone beds. The calcareous sequence consists predominantly of calcareous siltstone and very impure limestone composed of sand and granule-size shell and rock fragments in a limey matrix. Fossils are common in both lithologies and dropstones of quartzite, quartz, and slate occur. The bed thickness and proportion of limestone are variable.

In the lower part of the Limekiln Spur sequence, impure limestone exceeds siltstone and about eight metres of the sequence has been quarried for limestone. Analysis of a grab sample reported by Hughes (1957, p. 196) shows a $CaCO_3$ content of 24% and $SiO_2$ of 68%. The limestone beds exposed in the quarry range in thickness from 0.4-0.7 m and the siltstone forms beds 0.1 m thick. The limestone consists mainly of brachiopod, mollusc, bryozoan and crinoid shell debris. Branching stenoporids occur in the limestone and flat masses of *Stenopora crinita* occur in both lithologies. Other fossils include *Eurydesma* and *Deltopecten*.

Although this part of the sequence is similar to the Berriedale Limestone, the sequence is less uniform, contains a lower proportion of impure limestone beds, and a greater proportion of non-calcareous clastic grains. The fauna clearly indicates that the sequence is younger than the Berriedale Limestone.

Above the quarry workings the siltstone beds become thicker (0.3-0.6 m) and dominate the sequence. Impure limestone occurs as individual beds or as groups of beds 1-2 m thick. Dropstones up to 80 mm diameter occur. Some of the calcareous siltstone and calcareous sandstone layers are unfossiliferous.

Other workings occur towards the top of the spur. Here the most calcareous beds are massive lenticular siltstone (with spiriferids and bryozoans) that grade into gravelly siltstone in which the proportion of shell debris increases. These beds contain more sand and granule-size quartz than beds lower in the sequence. Subordinate bryozoan siltstone layers are present. Some lenticular beds occur and contain abundant brachiopods, quartz, and quartzite pebbles. The largest dropstones observed were 250 mm in diameter.

Towards the top of the sequence the limestone and calcareous siltstone beds contain more siliceous material from sand to pebble size. Other rock types include unfossiliferous siltstone, poorly fossiliferous sandstone with pebble lenses, as well as fossiliferous siltstone and sandstone devoid of matrix carbonate. Fossils include *Deltopecten*, *'Atomodesma'*, *Wyndhamia dalwoodensis*, *Ambikella* and other spiriferids, *Fenestella*, *Protoretepora*, and *Stenopora*. Some beds are particularly rich in *Wyndhamia* and *Deltopecten* and the lithology resembles rocks present in the Cascades Group of the Hobart area.

The top ten metres of the sequence at most localities is noticeably less fossiliferous and less calcareous. This part of the sequence on Limekiln Spur probably contains small faults and the field relationships may be slightly uncertain. It appears that the following sequence of beds occurs in descending order;

(i) sandstone beds (Ph)
(ii) sandstone
(iii) massive non-calcareous siltstone with rare fossils
(iv) small non-exposed interval
(v) fossiliferous sandstone with granules and pebbles
(vi) impure limestone beds

Further east at EP115084 interbedded limestone, calcareous siltstone, and sandstone, commonly with dropstones, are overlain by calcareous sandstone with sand to pebble grade quartz. The few metres between the calcareous sandstone and the overlying sandstone unit (Ph) is only poorly exposed but includes siltstone beds. A few hundred metres to the east a calcareous bryozoan siltstone occurs almost immediately below Ph. Core from a hole drilled at EP125063 shows that the top ten metres of the calcareous beds consist largely of slightly calcareous siltstone and fine-grained sandstone with hydro-plastic and bioturbation structures. Limestone is subordinate, the highest bed is only 80 mm thick and occurs 7 m below the Ph unit. Fossils are common and pebbles and quartz granules constitute over 5% of the rock in some horizons. The highest fossils occur in a 100 mm thick medium to coarse-grained sandstone with quartz granules. The sandstone passes up into bioturbated yellow and grey sandy siltstone with (3%) small quartz pebbles, which in turn grades up into the better sorted white sandstone of Ph. Poorly exposed fossiliferous siltstone and sandstone occupy the top ten metres at EP108074 and the beds immediately below Ph consist of a fossiliferous sandstone overlain by a fossiliferous siltstone.

About 20 m of the calcareous beds are exposed on the banks of the Jordan River at EP126068. Fossiliferous impure limestone, calcareous siltstone, and calcareous sandstone occur in the lower part, overlain by less calcareous siltstone and sandstone with horizons rich in pebbles and quartz granules. The top of the sequence consists of three metres of bioturbated siltstone rich in fenestellids.

On the east bank of the Jordan River [EP124056] eight metres of siltstone and sandstone, with subordinate unfossiliferous slightly calcareous beds, overlies the richly fossiliferous calcareous rocks. Fossils are rare in this top interval but *Stenopora* and *Ambikella* have been found to within two metres of the base of the overlying sandstone unit (Ph).

The calcareous sequence crops out east of Tunnack [EN394993] where strongly baked fossiliferous calcareous siltstone and fossiliferous sandstone are exposed.

Based on lithological and palaeontological evidence, xenoliths in dolerite [EP005017] have been identified as derived from the calcareous sequence.

*Fauna*

The leached and less calcareous beds towards the top of the sequence have proved amenable to fossil collecting, but it has proved difficult to collect from the lower impure limestone. Nevertheless examination of outcrops by M.J. Clarke and the author has not located any species restricted to Faunizone 5 of Clarke and Banks (1975). *Eurydesma* sp. and the common occurrence of *Deltopecten* spp. indicate that the fauna is no younger than Faunizone 7. *Streblochondria* sp. is present. Calcareous siltstone, probably less than 20 m from the top of the calcareous beds (Pl) [EP10700745; EP11000785] contains *Trigonotreta wairakiensis* (Waterhouse), *T. cracovensis* (Wass), *Wyndhamia dalwoodensis* Booker, *Sulciplica stutchburii* Auctt. and *Ambikella* spp. The first of these localities also contains *Deltopecten* sp., *Etheripecten fittoni* (Morris), and *Sulciplica phalaena* (Dana). *Eurydesma* appears to be absent, whereas the second locality yields *Ambikella brevis* McClung and Armstrong, *Promytilus mytiliformis* (Etheridge) and *Peruvispira* sp. This fauna is assigned to Faunizone 7 or 8.

Leached sandstone layers at EP123057, which are probably stratigraphically higher, contain *Aperispirifer lethamensis* Waterhouse
*Trigonotreta wairakiensis* (Waterhouse)
*Sulciplica transversa* Waterhouse
*S. phalaena* (Dana)
*Ambikella* spp.

*Wyndhamia dalwoodensis* Booker
*Fletcherithyris parkesi* Campbell
*Atomodesma (Aphanaia)* sp.
*Vacunella curvata* (Morris)
*Bransonia* sp.
*Mourlonia* sp.
Ostracods

This fauna is similarly assigned to Faunizone 7 or 8, although 8 is the preferred choice.

A higher fauna with alate spiriferids has been noted at EP10700745. *Fusispirifer avicula* (Morris), *F.* sp. nov. and probably *S. transversa* occur with *T. wairakiensis, Ambikella brevis?, F. parkesi, Sulciplica* sp., *P. mytiliformis,* and *Mourlonia* sp.

### *SANDSTONE HORIZON (Ph)*

The calcareous sequence (Pl) is overlain by a thin sequence containing massive sandstone which usually forms prominent outcrops and has proved to be a readily mappable unit. This unit has been mapped in the Limekiln Spur area and correlated with similar sandstone east of Tunnack. Where exposure is adequate the unit is seen to contain a siltstone which separates sandstone beds.

Drill core from EP125080 (fig. 3) reveals the lower sandstone to be 1.4 m thick and to consist of clean, white sandstone with silty granule sandstone and silty sandstone. This is overlain by 2.4 m of yellow and grey, bioturbated, muddy siltstone and then by 1.4 m of white sandstone grading through 0.2 m of bioturbated, silty sandstone back into bioturbated, muddy siltstone with granules and small pebbles.

The lower sandstone at EP115084 is a feldspathic quartz sandstone with some granules and silty zones. At the base the sandstone is of coarse sand to granule grain size and fines upward to medium to fine sand grade at the top. About 2.4 m of siltstone (some fissile) overlies the lower sandstone. The upper sandstone is 1.5 m thick and consists of fine-grained sandstone with granules and pebbles of quartz, quartzite, schist, and slate. Dropstones occur up to 250 mm diameter. The 10 m interval above the upper sandstone consists of interbedded sandy siltstone, sandstone, massive siltstone, and fissile siltstone. Although arenaceous beds up to 0.5 m thick occur, none are regarded as mappable, nor are they sufficiently distinctive to be treated separately.

Exposures beside the Jordan River at EP126069 show the lower sandstone to be 1.8 m thick and to consist of slightly silty sandstone which is pebbly at the base. Dropstones, some up to 100 mm in diameter, include granitic rocks. The siltstone portion is three metres thick. The upper sandstone comprises 0.8 m of very sandy siltstone with silt wisps. At EP124055 the lower sandstone appears to be lenticular and ranges in thickness from one metre to over two metres, with 2.6 m of interbedded massive and fissile siltstone underlying the one metre thick upper sandstone.

The appearance of arenaceous rocks immediately above the calcareous sequence is superficially similar in rock type and sequence to the appearance of sandstone of Member A of the Malbina Formation above the Cascades Group in the Hobart area. In contrast however, the beds described here are unfossiliferous, consist of two discrete sandstones separated by siltstone, and overlie beds containing a fauna of similar age to that occurring

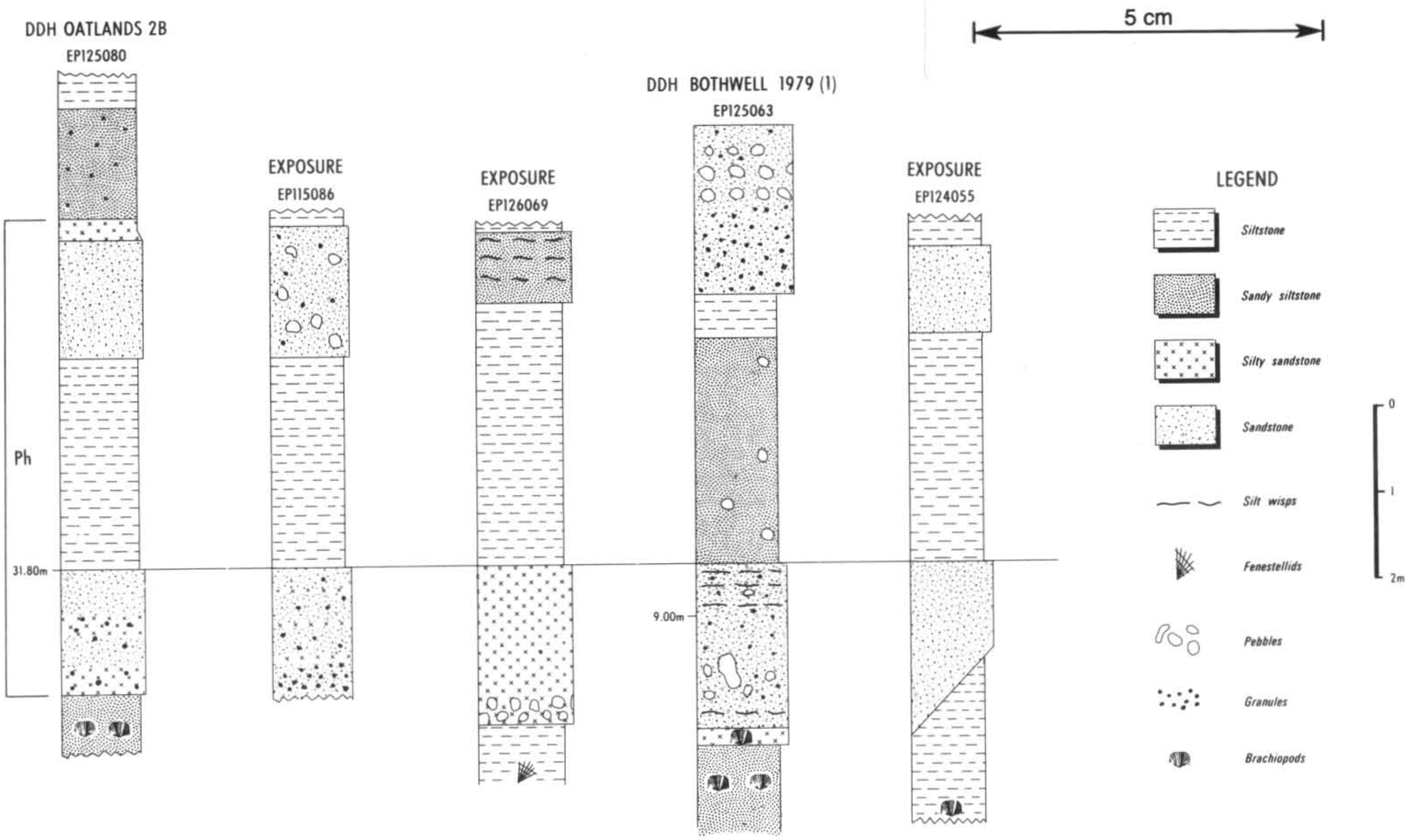



Figure 3. *Stratigraphic columns of the Lower Parmeener Super-Group sandstone horizon (Ph). Vertical limits of horizon indicated on column of DDH Oatlands 28.*

in Malbina Member A. At Mt Dromedary [EN094709] the sandstone of Member A is fossiliferous and often interbedded with calcareous siltstone (Leaman, 1977). These beds may be lateral equivalents of the top calcareous beds (Pl) at Limekiln Spur. However difficulties occur if the top beds of Pl are assigned to Malbina A, as no sharp break separates the top beds from the lower beds of Pl.

### *SILTSTONE FACIES (Ps)*

#### *Introduction*

Above the sandstone horizon (Ph) the Upper Marine sequence consists of interbedded, sparsely fossiliferous massive and fissile siltstone, sandy siltstone, mudstone, and sandstone (Ps unit) and contains dropstones. Generally these beds range from 0.1-1.0 m in thickness and in outcrop are usually continuous and of uniform thickness. A few centimetres of fissile mudstone frequently separates the thicker beds. No reliable method was found to subdivide these rocks other than by reference to two distinctive mapped horizons. The oldest of the horizons (Pe) is fossiliferous and associated with sandstone beds and occurs about 70 m above the base of the sequence. The younger horizon (Pb) is a sandy granule conglomerate and occurs 24-36 m below the top of the sequence. The interval separating the two horizons is not completely exposed in the Limekiln Spur area, but available sections suggest it is at least 120 m thick. Subsequent to the publication of the Oatlands map, sections have been found south of Tunnack [EN370950] where this interval is about 120 m thick.

#### *Lithostratigraphy and biostratigraphy*

The basal 0-13 m of the siltstone (Ps) as revealed by drill core [EP125080] consists of tough, interlaminated, light grey sandstone and grey siltstone. Although bioturbated and hydroplasticly deformed, some sand laminae, a few millimetres thick, remain discrete. Rarer silty sandstone also occurs. This portion of the sequence at EP115084 is described on p. 17.

Above this interval the most common rock type is medium grey muddy siltstone, variably micaceous and sometimes pyritic with blebs and wispy laminae of yellow, fine-grained sandstone, also hydroplasticly deformed and bioturbated. Dispersed wisps of dark grey mudstone may occur. Sand and granule-sized quartz and rock fragments occur, often constituting 1-5% of the rock. Laminae are frequently depressed below and dome over larger dropstones. Thick sandy pebble horizons up to 20 mm thick occur within this rock type, and sections up to several metres thick contain 15% sandy granule siltstone, commonly with pebbles. Individual beds in these sections may be almost free of sand and granule-sized clastic fragments. Light to dark grey homogeneous muddy siltstone occurs, usually containing negligible coarser grained clastic fragments. Uniform fissile fine-grained siltstone and mudstone with few dropstones crops out near EP115075.

Fossils are rare in the interval 13-60 m and usually occur as isolated specimens. Only unidentified pelecypods and *Ambikella magna, Sulciplica transversa, Fenestella* sp., and siliceous tubular foraminifera were noted. Foraminifera are particularly abundant at some localities.

About 60 m from the base fossils gradually become more plentiful and occur as thin lenses in buff weathering siltstone and fine-grained sandstone. The fauna at EP124078 includes:

*Sulciplica transversa*
*Fusispirifer avicula*
*Ambikella magna?*
A. sp. A with coarse micro-ornament
as present in Malbina Member E
*Terrakea* sp.
*Fletcherithyris* sp.
*Phestia* sp.
*Stutchburia* sp.
Hyolithids

Approximately 70 m above the base of the siltstone facies (Ps) is a low cliff-forming fossiliferous, feldspathic, lithic, quartzose, coarse-grained sandstone which passes up into an unfossiliferous, cleaner, more siliceous sandstone with conglomerate bands. No completely exposed section through the sandstone has been found, but the sandstone is at least 2.6 m and possibly up to 4 m thick. The siliceous upper part is at least 0.6 m thick at EP130081 and may exceed one metre in thickness elsewhere. The gastropod *Warthia micromphala* (Morris) is particularly common. Other fossils at EP124078 include:

*Sulciplica transversa*
*Fusispirifer avicula*
*Ambikella isbelli* (Campbell)
*Stutchburia* sp.
*Etheripecten* sp.
*Vacunella* sp.
*Astartila intrepida* (Dana)
*Atomodesma (Aphanaia)* sp.
*Keeneia* sp.
Hyolithids

Other fossils observed include:

*Myonia corrugata?* [EP113072]
*Stenopora* sp. [EP115070]
*Astartella* sp. [EP117053]
*Peruvispira* sp.

The fossiliferous siltstone and sandstone and unfossiliferous sandstone have been mapped collectively as unit Pe near Apsley. Similar rocks which crop out near Tunnack contain the following fossils:

*Echinalosia ovalis?* (Maxwell)
*Terrakea brachythaera* (Morris)
*Fusispirifer avicula* (Morris)
*Sulciplica transversa* Waterhouse
*Ambikella* sp. *cf. A. isbelli* (Campbell)
*Astartila intrepida* (Dana)
*Etheripecten fittoni* (Morris)
*Megadesmus grandis* (Dana)
*Merismopteria macroptera* (Morris)
*Myonia carinata* (Morris)
*Vacunella curvata* (Morris)
*Vacunella* sp. nov.
*Keeneia* sp.
*Warthia micromphala* (Morris)
*Stenopora crinita* Lonsdale

Hyolithids
Crinoidal debris

*M. macroptera* and *M. grandis* indicate a Faunizone 10 age, and *E. ovalis* is also confined to Faunizone 10 (Clarke and Farmer, 1976).

The rocks overlying unit Pe consist of interbedded bioturbated massive and fissile siltstone with subordinate mudstone and sandstone. Usually grey or mottled yellow-green-grey in drill core, these rocks frequently weather white to buff coloured in outcrop.

The most complete section occurs at EN373953. The lower part of this section consists largely of massive and fissile muddy siltstone. Dispersed granules seldom constitute more than 1% of the rock and pebbles are rare. In the upper part, fine-grained sandstone, some with pebble layers, is more common. Dropstones are up to 450 mm in diameter (*e.g.* granite [EP053065], schist [EP094055]). Fossils are rare except at EP059072 where *Ambikella* sp. A, *A. isbelli?, Fenestella, Stutchburia costata* (Morris), and other pelecypods occur and at EP066059 where a bed contains *Ambikella globosa* (Campbell). The occurrence of *S. costata* is probably not far from the type locality, Spring Hill West (Morris, *in* Strzelecki, 1845).

A sandy granule conglomerate (Pb) 1.5-4.0 m thick occurs 24-36 m below the top of the sequence. The conglomerate varies lithologically both vertically and areally but commonly consists of sub-angular coarse sand and granules of bluish quartz with subordinate lithic and feldspar grains and layers of pebbles. Pebble conglomerate similar to the Blackwood Conglomerate occurs at EP145200. Perhaps the most characteristic lithology is a pebbly granule conglomerate with a muddy matrix and open framework. This lithology caps the unit at EP147095 and EP088054, where some granules are found in siltstone below the otherwise sharp base of the unit.

The boundary between the siltstone facies (Ps) and the overlying Cygnet Coal Measures correlate (Pj) is also the boundary between the Lower Parmeener Super-Group and Upper Parmeener Super-Group. This part of the sequence is well exposed near Apsley [EP093056], near Tunnack [EP342022] and with minor excavation can be exposed at Sandy Toms Rocks [EP145092].

Several metres above the conglomerate (Pb), the siltstone (Ps) begins to show a general reduction in bed thickness and hardness and an increase in carbon content. Other features which typify the unit remain more or less constant. These are the general lack of shelly fossils, common bioturbation and hydroplastic structures, and the main lithologies of sandy siltstone, poorly sorted muddy siltstone, and mudstone and the common occurrence of dropstones. Dropstones up to one metre diameter occur to within a few metres of the top of the unit.

Where exposed, the top few beds show some characters which are different to those described above. These beds are usually dark-grey, carbonaceous muddy siltstone in which clasts become progressively smaller upwards. Clasts, although rare, are present as granules to the very top of the siltstone. At Sandy Toms Rocks thin sandstone laminae are interlaminated with muddy siltstone, but no convolute laminations have been noted.

The top of the siltstone unit is fully cored in Bothwell DDH2 [EP088055]. The youngest bed consists of 0.3 m of dark grey muddy siltstone with lacey white stringers parallel to bedding and siliceous organic tubes. Below this bed is 2.7 m of medium to dark grey carbonaceous muddy siltstone which is slightly bioturbated and contains further organic tubes and lacey white stringers. The highest pebble found is a 20 mm quartzite clast just over 3 m below the top of Ps, in the highest sandy bed which is strongly bioturbated and contains profuse organic tubes.

Most organic tubes lie sub-parallel to bedding, are subcircular to flattened elliptical in cross section with a major elliptical axis 1-4 mm long, and a length seldom exceeding 10 mm. The walls are siliceous, 0.2 mm thick, and may possess a faint radial structure. The tubes are probably the tests of foraminifera (V. Scheibnerova, oral comm.). The tubes have also been found in lower beds containing spiriferids and fenestellids and their presence here is interpreted as further evidence of a marine influence during deposition.

*Microflora of top beds*

The top beds of the siltstone facies (Ps) contain a microflora dominated by striate bisaccate pollen and trilete spores with granulate, baculate, and spinose ornament. *Protohaploxypinus limpidus* (Balme & Hennelly) Balme & Playford 1967 and *Acanthotriletes filiformis* (Balme & Hennelly) Tiwari 1965 are common. Monosaccates are rare and *Dulhuntyispora* was not recorded. The palynomorphs are of poor to fair preservation. Frequently the laesurae are removed from spores and the infrarecticulum of bisaccates unresolvable.

The following species occur:

*Leiotriletes directus* Balme & Hennelly 1956
*?Cyathidites* sp.
*Retusotriletes nigretellus* (Luber) Foster 1979
*Punctatisporites* sp.
*Osmundacidites senectus?* Balme 1963
*Cyclogranisporites gondwanensis* Bharadwaj & Salujha 1964
*Granulatisporites absonus?* Foster 1979
*Granulatisporites* sp. cf. *G. quadruplex* Segroves 1970
*Granulatisporites trisinus?* Balme & Hennelly 1956
*Microbaculispora tentula?* Tiwari 1965
*Acanthotriletes tereteangulatus* Balme & Hennelly 1956
*Acanthotriletes filiformis* (Balme & Hennelly) Tiwari 1965
*Neoraistrickia gracilis* Foster 1979
*Horriditriletes* sp.
*Didecitriletes ericianus* (Balme & Hennelly) Venkatachala & Kar 1965
*Didecitriletes uncinatus* (Balme & Hennelly) Venkatachala & Kar 1965
*?Cannanoropollis* sp.
*Pteruchipollenites indarraensis* (Segroves) Foster 1979
*Vitreisporites signatus* Leschik 1955
*Scheuringipollenites ovatus* (Balme & Hennelly) Foster 1979
*Scheuringipollenites* sp.
*Platysaccus* sp.
*Striomonosaccites* sp.
aff. *Leuckisporites*

*Protohaploxypinus amplus* (Balme & Hennelly) Hart 1964
*Protohaploxypinus limpidus* (Balme & Hennelly) Balme & Playford 1967
*Protohaploxypinus* sp. aff. *P. samoilovichi* (Jansonius) Hart 1964
*Striatoabieites multistriatus* (Balme & Hennelly) Hart 1964
*?Marsupipollenites*
*Quadrisporites horridus* Hennelly ex Potonié & Lele 1961
*Circulisporites parvus?* de Jersey 1962

The presence of *D. ericianus* indicates that the microflora is younger than Stage 5a (Kemp *et al.*, 1977). However, the absence of *Dulhuntyispora* prevents greater refinement within Stage 5.

*Correlation of Ps, Pe, Pb*

The fossiliferous siltstone and fine sandstone of Pe lithologically and palaeontologically resembles the lower part of Malbina Member E of the Hobart area, but no richly fossiliferous productid bed is present in the Oatlands Quadrangle. The Risdon Sandstone is unfossiliferous in the Hobart area but fossils occur at the base of the Risdon Sandstone at Mt Dromedary (McDougall, 1959). *Warthia micromphala* bearing sandstone associated with Malbina Member E at Mangalore appears very similar in hand specimen to the *W. micromphala* bearing sandstone of Pe. Although a 30 km gap separates the exposures at Mt Dromedary from those in the Limekiln Spur area, a tentative correlation is made between the sandstone-fossiliferous siltstone horizon near Limekiln Spur and the Malbina Member E and Risdon Sandstone horizon at Mt Dromedary.

Since the Oatlands map was published further outcrops of Pe have been found south of Tunnack [EN370950] where the sandstone more closely resembles the Risdon Sandstone at Risdon and consists of about 6 m of quartz sandstone and feldspathic lithic quartz sandstone. Fossils including *Megadesmus* sp. occur in sandstone. The sandstone appears to thin north towards Tunnack.

*W. micromphala* bearing beds below the Palmer Sandstone in the Interlaken Quadrangle may represent a development of Pe, but correlation must await further mapping of the Interlaken Quadrangle.

There seems to be no reliable lithological basis and insufficient fossils to separate the beds of the siltstone facies (Ps) occurring above Pe from those occurring below it. Furthermore, as faulting is complex in the Limekiln Spur area, the stratigraphic position of strata relative to Pe is not always known with certainty. Consequently although the strata above Pe resemble the Ferntree Mudstone and the strata below in part resemble the Malbina Formation, this subdivision has not been retained for the Oatlands Quadrangle.

The Blackwood Conglomerate is more or less continuous along the Western Tiers from Poatina to within 17 km of the northernmost outcrops of the sandy granule conglomerate (Pb) in the Oatlands Quadrangle (Matthews, 1974). The Blackwood Conglomerate in the Interlaken Quadrangle includes open framework granule conglomerate with muddy matrix like that in the Pb unit; Pb has thus been correlated with the Blackwood Conglomerate.

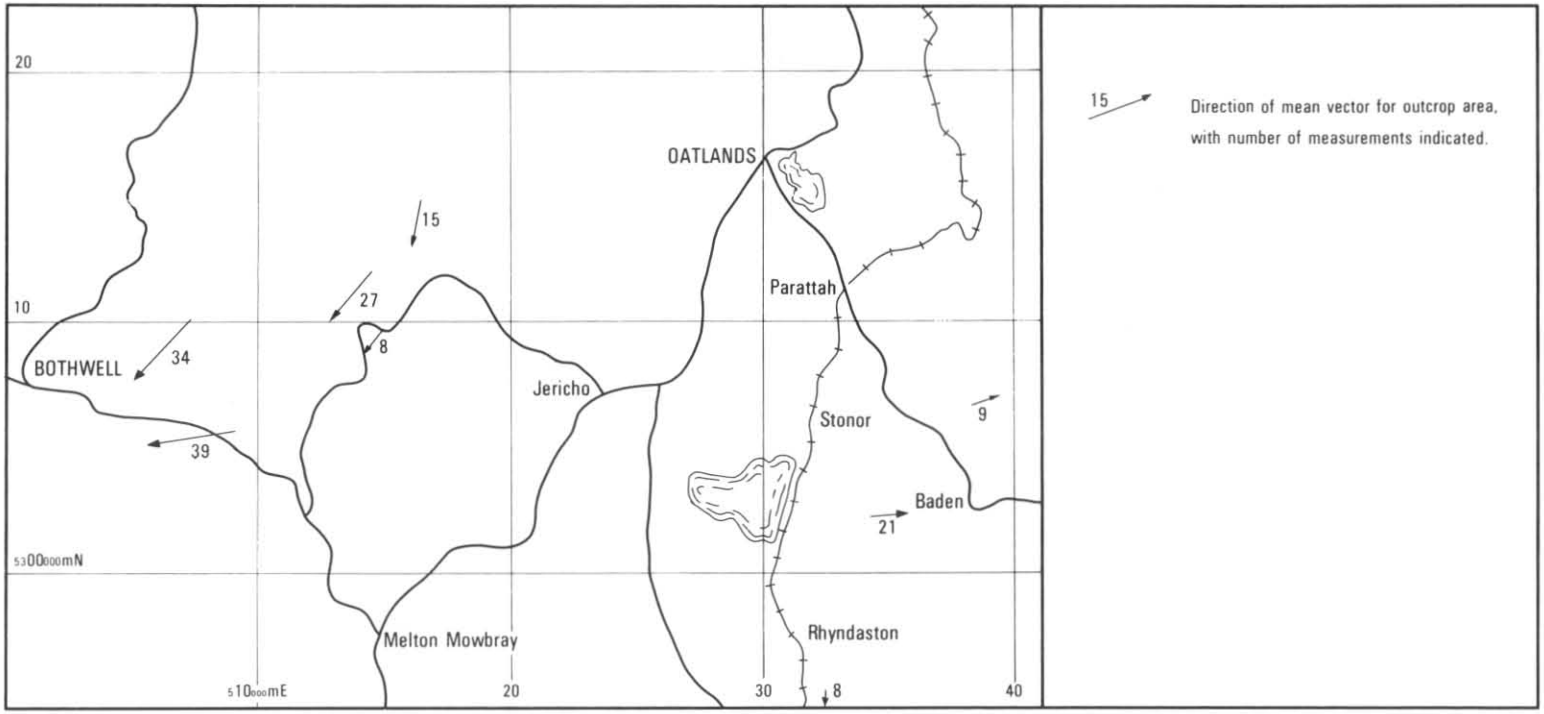



Figure 4. *Palaeocurrent vectors for the Cygnet Coal Measures correlate (Pj), lower member of predominantly pebbly sandstone. Mean vector for each outcrop area calculated from individual crossbedding and festoon axis measurements of relative unit magnitude.*

5 cm

## LOWER PARMEENER/UPPER PARMEENER SUPER-GROUP BOUNDARY

Except for some small scale troughs, erosional bases of cross-bedded sandstone immediately overlying the siltstone facies (Ps), and some possible redeposition of Ps-derived clasts, no evidence has been found within the Oatlands Quadrangle for any major erosion of the siltstone facies prior to Upper Parmeener Super-Group deposition. Investigation of the thickness variation of the siltstone between Pb and Pj has proved difficult because of problems in accurately measuring thickness. The thickness range of 36-24 m does not appear to be caused by regional erosion after Ps deposition, as the distinctive zone (<3 m thick) at the top is present in all well exposed localities near the Jordan River valley and also near Tunnack.

It appears that the glaciomarine influence on deposition decreased prior to the deposition of the Cygnet Coal measures correlate (Pj). The reduction in dropstone size and frequency in the top few metres of Ps, together with the absence of dropstones in Pj may indicate a climatic warming or the presence of a barrier (perhaps by shallowing of the sea or freshwater currents) to ice transported dropstones. The rare occurrence of sandstone laminae immediately beneath Pj may be a precursor to sand deposition but may only indicate a reduction in bioturbation. Silicified clasts in the basal Pj unit [EP342022] of Ps-like lithology with bisulphate crystal moulds may indicate desiccation.

The onset of Pj sedimentation is most commonly marked by the abrupt appearance of current deposited sandstone or conglomerate with no interdigitation with Ps lithologies. The basal sandstone and conglomerate indicate unidirectional currents at each locality, which for the Jordan River area are towards the south to west and near Baden towards the east (fig. 4). This may represent an initial advance of fluviatile sedimentation controlled by locally depressed zones in the top of the siltstone facies or the random advance of a sand-gravel body, as subsequent Pj units were deposited regionally by currents that swung towards the south-east and north-east.

## Upper Parmeener Super-Group

### CYGNET COAL MEASURES CORRELATE (Pj)

This unit is divisible into three members, but no rigorous attempt was made to map these members. In general the grain size ranges from pebble conglomerate and sandstone in the lowest member through medium-grained sandstone in the middle member to fine-grained sandstone to mudstone in the upper member. The Cygnet Coal Measures correlate crops out in the western portion of the quadrangle, in and west of the Jordan River Valley, and in the Coal River Valley, extending into the Baden [EP380020] - Mt Seymour [EP370065] area. It is known to extend beyond the limits of the quadrangle west in the River Clyde valley (Ouse Quadrangle), south (Brighton Quadrangle), and north into the Interlaken Quadrangle, where similar lithologies have been noted by the writer. The maximum recorded thickness of about 80 m occurs in the central western side of the quadrangle, from where thickness appears to decrease to between 60-80 m near the northern and southern boundaries. It is about 50 m thick in the south-eastern portion of the quadrangle.

The Cygnet Coal Measures correlate typically forms subdued, low, rounded cliff outcrops with low joint frequency, which contrast with the blocky nature of the overlying quartz sandstone (Rp). Mega-joints are prominent on aerial photographs. In some areas erosion has produced intricate outcrop forms including broadening-upward pillars and overhangs in cavernous

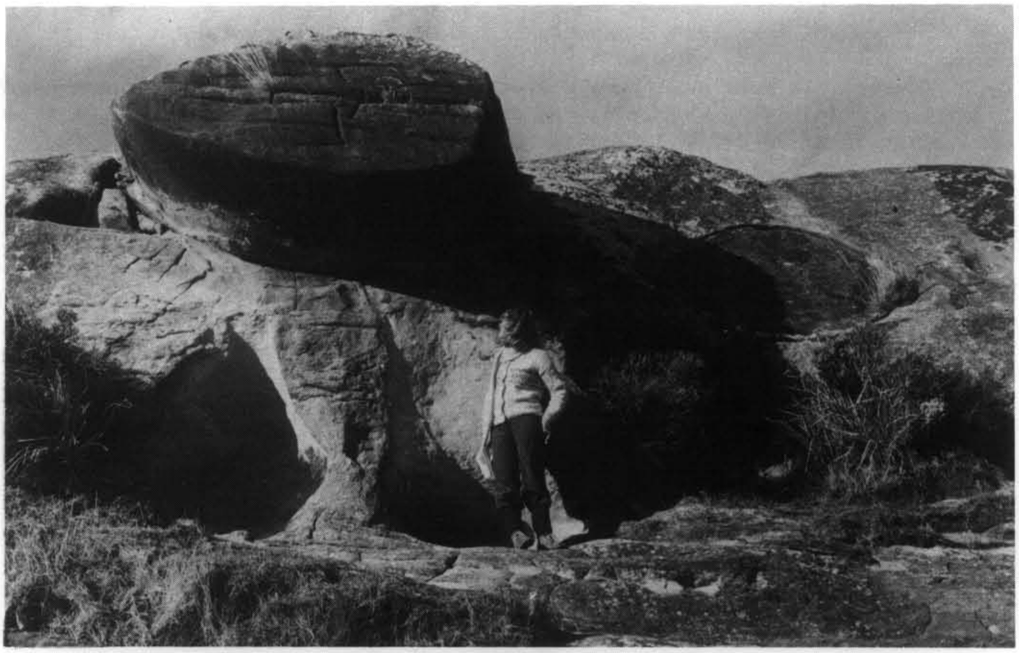
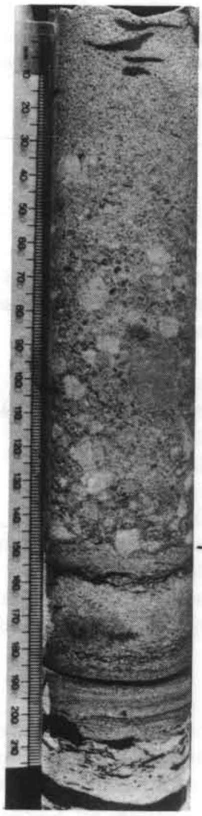


Plate 1. *Rounded sandstone outcrop with very large carbonate cemented concretions, middle member of predominately sandstone, Cygnet Coal Measures correlate (Pj) [near EP132063]. Note strong positive relief of concretion to left of person and lack of relief of concretion to the right.*



—86.7 m

Plate 2. *Thin (120 mm) pebble conglomerate overlain by sandstone with grey siltstone fragments. Lower member of predominately pebbly sandstone, Cygnet Coal Measures correlate (Pj). DDH Bothwell 2, 86.7 m. Scale in millimetres with centimetres in figures.*

5 cm

cliffs. Changes in the degree of calcite cementation and other lithological changes partially determine outcrop form. Calcite cemented concretions occur up to three metres in diameter (Plate 1).

The most distinctive rock type is a medium-grained quartzose sandstone with feldspathic and lithic grains and containing carbonaceous fragments. The rock has a characteristic mottled appearance caused by the weathering of optically continuous calcite cement. The presence of rocks with pebbles, including quartz pebble conglomerate, is also distinctive. A high proportion of garnet (of eclogitic origin) has been noted concentrated in laminae of rocks of grain size coarser than fine sand.

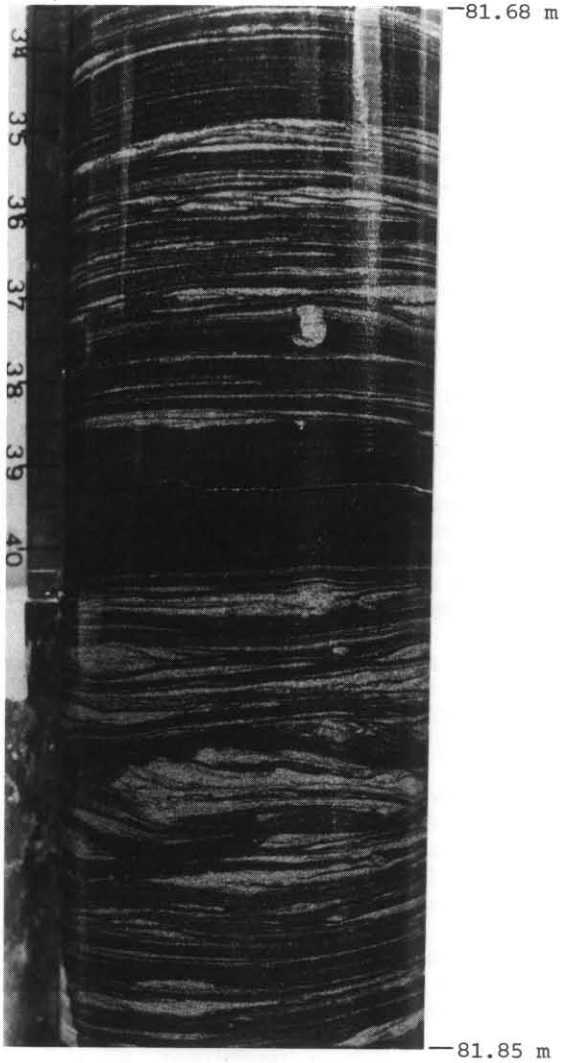
### *LOWER MEMBER OF PREDOMINANTLY PEBBLY SANDSTONE*

This member contains interbedded medium-grained sandstone, notable pebble conglomerate (Plate 2), pebbly sandstone and granule sandstone, and a higher proportion of sandstone coarser than medium-grained sand than is generally found in the other members. Argillaceous beds are known only from drill core and are uncommon, but fragments frequently occur as intrabasinal clasts (Plates 2, 3). Rare, very thin coal seams [EP095047] and coaly partings occur. The coaly partings are frequently associated with pebbly beds and represent coalified pieces or mats of vegetation, possibly representing small log jams formed during deposition.

The conglomerate beds have erosional bases and are strongly lenticular, ranging from a few pebbles thick to rarely two metres thick. Constituent pebbles and rarer cobbles most commonly consist of well rounded milky quartz with quartzite, slate, schist, and granitic rocks, together with bent clasts of carbonaceous mudstone up to 0.2 m long. Clast origin has not been determined. The pebbles need not be derived from an upland source area, as they could be recycled dropstones from the Permian glaciomarine sequence outside of the mapped area. The bent mudstone clasts near the base of the coal measures may be derived from mudstone from within the coal measures, or eroded from the top beds of the underlying siltstone.

The sandy granule conglomerate and pebbly sandstone usually exhibits crudely developed tabular cross laminae and small festoons. Current directions obtained in the Bothwell area are shown on Figure 4.

The basal or near-basal beds at Basin Sugarloaf [EP075099], Sandy Toms Rocks [EP143092], and Ironpot Hill [EP143115] usually consist of up to three metres of conglomerate and pebbly granule sandstone and contain clasts up to 150 mm in size. Rare clasts of green quartzite occur up to 300 mm diameter. Further south in the vicinity of DDH Bothwell 2 the basal bed contains wood fragments up to about 0.1 x 1.0 m in size. In DDH Bothwell 2 thin pebble beds occur in the lower 20 m of the coal measures. The sandstone beds are cross-bedded, planar laminated or massive, and rarely show penecontemporaneous deformation (Plate 4) and microfaulting. Six metres above the base of this borehole is a three metre thick horizon consisting of interbedded sandstone and interlaminated medium to dark grey, carbonaceous, muddy siltstone and fine to medium-grained sandstone. The laminae are 6 mm to paper thin in thickness and contain a few discrete sand-filled steep burrows, but lack the intense bioturbation and hydroplastic structures and admixture of coarse grains common in the glaciomarine rocks.



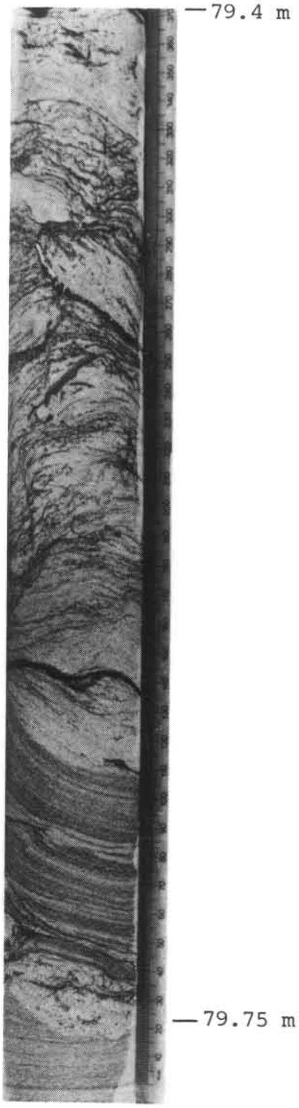




Plate 3 (left). *Dark grey silty mudstone and light coloured fine and very fine-grained sandstone with rare sand-filled burrows. Probably channel fill deposit in lower member of predominantly pebbly sandstone of Cygnet Coal Measures correlate (Pj). DDH Bothwell 2.*

Plate 4 (right). *Deformation structures in Cygnet Coal Measures correlate (Pj), DDH Bothwell 2.*

*79.40-79.66 m - deformed medium-grained sandstone with grey carbonaceous laminae, black coalified wood and some quartz granules.*

*79.66-79.73 m - inclined interlaminae of medium-grained sandstone and grey fine-grained sandstone.*

*79.73-79.75 m - scouring, pebbly coarse-grained sandstone with coalified wood pieces.*

5 cm

## *MIDDLE MEMBER OF PREDOMINANTLY SANDSTONE*

This member consists mainly of fine to medium-grained sandstone with subordinate medium to coarse-grained sandstone. Lutite may be present. The sandstone is quartzose with feldspathic, lithic, and carbonaceous grains, and is commonly micaceous. It is characteristically mottled. Calcite cemented concretions, from a few millimetres up to several metres in diameter, occur with spheroidal to tabular shapes. Concretions have yielded *Glosscpteris* spp. at EP057050 and EP112118.

Sedimentary structures in the sandstone include large scale cross-bedding with crest lengths in excess of 150 m, either at right angles to the normal direction of flow or up to 40° away from transverse (fig. 5). These sets are usually deposited on low angle erosional surfaces and have tangential toe sets. Individual sets may reach 1.5 m in height and are usually overlain by festoon cross-bedding 3-6 m across. Near Lower Marshes [EP162140] cross-bedded sets yield a uniform current direction for hundreds of metres down stream, whilst the available exposures indicate crest lengths in excess of ten metres. The foresets are planar and the toe sets tangential. These sets seldom exceed one metre in height, although several sets of the same azimuth may occur in close vertical proximity. Festoon cosets with sets of less than 0.5 m amplitude and festoons 2-6 m across occur commonly in all areas. Cosets of similar amplitude, but composed chiefly of sets of low angle cross-bedding also occur. Single sets of 0.1-0.2 m amplitude with planar bases and angular planar laminae are not common and are usually composed of coarser grained sand than the enclosing larger scale cross-sets.

Cosets of ripples (usually of the linguoid type with excess sand deposition) occur interbedded with festoon and low angle cross-bedding. Climbing transverse ripples occur less commonly and sometimes in association with large scale cross-sets. Occasional mud drapes on ripples have been observed. Some planar beds are massive, others show horizontal lamination, and others contain numerous silt or mud laminae or partings which are variably carbonaceous and/or micaceous. Primary current lineation occurs down the foresets of some crossbeds, and also with near-planar beds associated with beds and ripples capping larger scale cross-bedding.

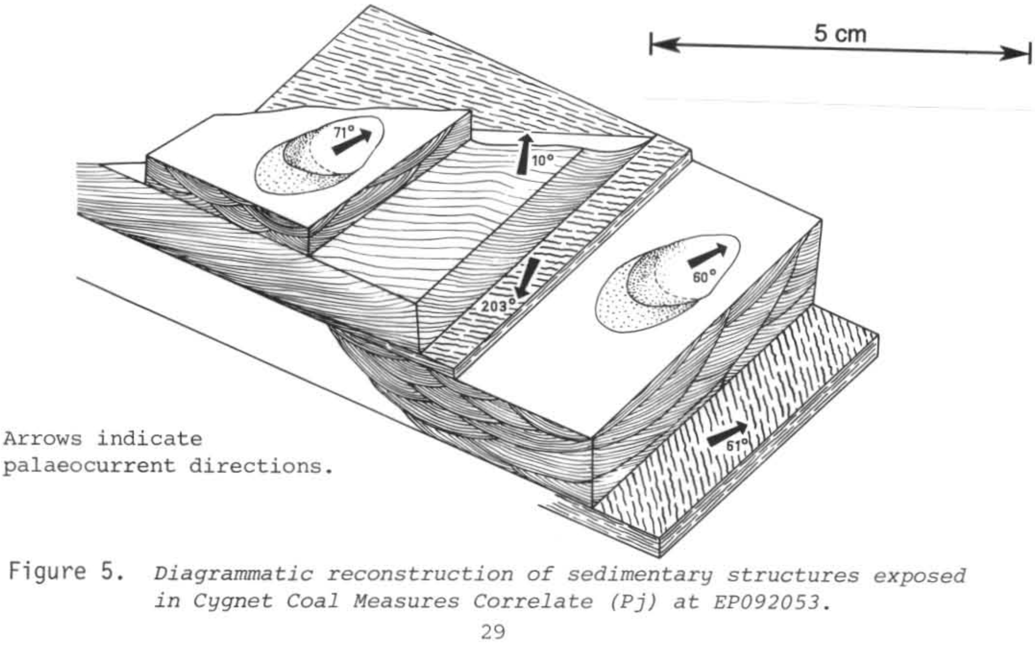



Figure 5. *Diagrammatic reconstruction of sedimentary structures exposed in Cygnet Coal Measures Correlate (Pj) at EP092053.*

### *UPPER MEMBER OF PREDOMINANTLY SILTSTONE*

Compared with the lower and middle members the top part of the Cygnet Coal Measures correlate contains more mudstone, siltstone, and fine-grained sandstone and is more micaceous. The mudstone includes both carbonaceous and non-carbonaceous types and a distinctive brown micaceous silty mudstone with filmy, curved authigenic ?micas up to 8 mm diameter. Cosets of linguoid rippled, fine-grained sandstone and coarse-grained siltstone are common. The section at Sandy Toms Rocks includes beds of medium to coarse-grained sandstone that are more siliceous than the sandstone occurring in the middle sandstone member. These beds are seldom more than one metre thick. In some areas feld-spathic sandstone bodies up to several metres thick occur within the upper member.

Some beds of poorly sorted sandy siltstone, interlaminated and inter-bedded sandstone and siltstone, and beds of fine-grained sandstone show a disrupted framework which may be caused by bioturbation. Six metre thick sequences of crudely interlaminated mudstone, siltstone, and very fine-grained sandstone also occur. The mudstone laminae may be brecciated and the sand remobilised into small sandstone dykes up to 20 mm across and 150 mm long. Other deformation may be biogenic. In drill core these beds are usually light bluish-grey in colour when fresh, weathering to greenish brown. In core, rocks spotted purple-red were noted underlying layers with red-purple and other coloured mud pellets.

### *AGE AND CORRELATION*

#### *Microflora of the upper member*

Samples collected from the upper member contain poorly to moderately well preserved microfloras. Palynomorphs are brown and the exines are frequently corroded, so that it is difficult to distinguish separate proximal and distal exine, although labra of trilete spores are not always detached.

Some difficulty was experienced in the generic assignment of spinose cavate specimens. The majority of specimens are probably assignable to *Lundbladispora springsurensis* de Jersey, 1979 but other specimens sometimes showed ragged pieces of spinose tissue extending beyond the cingulum. This spinose tissue could be interpreted as torn from the distal surface due to oblique compression, or it may be the remnants of a spinose zone. Other similar specimens were clearly zonate, but none could confidently be assigned to *Indotriradites rallus* (Balme) Foster, 1979. The spinose character of these specimens varied from spines similar to *L. springsurensis* to uniformly tapering spines, sparse stout large processes, and fine hair-like spines. No systematic relationship was observed between cingulate, zonate, and possible zonate spores and their spine type. A further variation noted upon the more delicate spores was a suggestion of a monolete character. However, because of axial folding and poor preservation, the presence of monolete cavate spores could not be definitely confirmed. The definition of species limits within the spinose cavate group must await better preserved material.

Species occurring in the upper member of the Coal Measures correlate include;

*?Calamospora* sp. No trilete observed

aff. *Phidiaesporites fosteri* Foster, 1979. The size range and conate sculpture strongly resemble those of *P. fosteri*

*Brevitriletes hennellyi* Foster, 1979

*B. levis* (Balme and Hennelly) Bharadwaj and Srivastava, 1969

*Acanthotriletes tereteangulatus* Balme and Hennelly, 1956. Spores rare, heavily carbonised and fragmentary believed to be reworked.

*A. ramosus* Balme and Hennelly, 1956. Rare and reworked?

*Limatulasporites* sp. *cf. L. fossulatus* (Balme) Helby and Foster, *in* Foster, 1979. The specimens are not granulate.

*Limatulasporites* sp. Ornamented with grana and microplications but no distal thickening.

*Cingutriletes* sp.

*Densoisporites* sp.

*Lundbladispora springsurensis* de Jersey, 1979

*L.* sp. *cf. L. willmotti* Balme, 1963. This species has larger spines (4μm) than *L. willmotti*

*Lundbladispora* spp.

*Indotriradites* spp.

*Secarisporites bullatus* (Balme and Hennelly) Smith, 1971

*Thymospora ipviciensis* (de Jersey) Jain, 1968

*Vitreisporites signatus* Leschik, 1955

*Protohaploxypinus microcorpus* (Schaarschmidt) Clarke, 1965

*Weylandites lucifer* (Bharadwaj and Salujha) Foster, 1975

*Cycadopites follicularis* Wilson and Webster, 1946

*Grebespora magna* de Jersey, 1970

*Maculatasporites gondwanensis* Tiwari, 1965

*?Rugaletes* sp.

zygospore?

*Brazilia scissus* (Balme and Hennelly) Foster, 1975

large cysts, possibly *B. helbyi* Foster, 1979

This microflora differs considerably from that found in the top of the siltstone facies (Ps). In overall terms there is a replacement of the striate bisaccates and members of the apiculati of earlier Permian microfloras by *P. microcorpus* and *B. hennellyi*. Spinose cavate forms such as *Lundbladispora* form a prominent group and cingulate acavate forms are present. Permian forms such as *W. lucifer, S. bullatus,* and *B. levis* are present, but other species, *A. tereangulatus* and *A. ramosus,* are heavily carbonised, dark and corroded, and almost certainly reworked from earlier sediments.

The presence of *B. hennellyi, T. ipsviciensis,* and a species similar to *L. fossulatus* suggest the assemblage is as young as the *Protohaploxypinus microcorpus* Zone. The absence of many species common to Stage 5 assemblages and the presence of *L. springsurensis,* not recorded below the Rewan Formation in Queensland (Foster, 1979; de Jersey, 1979), suggests the flora belongs to the upper *P. microcorpus* Zone (Helby, 1973; Foster, 1979). The presence of *G. magna,* which does not appear before the upper Rewan Formation in Queensland (de Jersey, 1979), is not considered to indicate an equivalent age as:

(i) characteristic Permian forms are still present (*e.g. W. lucifer*);

(ii) microfloras more typical of higher Rewan assemblages occur above the coal measures;

(iii) elements of the *Glossopteris* flora occur within the underlying middle sandstone member.

Foster (1979) has suggested a latest Chhidruan to early Griesbachian age for the upper *P. microcorpus* Zone.

Microfloras previously reported from rocks correlated with the Cygnet Coal Measures (*e.g.* Balme, 1964; Banks and Naqvi, 1967) have been regarded as being indicative of Stage 5 age (*e.g.* Kemp *et al.,* 1977). Davidson (1969) considered the microflora from his unit J of the Cygnet Coal Measures at Mt La Perouse and microflora from the Adventure Bay Coal Measures (Rigg, 1970) to be assignable to the Tr1a of Evans (1966). The microflora of unit J is probably older than that of the Cygnet Coal Measures correlate, as it is dominated by Permian species and *Quadrisporites horridus* Hennelly, 1958, although *P. microcorpus* and apiculate forms like *B. hennellyi* are present.

*Lithological correlation*

Carbonaceous and/or coal-bearing freshwater sequences are widespread at the base of the Upper Parmeener Super-Group throughout central and southern Tasmania, and include the Cygnet Coal Measures and Mt Pelion Coal Measures (Voisey, 1938), the coal measures at Adventure Bay, the Jackey Shale (McKellar, 1957), the Clog Tom Sandstone (Gee and Legge, 1974) and their correlates. These sequences underly siliceous cliff-forming sandstone of assumed Triassic age at cliff bases. Except for the Clog Tom Sandstone, *Glossopteris* macrofloras and/or palynomorphs indicate a Permian age for these formations. The Cygnet Coal Measures correlate (Pj) may be considered to be a correlate of these formations in the general sense in that it too consists of carbonaceous freshwater rocks of Permian age occurring at the base of the Upper Parmeener Super-Group below quartz arenite. Rocks which appear identical to sandstone of the middle member occur within or above the Jackey Formation at Millers Bluff, in the basal Upper Parmeener Super-Group near Ross, and in the Cygnet Coal Measures in the Brighton and Hobart Quadrangles (Leaman, 1973; 1975*a*).

The equivalent rocks to the Cygnet Coal Measures near Cygnet (Pf; Farmer, 1981) and the coal measure sandstones of Adventure Bay are less similar to the Oatlands Quadrangle sandstones, but similarities do exist. Parts of the Gould Formation (MacLeod *et al.,* 1961), where it is arkosic and pebbly, resemble the basal beds of the Coal Measures correlate; this is particularly so where the Gould Formation rests directly on Permian marine beds (Gulline, 1965).

## *DEPOSITIONAL ENVIRONMENT*

The Cygnet Coal Measures correlate abruptly overlies, without interdigitation, glaciomarine sedimentary rocks and forms a fining upward sequence. The basal beds are usually pebbly. The individual sandstone units, which contain mud pellets and in which bioturbation is rare, form fining upward cycles with sedimentary structures indicating deposition from unimodal currents. Average current vectors, determined at eight localities in the middle member (fig. 6), range through a 126° sector and 89% of individual current-produced structures are within a 180° sector. The average current vector for the middle member is within a few tens of degrees of the average current vector of the individual cyclic sandstone units that constitute an approximately 150 m thick quartz arenite sequence overlying the Cygnet Coal Measures correlate.

The above characters indicate that the Cygnet Coal Measures correlate was neither deposited by a gradually prograding delta, as a beach or barrier sand complex, nor was it deposited as a marine sand with regular bed forms, as such deposits differ in texture and sedimentary structure. The characters listed and discussed in more detail above are consistent with a fluviatile environment. The lack of marine invertebrate fossils and the lack of marine micro-organisms in palynological preparations from the upper member would also suggest a non-marine origin.

Evidence from Tunnack, suggesting silicification and possible dessication of a skin on the upper surface of the Lower Parmeener Super-Group, supports a complete withdrawal of the sea from that area prior to commencement of fluviatile sedimentation.

The large size of some transverse dunes indicate that the rivers depositing the Cygnet Coal Measures correlate were of considerable magnitude, probably with widths measured in hundreds of metres. The presence of conglomeratic rocks near the base indicates that the rivers were of considerable competency. Rapid grain size reductions from medium to coarse-grain sandstone to siltstone in DDH Bothwell 2 are probably caused by channel abandonment.

The upper part of the Cygnet Coal Measures correlate contains more lutite and thinner and finer grained sandstone. The lutites are probably over-bank deposits. Some are poorly sorted, and lamination tends to be more irregular and sometimes disrupted by sand dykes and rarer bioturbation. Red and purple coloured lutites, in which bedding is more irregular, occur rarely. As these features occur throughout the area, they appear to be related to decreased competency of the rivers rather than to a more distal position away from the major channels.

The lutites show rare bioturbation but in the lower part of the coal measures are often finely laminated without any sign of biogenic activity or dessication features. Rippled sandstone that occurs in these sequences reveals a current flow parallel to the main channel direction. Although some rocks resemble crevasse splay deposits, particularly the interlaminated mudstone, sandstone, and siltstone, the parallelism of current directions and rapid grain size reductions suggest that some of these deposits may be channel fills. Such an explanation may account for thick (>8 m) sequences composed almost entirely of rippled sandstone. An abandoned channel through which a limited current flow is maintained is suggested as the depositional environment for such rocks. The thickness of this type of deposit and the thickness of the fining upward coarser sandstone units suggests channels may have been about ten metres deep. Rapid deposition by fast flowing streams may have prevented local vegetation development and burrowing, although allochthonous wood and finely divided plant remains are sometimes common. The sandstone may be a distal facies of braided streams draining distant retreating glaciers.

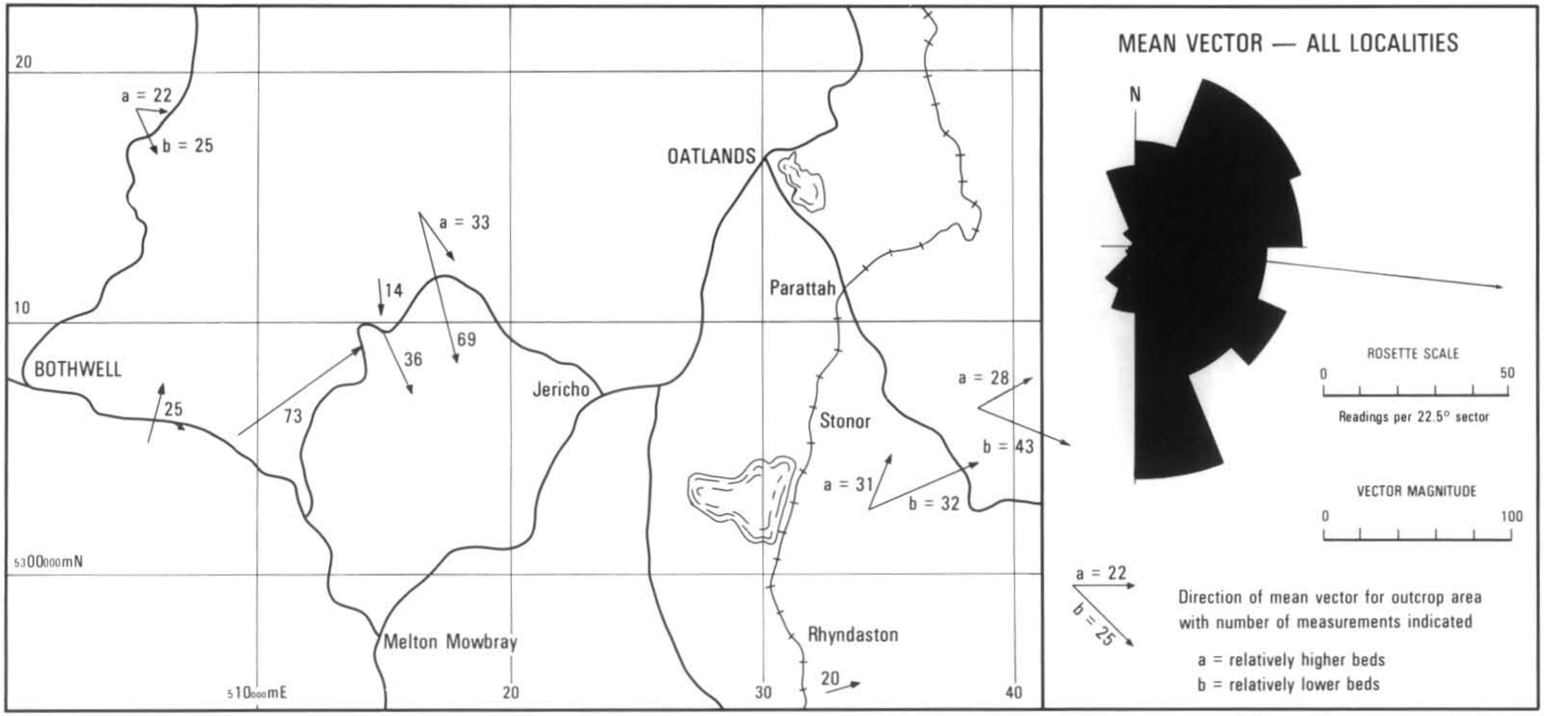



Figure 6. *Palaeocurrent vectors for the Cygnet Coal Measures correlate (Pj), middle member of predominantly sandstone. Mean vector for each outcrop area calculated from individual crossbedding, festoon axis, and ripple mark measurements of relative unit magnitude.*

5 cm

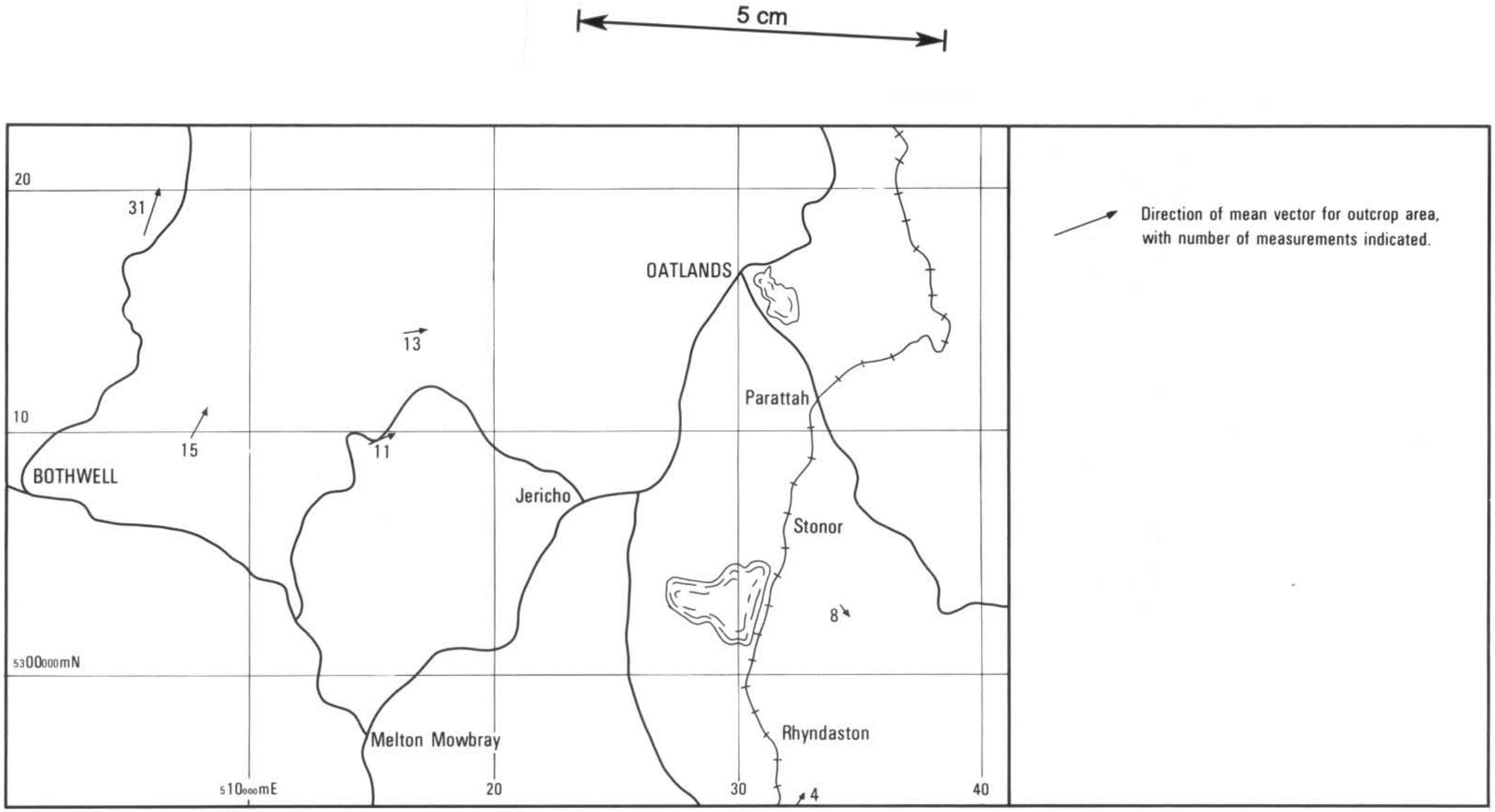



Figure 7. *Palaeocurrent vectors for the Cygnet Coal Measures correlate (Pj), upper member of predominantly siltstone. Mean vector for each outcrop area calculated from individual crossbedding and ripple mark measurements of relative unit magnitude.*

Plate 5. *Undulatory erosional surface at top of Cygnet Coal Measures correlate (fretting shale) overlain by cross-bedded quartz arenite (Rp). Near Woods Quoin [EP061181].*

Plate 6. *Early Triassic quartz sandstone obscurely laminated in cliff face is clearly laminated in cave exposure. More steeply inclined cross-bedded cosets above hammer contrast with lower angle cross-bedding at base and top of exposure. Serpentine Valley Creek north of Chinas Hill.*

## QUARTZ SANDSTONE (Rp)

A relatively homogeneous sequence consisting predominantly of cross-bedded quartzose sandstone with subsidiary mudstone and siltstone overlies the Cygnet Coal Measures correlate. Near Rhyndaston [EN328954] the sequence is approximately 200 m thick and is between 160-180 m thick at Woods Quoin [EP077178]. This sequence is the most widely distributed of the Upper Parmeener Super-Group rocks in the Oatlands Quadrangle, with strong outcrops forming blocky cliffs, particularly on hillsides and in deeply incised gorges (*e.g.* Bedlam Walls; EN328960]. Euhedral overgrowths on quartz grains commonly impart a glistening appearance to the sandstone which when weathered is usually yellow, brown, or pink due to iron staining. The sandstone is composed largely of grains of strained quartz, quartzite, chert, micro-crystalline quartz, plagioclase, and potash feldspar, with muscovite and graphite usually in well-defined bedding planes. The non-siliceous grains usually constitute 3-7% of hand specimens but occasionally feldspar comprises 10-15% of the rock.

The contact between the Cygnet Coal Measures correlate (Pj) and the quartz sandstone (Rp) is exposed at EP147117 and near Woods Quoin [EP061181] (Plate 5). At the latter locality cross-bedded basal sandstone fills shallow scours in the top siltstone of the Cygnet Coal Measures correlate. Clasts of the underlying siltstone occur in the basal sandstone. Mud drapes with probable animal trails overlying the basal metre of sandstone may be related to currents that eroded the top of the Cygnet Coal Measures. The degree of erosion at the contact is no more marked than that observed at the base of sandstone units higher in the Parmeener Super-Group.

Generally the basal few metres of the quartz sandstone includes beds of coarse to granule-grain sandstone with medium-grained sandstone. The coarsest beds may contain scattered small quartz pebbles and usually form the basal beds, but need not occupy this position. A labyrinthodont bone was found near the base of the quartz sandstone at EP101056.

Most outcrops show the sandstone to be formed of cycles or portions of cycles. Cross-bedding is ubiquitous, the cross-bedded sets being usually less than 0.6 m thick (Plate 6). Typical cycles begin with massive and tabular cross-bedded medium to coarse-grained sandstone. Thin granule sandstone may occur, but more common is lenticular mud pellet conglomerate a few tens of millimetres to a few hundred millimetres thick, or rarer pellets dispersed in sandstone. The mud pellet conglomerate frequently contains some siliceous granules and small quartz pebbles, and bone fragments of amphibians have been found [EP134084, EP124124, EP126163]. The mud pellets are normally pebble size, well rounded and oblate, but larger platy, well rounded types occur. Boulder size mud clasts maintaining an angular appearance are less common. Some pellets are rolled tubes, others resemble thick buttons with a central hole (Plate 7) and may represent mud accreted around reeds, traces of which have since disappeared. Sub-rounded clasts of laminated sandstone up to 80 mm diameter occur rarely [EN163995].

Higher in the cycles occur cosets of planar erosive cross-bedding or festoons several metres across, composed of medium to fine-grained sandstone (Plate 8). Overturning of cross-bedding is a common feature at this level, the direction of overturning being down current with a fold hinge-line perpendicular to current flow. Rarely some thicker beds possess a more complex overturning in which the overturned laminae swing back to an unfolded orientation towards the top of the bed. This is essentially a maximum downstream translation of the laminae in the central part of the bed, the amount of translation reducing more or less uniformly towards the top and base of the bed (Plate 9). More intense deformation does occur,

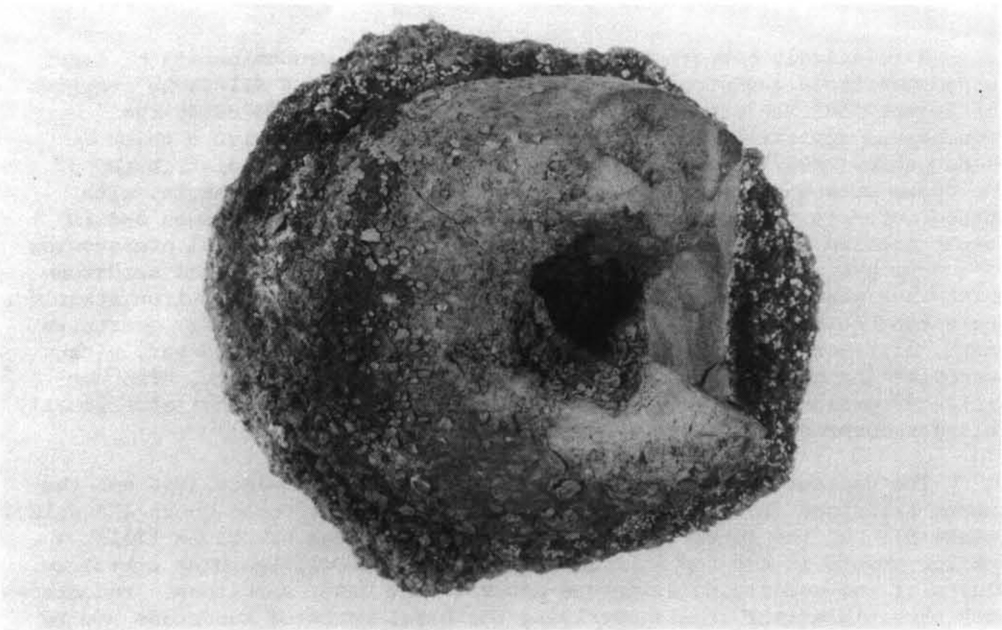


Plate 7. *Annulus-shaped mud pellet in quartz sandstone (Rp) from EP148097. Specimen is approximately 35 mm diameter.*

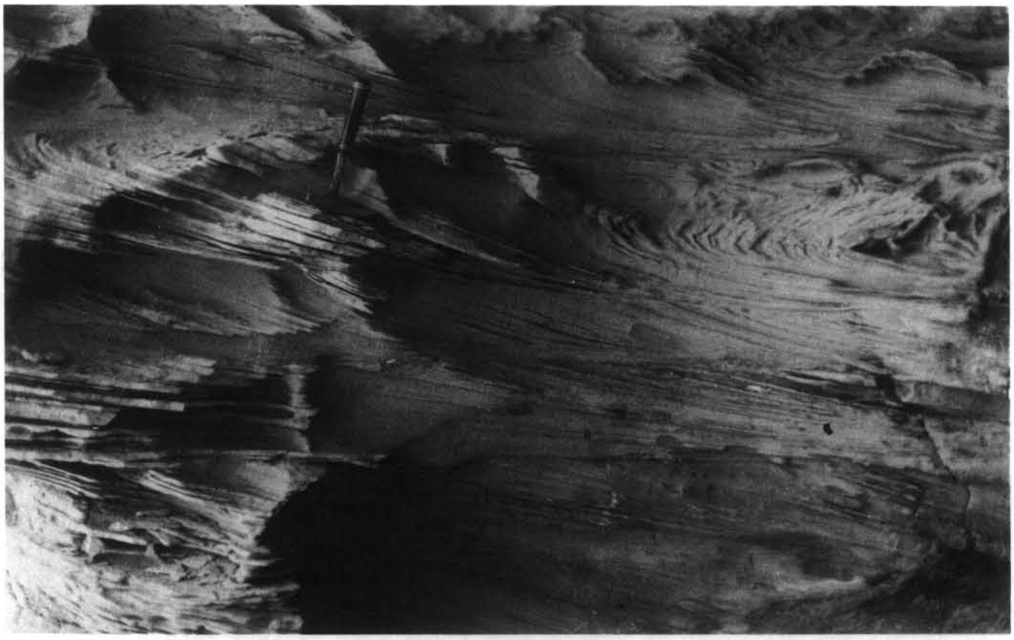


Plate 8. *Detail of cosets and overturned cross-bedding in Early Triassic quartz sandstone. Serpentine Valley Creek north of Chinas Hill.*

5 cm

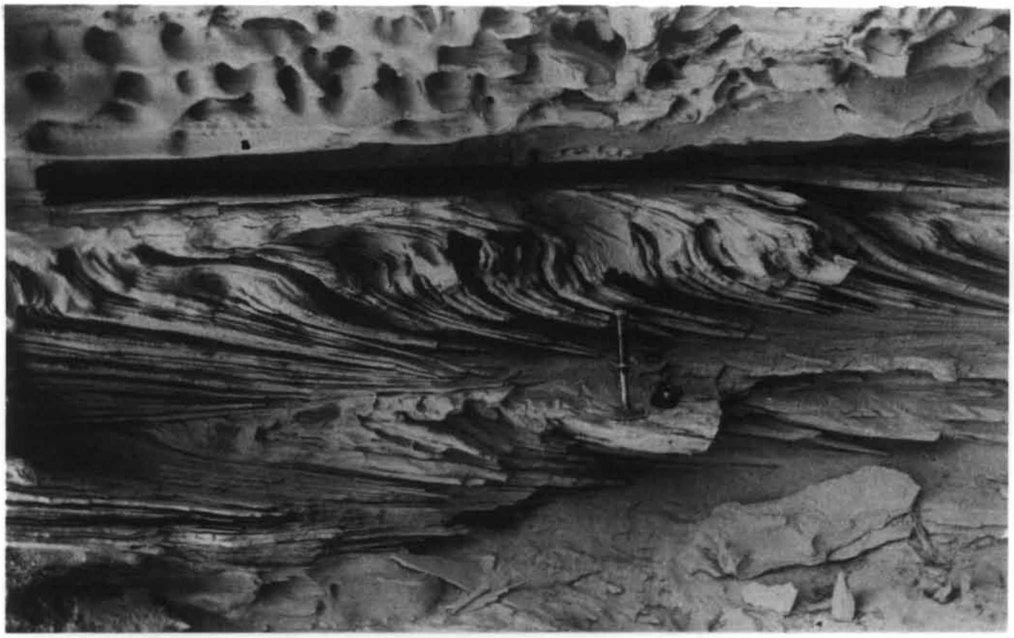


Plate 9. *Deformation by down-current translation of foresets of cross-bedding in Early Triassic quartz sandstone. Serpentine Valley Creek north of Chinas Hill.*

Plate 10. *Ripple marks in Early Triassic quartz sandstone at EN184999. Currents towards east quadrant.*

Plate 11. *Portions of festoon cross-bedding in Early Triassic quartz sandstone at EP181004.*

Plate 12. *Flame structure of poorly sorted siltstone into overlying quartz sandstone near top of Early Triassic quartz sandstone (Rp), Midland Highway north-east of Melton Mowbray [EN163995].*

with folds of various declination and azimuth and with disrupted laminae. Smaller scale cross-bedding and less commonly ripples and primary current lineations on planar beds of fine-grained sandstone occur near the top of cycles (Plates 10, 11). Siltstone is rare. Cycles may be much attenuated, new cycles commencing with an erosive sandstone.

West of Hutton Park [EP163052], hill profiles generally show a maximum of four major benches, with each bench being about 50 m high. The steeply rising portions appear to be composed entirely of sandstone. Traces of massive or laminated orange-yellow siltstone have been found on the poorly exposed bench tops. The benches may be related to large scale cycles of deposition, or developed where siltstone has been randomly preserved in the sequence.

In a general fashion, for there are many exceptions, the quartz sandstone shows a number of variations in grain size, composition, and sedimentary features up through the sequence. The grain size shows a reduction from mainly medium and coarse-grained sandstone in the basal 70 m, through medium to fine-grained sandstone, to mainly fine to very fine-grained sandstone near the top. Feldspar content decreases and muscovite and graphite content begins to increase in the upper parts. The upper part of the quartz sandstone contains a greater proportion of low angle cross-bedding, planar beds, primary current lineations, and ripples.

In the Tunnack-Rhyndaston area [*e.g.* EN349966] the lower part of the quartz sandstone sequence consists of thickly bedded medium to coarse-grained sandstone which contains minor, usually black shale layers (Leaman, 1971). This unit has been mapped separately as Ꞧls and is overlain by a unit (Ꞧlq; Leaman, 1971) of dominantly medium to coarse-grained sandstone with minor mudstone, mica, and feldspar.

Current directions determined from cross-bedding and primary current lineations vary little areally or vertically up the sequence. The direction of the current vector determined from 10-15 randomly chosen cross-bedded exposures at a locality is usually parallel to the vector obtained from 50-80 readings. Current directions obtained for the basal cycles of Ꞧp are shown in Figure 8. Vectors obtained from higher in the sequence usually range from ENE to SSE. Individual readings seldom have a westerly component.

*DEPOSITIONAL ENVIRONMENT*

The preponderance of water-laid sand grade material forming upward fining cycles deposited by unimodal currents of consistent direction is indicative of a fluviatile depositional environment. The dearth of possible overbank deposits and the uniformity of current direction is particularly notable. This is interpreted as indicating that the fluviatile system was not of high sinuosity, but rather a low sinuosity system. This is supported by the apparent lack of lateral accretion surfaces of point bars normally associated with more strongly meandering rivers. The low divergence of individual current vectors, and the strong dominance of cross-bedded sandstone compared to lutite, resembles the deposits of sandy braided rivers, but no conclusive evidence for braid bars has been found.

The presence of mud pellets at the base of many cycles which contain no lutite beds indicates that lutite beds were easily eroded. This may be related to frequent and easy reworking of the sandy, well sorted alluvial plain or to the occurrence of lutites in or close to the main channel. In contrast to grey carbonaceous mud pellets observed higher in the

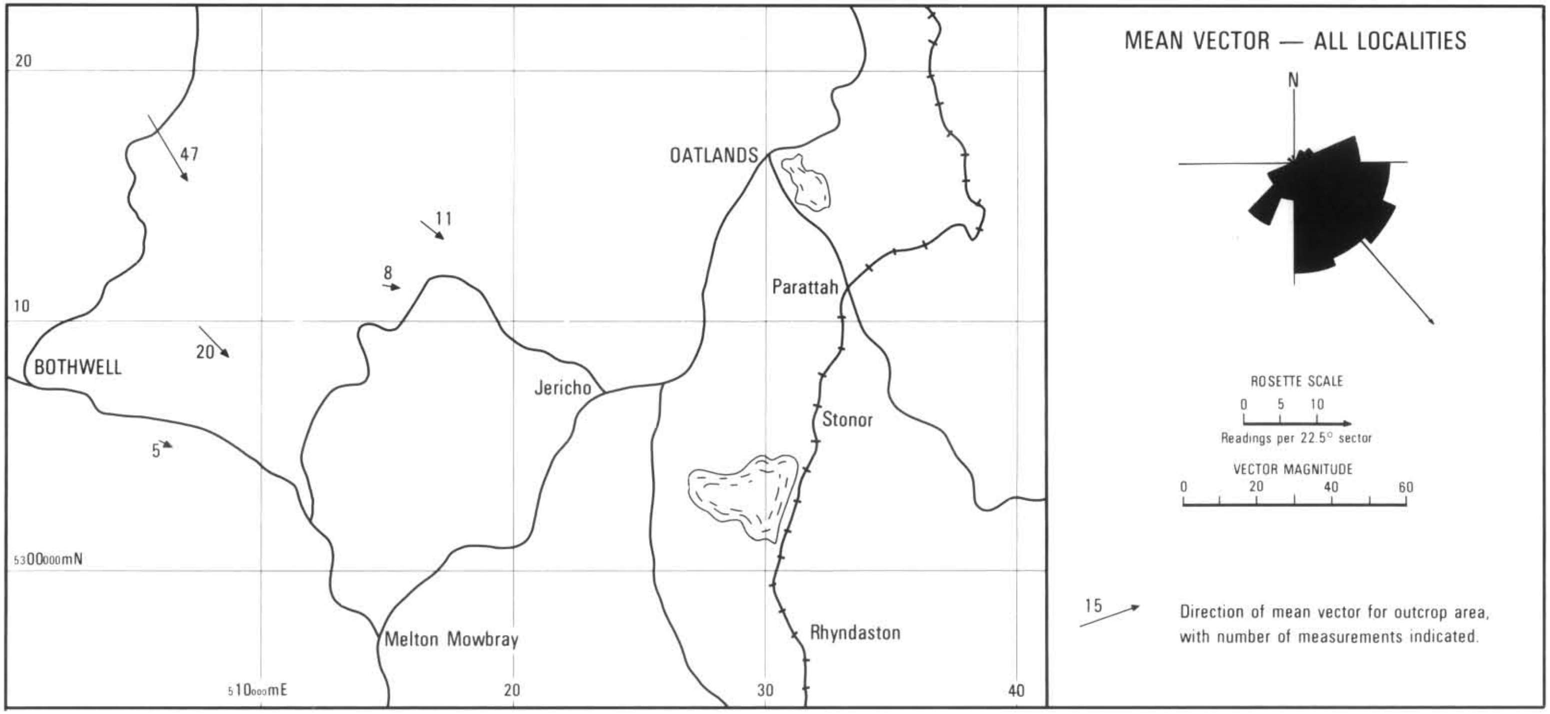



Figure 8. *Palaeocurrent vectors for the quartz sandstone (Rp) (basal beds only). Mean vector for each outcrop area calculated from individual crossbedding measurements of relative unit magnitude.*

5 cm

Parmeener Super-Group, the mud pellets in the quartz sandstone are normally white to light brown, suggesting they are derived from oxidising or dessicated environments. Although palynomorphs indicate a flora existed, the few vertebrate fossil localities surprisingly exceed the leaf fossil localities in number. Macroplants found are sphenopsid stems and leaves and rare small lycopods. Wood has not been found in the sandstone cycles, although it occurs frequently at most other horizons in the Upper Parmeener Super-Group.

A model based on low sinuosity rivers flowing intermittently, perhaps on a seasonal frequency with periods of aridity, can account for many of the observed features, including the apparent reduced vegetation, mud drapes on dunes, and deposition and then erosion of mud and silt facies within the channel area.

### *MUDSTONE, SILTSTONE AND SANDSTONE ASSOCIATION (Rpc)*

In some sections lutite associations (Rpc) occur in the otherwise quartz sandstone dominated sequence (Rp). The lutite associations contain, or sometimes consist predominantly of, micaceous mudstone and siltstone which are of variable fissility and occasionally carbonaceous. The exposures are mostly weathered to buff to tan coloured rocks but some fresher outcrops expose green siltstone. Rarely purple-grey lutite is present. Leaves and stems of sphenopsids are the only macrofossils found to date.

Because of the inadequate exposure, sometimes related to the thinness of the lutite associations, these units have not generally proved mappable. Exceptions occur around Woods Quoin [EP077178] and at Ironpot Hill [EP153130]. The Woods Quoin occurrence is well exposed in cuttings on the Bothwell-Interlaken Road at EP065181 and is about 20 m thick and includes micaceous shale, carbonaceous siltstone, purple coloured siltstone, and cross-bedded sandstone layers a few metres thick. Some thin (20-200 mm) sandstone beds with quartz granules occur towards the top and bottom of the association. Further outcrops of the lutite association north and east of Woods Quoin, but outside the area of mapped continuity, may also belong to the main Woods Quoin horizon.

Lutite outcrops are also common in the Monks Sugarloaf-Ironpot Hill area. West of Ironpot Hill three horizons of lutite occur within the one sequence. Leaf-bearing localities occur on the Lake Highway at EP098045 and on the west bank of the Jordan River at EP133082.

Occurrences of the lutite association at the base of sections are similar to the upper siltstone member of the Cygnet Coal Measures correlate in areas where the basal quartz sandstone is free from granule-size clasts.

### *AGE AND CORRELATION*

Similar sequences to Rp and Rpc overlie the Lower Parmeener Super-Group or the Permian portion of the Upper Parmeener Super-Group (the Cygnet Coal Measures and equivalents) throughout central and south-eastern Tasmania, except for the St Marys area. Where palaeontological control is available, for example at Poatina (Playford, 1965; Cosgriff, 1974), Mt La Perouse (Davidson, 1969), Knocklofty and other areas around Hobart (Camp and Banks, 1978; Cosgriff, 1974), and Schouten Island (Forsyth, in prep.), Griesbachian to Smithian ages have been obtained in or above these similar sequences. These ages are based on palynological correlation with the *Krauselisporites saeptatus* Assemblage zone of

Griesbachian to mid-Smithian age (Dolby and Balme, 1976) and a Late Griesbachian to Smithian age determined by Camp and Banks (1978) for a vertebrate fauna typical of those faunas described by Cosgriff (1974).

The quartz sandstone at Poatina (Ross Sandstone of McKellar, 1957), the basal 200 m of the La Perouse Formation, and the older quartz sandstone on Schouten Island are lithologically similar and are regarded as, in part, biostratigraphic correlates of Ꞧp. The Mountain Lodge Member of the Springs Sandstone at Mt Wellington (Banks and Naqvi, 1967) and the Ossa Formation at the Pelion Range (MacLeod *et al.*, 1961) are lithologically similar to Ꞧp. The lithological similarity and stratigraphic position suggests the Mountain Lodge Member and the Ossa Formation are litho-stratigraphic correlates of Ꞧp. The Poets Road Member of the Knocklofty Formation at West Hobart is younger than the dated portion of Ꞧp, but may be time equivalent in part to the top portion.

*Microflora*

Microfloras have been obtained from outcrops about 80 m above the base of the quartz sandstone at Sandy Toms Rocks and from a fresh road cut at EP135082 at an unknown height above the base. The second microflora is moderately well preserved and contains the brown to red-brown palynomorphs listed below. The first microflora is very poorly preserved and contains no species not listed below.

*Dictyophyllidites mortoni* (de Jersey) Playford and Dettmann, 1965
*Osmundacidites wellmanii* Couper, 1953
*?Granulatisporites* sp. *A*. Grana are fine and absent on the proximal face. Resembles *Microbaculispora tentula* Tiwari, 1965
*?Cyclogranisporites* sp. *A*. Circular, grana only distinct distally.
*Brevitriletes hennellyi*
*?Cadargasporites*
*Polycingulatisporites dejerseyi* Helby ex. de Jersey, 1979
*P*. sp. *cf*. *P*. *dejerseyi*, the form illustrated by de Jersey (1979, plate 5, fig. 6)
*Limatulasporites fossulatus* (Balme) Helby and Foster *in* Foster, 1979
*L*. sp. *cf*. *L*. *fossulatus*, the form illustrated by de Jersey (1979, plate 5, fig. 3)
*Stenozonotriletes* sp.
*Retusotriletes* sp. The closest comparison is with *R*. *junior* de Jersey and Hamilton, 1967
*Densoisporites playfordii* (Balme) Dettmann, 1963
*D*. sp. *cf*. *D*. *playfordii*. The intexine is larger than in *D*. *playfordii*
*D*. *nejburgii* (Schulz) Balme, 1970
*D*. sp. *A*. Resembles *D*. *playfordii* intexine strongly triangular and very dark.
*Lundbladispora brevicula* Balme, 1963
*L*. *willmottii*? Balme, 1963
*L*. sp. *cf*. *L*. *willmottii*
*L*. sp. *A*. Except for the presence of equatorial and distal irregular spongy coni-like projections, this species closely resembles *Densoisporites poatinensis* Playford, 1965.

*Krauselisporites cuspidus* Balme, 1963
*K. saeptatus* Balme, 1963
*Rewanispora foveolata* de Jersey, 1970
aff. *Aratrisporites banksi* Playford, 1965. Elliptical, cavate, monolete? with distal and equatorial coni and rugulae which are predominantly radial. Cingulate?
?*Aratrisporites* sp. Cavate, probably monolete, spongy appearance but no projecting ornamentation or rugulae.
*Platysaccus* sp.
monopseudosaccate with unstructured exoexine
*Scheuringipollenites ovatus* (Balme and Hennelly) Foster, 1975
*Vitreisporites signatus* Leschik, 1955
*Lunatisporites pellucidus* (Goubin) Helby *in* de Jersey, 1972
*L. noviaulensis* (Leschik) de Jersey, 1979
*Striatopodocarpites phaleratus* (Balme and Hennelly) Hart, 1964. Two specimens with fragmentary sacci, reworked?
*S. pantii* (strongly corroded, reworked?)
*S. rarus* (Bharadwaj and Salujha) Balme, 1970, fragmentary specimen, reworked?
*Marsupipollenites klausii* de Jersey, 1970
*Grebespora concentrica* Jansonius, 1962
?*Naumovaspora* sp.
*Brazilia* sp.
paired rectangular cysts

The presence of *L. pellucidus* indicates the microflora is younger than the *Protohaploxypinus microcorpus* Assemblage zone as applied both in the Sydney Basin (Helby, 1973) and the Bowen Basin (de Jersey, 1979). According to Helby (1973) *L. pellucidus* ranges through the *L. pellucidus* Assemblage zone to the *Protohaploxypinus samoilovichi* Assemblage zone. *L. noviaulensis* ranges from the *L. pellucidus* zone to the *A. parvispinosus* Assemblage zone, *P. dejerseyi* ranges from the *L. pellucidus* zone through the *P. samoilovichi* zone, and *B. hennellyi* and *K. cuspidus* range to the *P. samoilovichi* zone. The TRp assemblage therefore belongs to either the *L. pellucidus* or the *P. samoilovichi* Assemblage zones. The later assignment is preferred because of similarities with the low proportion of *Alisporites* spp., the high pteridophyte component, the high abundance of *P. dejerseyi* and the presence of *R. foveolata* which is confined to the *P. samoilovichi* zone in N.S.W., although it is much longer ranging in the Bowen Basin. The possible occurrence of *Aratrisporites* in TRp lends further support to this assignment.

The incoming of *L.pellucidus* defines the base of the upper Interval zone of the Bowen Basin (de Jersey, 1979). Other species in TRp known in Queensland only from the Rewan Formation include *P. dejerseyi, D. nejburgii*, and *M. klausii* which occurs from about 1940 to 1990 m above the base. *L. willmottii* and *K. cuspidus* range up to about 1700 m from the base, *K. saeptatus* 1730 m, and *L. brevicula* 1990 m (de Jersey, 1970*a*). *B. hennellyi, P. dejerseyi, L. fossulatus,* and *S. ovatus* have as yet only been recorded up to the basal 460 m of the Rewan Formation, but these species do overlap the range of *Aratrisporites wollariensis* Helby, 1967 over a short interval.

The TRp assemblage may be directly correlated with the *Krauselisporites* *saeptatus* Assemblage zone (Dolby and Balme, 1976) developed in Western Australia, where marine faunas indicate that the zone ranges from the Griesbachian to the mid-Smithian. *Aratrisporites* first appears in the Western Australian sequence during the Dienerian.

In Tasmania similar assemblages to that of the quartz sandstone (Rp) occur in the Ross Sandstone at Poatina (Playford, 1965), quartz sandstone on Schouten Island (Forsyth, unpubl.data), and unit 20 of the La Perouse Formation (Davidson, 1969), which contains *L. pellucidus*.

## MUDDY FLUVIAL PLAIN FACIES (Rm)

The muddy fluvial plain facies (Rm) overlies the quartz arenite (Rp) and consists of about 60 m of micaceous lutite with interbedded, subordinate, variably micaceous sandstone and arenite. In some features, this facies resembles the lutite intercalations (Rpc) in the quartz arenite, but has been mapped separately because of its greater thickness and persistence. The facies occupies a unique position above the quartz arenite sequence in the Melton Mowbray [EN148978]-Spring Hill [EP208049] area and possesses features which distinguish it from the lutite intercalations. The microflora is younger than that obtained from the Rpc outcrops studied to date.

The base of the fluvial plain facies is well exposed in an agricultural dam spillway at EN189953. The transition from the underlying rock occurs initially by the appearance of thin beds (100-200 mm thick) of silty sandstone or siltstone in dominantly fine-grained sandstone. Within a ten metre stratigraphic interval very micaceous, wavy, or planar laminated siltstone becomes common and lutite may become dominate over sandstone. On the realigned Midland Highway near EP179006 grey siltstone ranging between two and fifty millimetres in thickness occurs interbedded with sandstone probably at the base of Rm in a faulted exposure.

Most sandstone beds are also micaceous, with the mica (mainly muscovite) occurring both on well-defined bedding planes with graphite, and dispersed through the laminae. The sandstone contains a ferruginous muddy matrix; in some instances the matrix may be primary, but much appears to form by the weathering of labile grains. Although more feldspathic? and lithic grains are present than in the underlying quartz arenite, these sandstone beds are still quartzose and are easily distinguished from the lithic and volcanic-lithic arenites found higher in the Parmeener Super-Group.

In thin section, the sandstone contains from 65-80% subangular to subrounded quartz grains which may form an open to closed fabric separated by non-quartzose grains and matrix. Some rocks contain 5-10% microcrystalline quartzose grains. Up to 5% muscovite is usually present, often occurring as broad laths of similar grain size to quartz. Rarer weathered biotite? may be present in some sandstone. About 2% dark brown to black opaque grains are usually present, occasionally reaching 5-10%, and plant fragments may occur.

Recognisable feldspar is usually absent, but may comprise up to 5% of the rock. Most sandstone contains 15-30% grey-brown to orange-brown unidentified grains and matrix. These grains are subrounded, of similar grain size to the quartz, and are composed of fine-grained material. In some cases these grains may be weathered feldspar, but others may be intrabasinal mudstone.

The matrix is slightly redder than the grains and forms thin films around them, or merges into the unidentified grains. Volcanic and hypabyssal acid igneous grains do not form a notable constituent. Some arenite is very quartzose and is indistinguishable from the Rp-type arenite.

The lutite beds show considerable variation. Both mudstone and siltstone range from massive to finely laminated. Some very finely laminated mudstone breaks with a conchoidal fracture, whereas the very micaceous siltstone usually parts readily into large sheets a few millimetres thick. In other laminated mudstone layers, a strong fissility is induced by numerous sphenopsid stems on bedding planes. In drill core, most lutite of this unit is light grey to light bluish-grey in colour, but upon exposure often adopts an orange tinge. Field exposures are usually buff, orange, or brown in colour, and red and pink ferruginous stain on joint surfaces is characteristic. Beds with a significant carbonaceous content may be light to dark grey. Some purple beds sometimes contain green mottling and vice versa.

A spectrum exists between planar bedded lutite and coarser beds with linguoid and straight crested ripple marks. The lutite sometimes shows sand filled mud cracks and signs of bioturbation (Plates 13, 14), the bioturbation including short isolated inclined burrows, clusters of vertical tubes which may be burrows or root casts (Plate 15), sub-horizontal tubes from 2-10 mm thick (Plate 16), and less commonly, tubes several centimetres across. These later structures may be vertebrate burrows. Not uncommonly the bioturbation structures are found in partially silicified beds about 100 mm thick enclosed in lutite sequences as, for example, in a silicified fine sandstone near Lovely Banks Road [EN216988]. Other silicified fine-grained rocks resemble silcrete and include massive orthoquartzite north of Northumbria Hill [near EP222131] and crudely laminated silica stone resembling the silicified hardpan of McDonnell (1974, fig. 16).

The massive orthoquartzite breaks with a conchoidal fracture and in thin section (75-800) consists of interlocking, very fine-grained quartz grains displaying triple junctions. A small proportion (<5%) of non-quartz grains occurs. Some micas (including biotite) are enclosed in quartz, and quartz forms overgrowths on some microcrystalline quartz grains. No colloform silica occurs.

The percentage of lutite in core sections of Rm from three bore holes has been determined, and the results are given below:

| *Hole* | *Interval* | *Lutite (%)* | *Remarks* |
|---|---|---|---|
| Spring Hill 4 [EP206011] | 16.3 m 90% recovery | 72 | Sequence underlain by a further 9 m of cross-bedded sandstone (Rp?) |
| DMR Midland Highway 3 [near EP173002] | 11.6 m | 55 | All Rm |
| Kempton 1 [EN174951] | 46.6 m below 166 m | 67 | Interpreted as Rm underlain by a further 13 m of cross-bedded sandstone (Rp?) |

Three main lithological assemblage types, loosely recognisable by

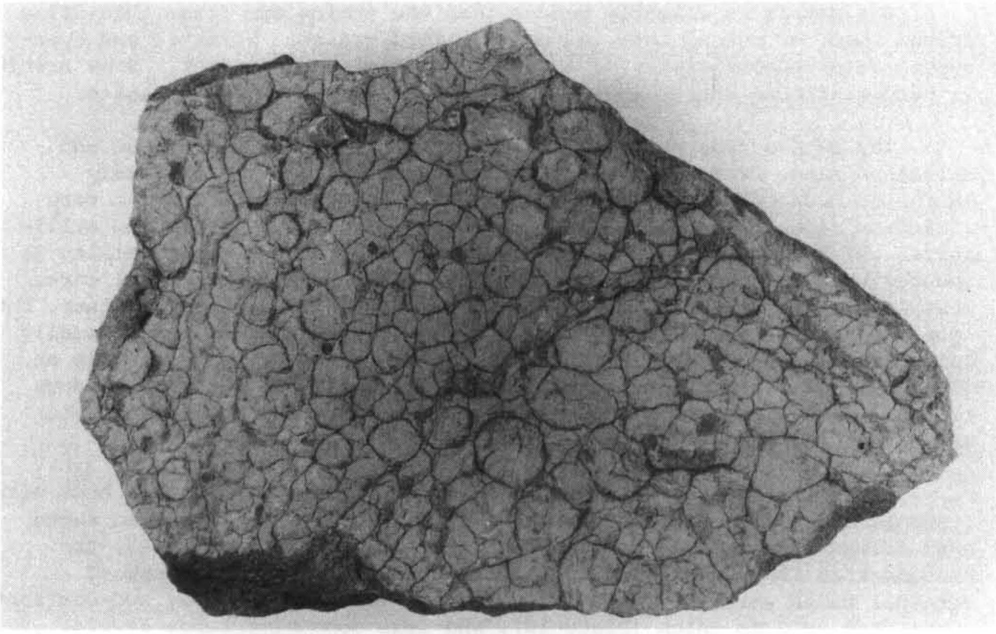


Plate 13. *Muddy siltstone of the muddy fluvial plain facies (Rm) showing small-scale mud cracks [EN168993]. Length of specimen 170 mm.*

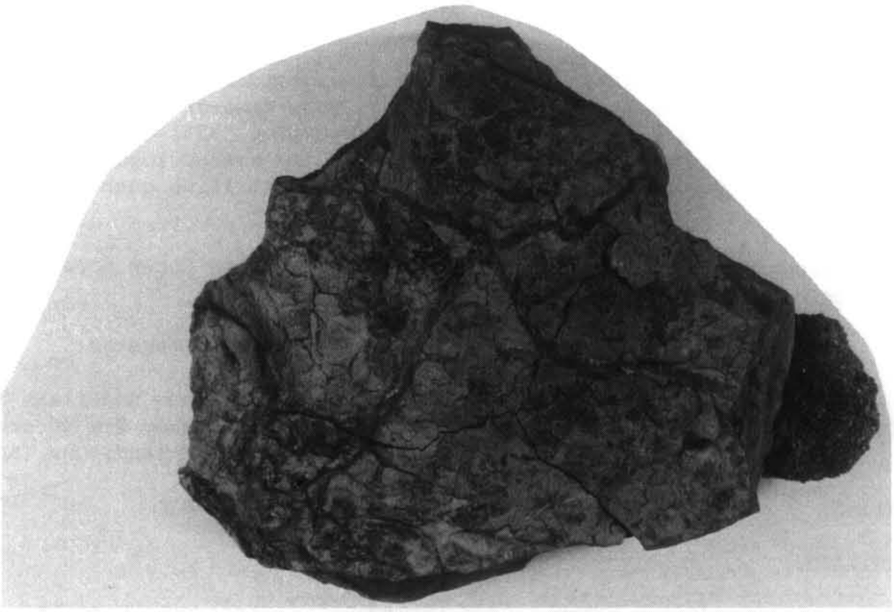


Plate 14. *Sand-filled mud cracks in muddy siltstone of the muddy fluvial plain facies (Rm). Width of specimen 120 mm.*



5 cm

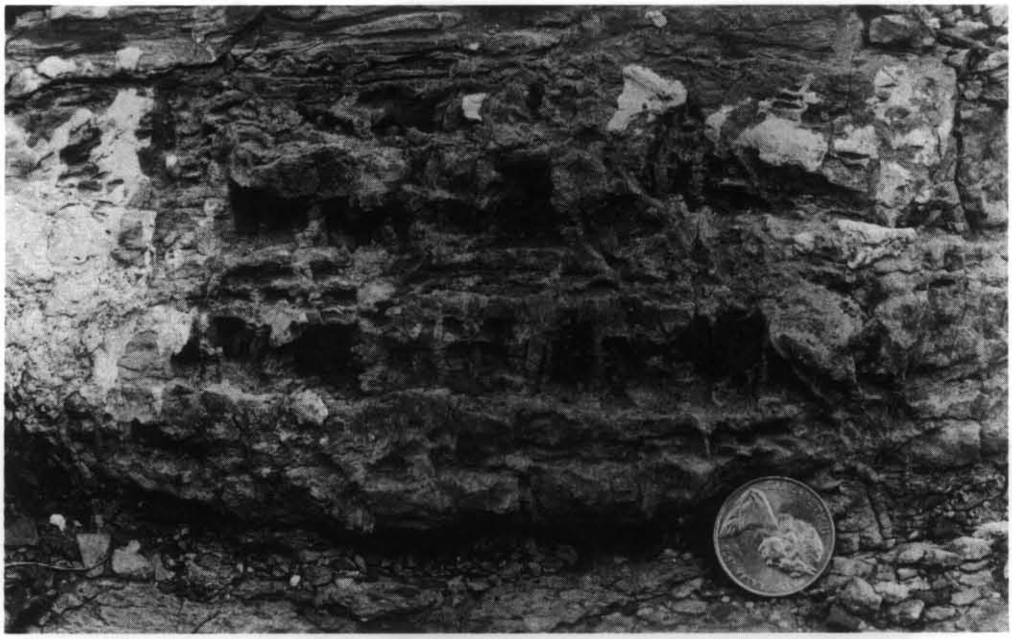


Plate 15. *Vertical and steeply inclined infilled tubes (burrows or roots?) in partially silicified coarse-grained siltstone of the interbedded micaceous quartz sandstone, siltstone and mudstone unit (Rm). Midland Highway, Lovely Banks [EP178006].*

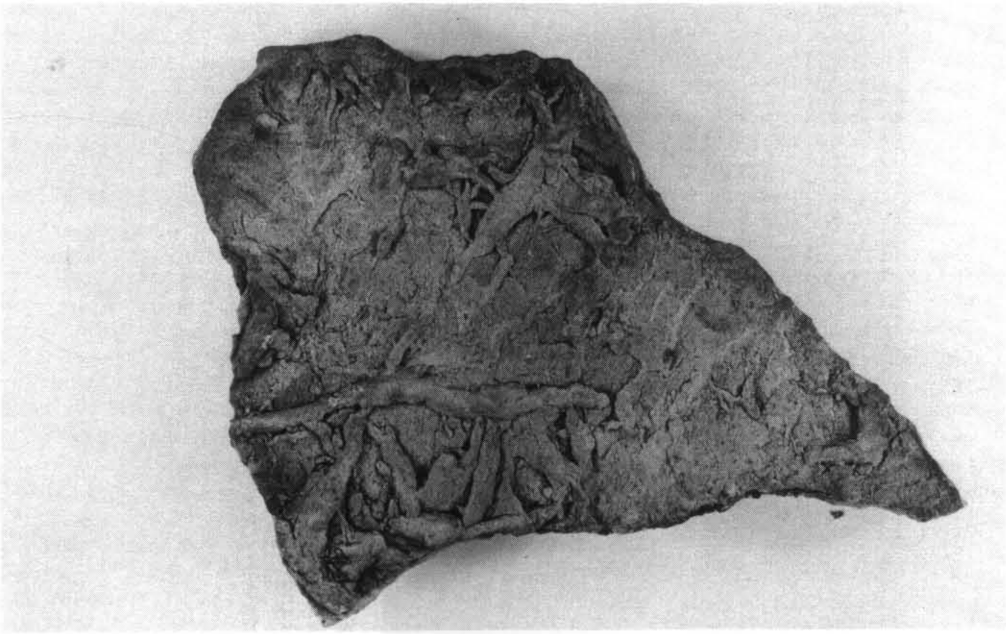


Plate 16. *Worm casts in thinly bedded silicified fine-grain quartz sandstone of the muddy fluvial plain facies (Rm). Maximum length of specimen 160 mm.*

5 cm

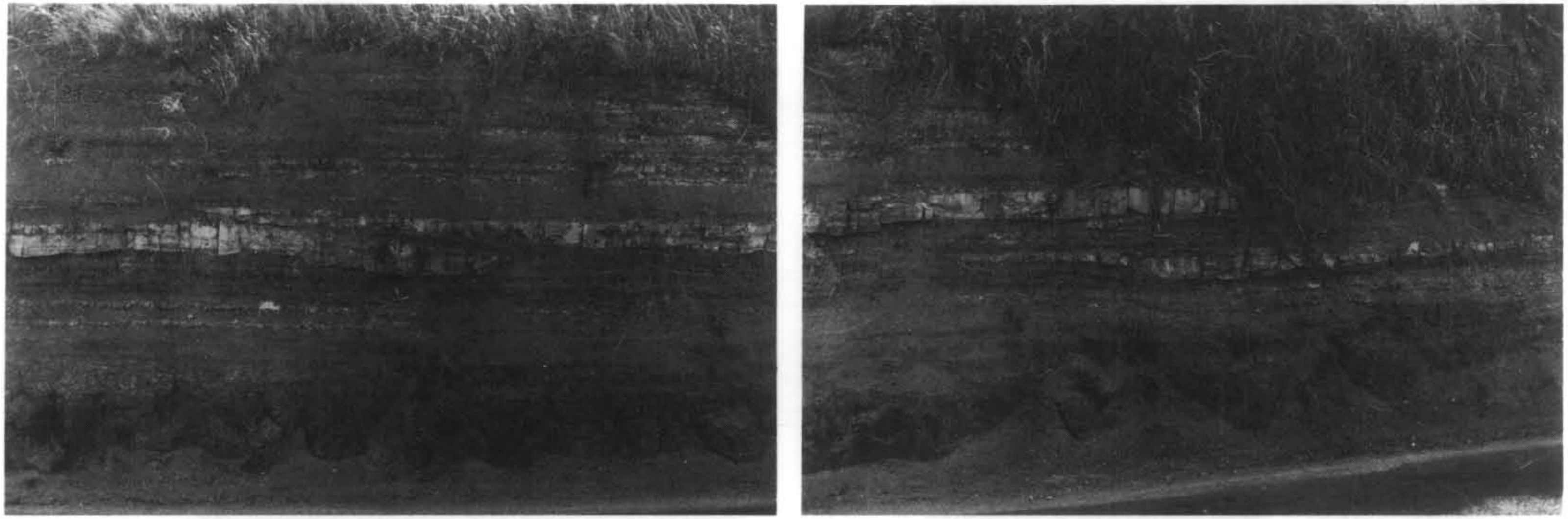


Plate 17. *Abruptly lenticular thin cross-bedded sandstone beds in very finely laminated mudstone and siltstone of Type 1 assemblage of Rm. Interpreted as lacustrine sediments of floodplain basin with crevasse splay deposits. Old Midland Highway at EP211014.*

Plate 18. *Detail of ripple cross-lamination in fine-grained sandstone of interbedded micaceous sandstone, siltstone and mudstone unit (Rm) [EP186005].*

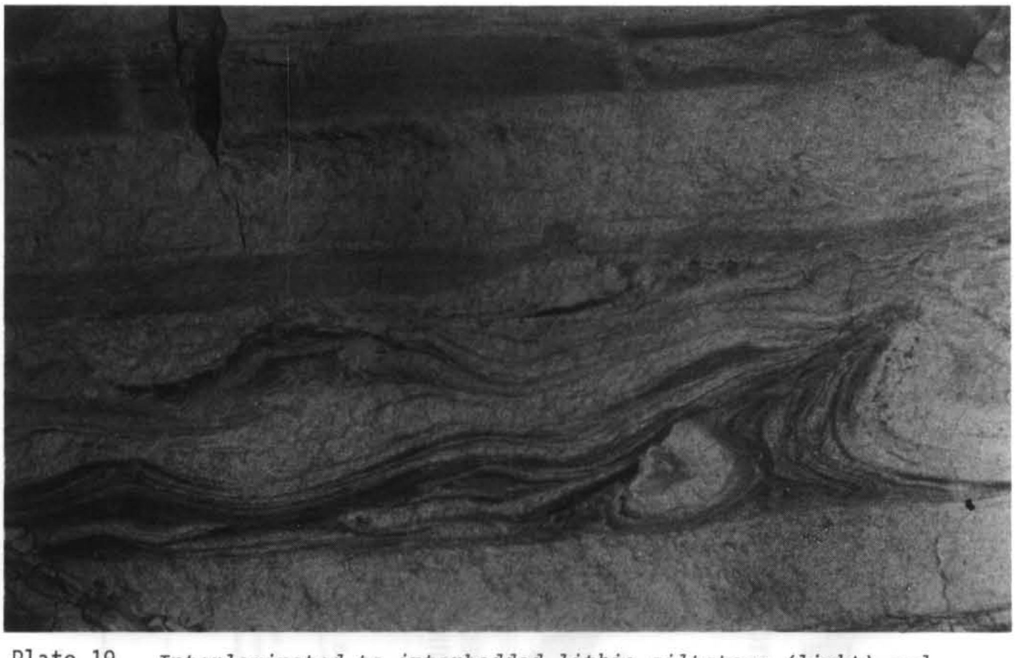


Plate 19. *Interlaminated to interbedded lithic siltstone (light) and finer grained silty mudstone (dark) of litho-facies Rsf, showing load casts, pseudonodule, and flame-like structures. Midland Highway, Spring Hill.*

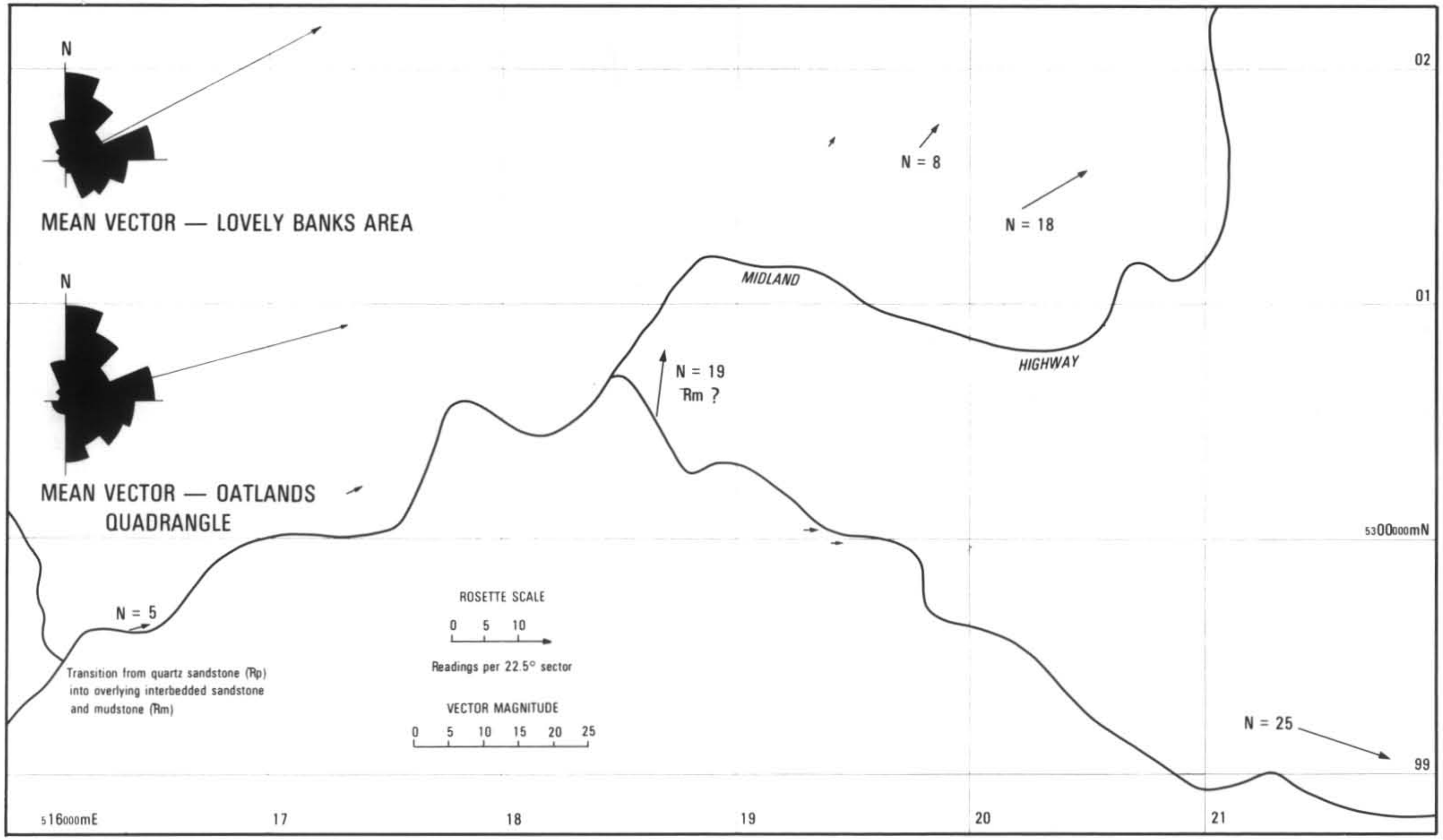



Figure 9. *Palaeocurrent vectors for interbedded micaceous mudstone and sandstone sequence (Rm), Lovely Banks area. Current vectors derived from crossbedding of major and minor channel sandstones.*

5 cm

the ratio of lutite to arenite, occur within Rm. These are:

*Type I* : Dominantly lutite, very minor arenite; considered to be a lacustrine facies,

*Type II* : Dominantly arenite; considered to be a major channel facies,

*Type III* : Interbedded arenite-lutite; considered to be largely overbank facies with small channel facies.

Type I assemblages are exposed on the old Midland Highway at EP208010 and probably in a new cutting at EP189010. The mudstone is finely laminated and shows no sign of subaerial exposure such as mudcracks, root casts, duricrust or palaeosols. The mica content is surprisingly low. Some sub-horizontal surfaces separate lutite units. Presumably the waters in which these sediments were deposited were strongly oxidising, as such sequences seem to be devoid of any vegetative fossil remains. The lutite beds are orange to brown in colour. Thin (1.0-0.1 m), well sorted cross-bedded sandstone beds occurring in this facies may represent sand introduced by streams flowing into lakes, or crevasse splay type sediments deposited into lakes. These sandstone layers commonly pinch out abruptly. The thinning is usually accompanied by a corresponding thickness increase in a stratigraphically close sandstone (Plate 17).

Type II assemblages consist of fining upward medium to fine-grained cross-bedded sandstone, forming bodies several metres thick. Such sandstone beds usually show an upward reduction in the scale of cross-bedding. Large festoons 2-3 m across are overlain by small festoons of less than one metre across, and these pass up into linguoid and straight crested ripple cosets (Plate 18). Three such sandstone bodies separated by lutite occur in the one sequence in some areas. The individual sandstone bodies maintain a fairly consistent average current direction over areas of 1-2 $km^2$ but greater variability is shown between individual sandstone bodies. The current directions (fig. 9) approximately conform to those obtained from Rp.

Type III assemblages may dominate some sequences or occur between Type II assemblages. Type III assemblages show the largest variation of rock types and probably include minor intercalations of Type I assemblages. Most of the features already listed as being characteristic of Rm are also typical of Type III assemblages. Some particular features are discussed below. At some localities are beds less than 100 mm thick composed of impure, poorly sorted sandstone containing mud pellets, quartz granules, and pith casts of sphenopsids. These beds are enclosed in lutite and have been interpreted as crevasse splay deposits. The sequence north of Northumbria Hill contains three silicified horizons, each 100-300 mm thick and composed of massive protoquartzite and crudely laminated quartzite. Elsewhere, most intensely bioturbated horizons have usually undergone some degree of silicification. All such silicified rocks are considered to have been silicified by groundwater soon after deposition and may represent duricrusts.

Purple and purple-grey muddy siltstone and mudstone are exposed in road cuts on the old Midland Highway [EP176004]. These beds display a blotchy green colouration, and abrupt lateral colour changes across steep irregular boundaries not related to bedding have been observed. Grey carbonaceous mudstone and siltstone occur locally and in some localities certain horizons are densely covered by leaves and stems of sphenopsids and rarer leaves and seeds of pteridosperms and lycopod cone scales. Sphenopsids are locally abundant in some buff coloured coarsely laminated siltstone. Some sandstone layers contain abundant bipinnate *Dicroidium (Zuberia)* fronds, megasporophylls, *Karibacarpon*, and seeds. Lycopod stems with dense leaf crowns have rarely been found preserved in micaceous fine sandstone. The more prominent sandstone beds range from single cross-bedded sandstone about 200 mm thick to composite bodies composed of several cross-bedded beds.

Limited exposure has prevented a proper assessment of the inter-relationships of the various lithofacies. For example the minor arenite layers interbedded in the Type III assemblages may be the main distributaries for the overbank deposits, or may be lateral distal facies of rivers depositing the Type II assemblages or deposits laid down during major flooding from the main channels. Type I assemblages may represent a complete environmental change for the whole area or may be the deposit of a coexisting environment, perhaps an integral part of the total fluvial system.

A muddy plain crossed by rivers and with more or less permanent small lakes is envisaged for TRm deposition. Carbonaceous deposits accumulated in ponded water, probably in small abandoned channels. Channel migration across the plain was sufficiently infrequent to allow intense bioturbation and probable surface silicification of some deposits, and to allow thick lacustrine deposits to accumulate. Vegetation included reed-like sphenopsids and rarer lycopods. Some sphenopsids were quite substantial plants with stem diameters up to 100 mm. Seed ferns probably occupied the better drained portions of the plain, probably the levees of streams. The low deviation of current directions and lack of abandoned channel deposits in Type II assemblages suggests the rivers were not of high sinuosity. Current directions range from 6° to 157°. Compared to the major part of the underlying quartz arenite sequence (TRp), the currents depositing TRm sandstone show a stronger bias towards the north-east quadrant. This is not an abrupt change of depositional current vectors however, as the upper sandstone units of TRp indicate some currents towards the north-east quadrant.

The transition of TRp into TRm, the similarity of current directions in TRm to those of TRp, and the similarity between TRp and Type II assemblages of TRm suggest that TRm and TRp may belong to the same major cycle of deposition. Whether TRm represents a more mature stage of the cycle or whether the difference is caused by climatic change has not been determined.

### *AGE AND CORRELATION*

Microfloras obtained from TRm are characterised by the presence of *Aratrisporites* spp.. *Falcisporites australis* and *Osmundacidites* are usually present and diversity is low.

A microflora has been extracted from carbonaceous grey-green siltstone in the transitional zone between TRp and TRm [EN203980]. This siltstone contains *Aratrisporites* spp. (mostly *A. wollariensis* Helby, 1967) and possibly *A. strigosus* Playford, 1965, with *Osmundacidites* spp. and forms resembling the central body of *'Taeniaesporites' hexagonalis* Jansonius, 1962. At EN166993 *A. wollariensis, A. rugulatus* de Jersey, 1970, *Limatulasporites limatulus* (Playford) Helby & Foster 1979 and *Limatulasporites* sp. occur in carbonaceous fine-grained grey siltstone about 20 m above the base of TRm. This horizon is associated with dirty fine-grained sandstone containing numerous seeds probably of pteridospermous origin, empty opened megasporophylls *Karibacarpon feistmantelii* Holmes and

Ash, 1979, *Dicroidium zuberi* var. *zuberi* (Szajnocka) Archangelsky, 1968 and *Dicroidium dubium* var. *australe* (Jacob and Jacob) Retallack, 1977.

An horizon of dark grey carbonaceous shale rich in sphenopsid stems about 20 m above the base of TRm, or slightly higher [EP176003], contains *Thymospora ipsviciensis* (de Jersey), Jain, 1968, *Densoisporites playfordi, A. wollariensis, A. tenuispinosus* Playford, 1965 and *A.* sp. *cf. A. goulbourniensis* Helby, 1966. The shale also contains lycopod cone scales and rarer seeds of probable pteridospermous origin. Cone scales with an extruding limb have been referred to *Skilliostrobus australis* Ash, 1979 whereas the remainder are of the *Cylostrobus sydneyensis* (Walkon) Helby and Martin, 1965 type. The latter cone scale type also occurs with sphenopsid stems [EP193041].

The introduction of *Aratrisporites* is an important horizon in Australia (Helby,1973; Dolby and Balme,1976; de Jersey, 1979). In Western Australia it first appears in the Dienerian but does not become common until the mid-Smithian, at the base of the *'Tigrisporites playfordii'* Assemblage Zone. *A. tenuispinosus* occurs in the *'T. playfordii'* Assemblage Zone. *D. playfordi* occurs in this zone but not above it, and *L. limatulus* has a Western Australian range restricted to the *'T. playfordii'* zone. The *'T. playfordii'* zone may possibly include part of the Anisian. In the Bowen Basin (de Jersey and Hamilton,1967; de Jersey,1968; de Jersey, 1970*a*; de Jersey, 1979) *Aratrisporites wollariensis* first appears about 390 m above the base of the Rewan Formation in Taroom 8; the only occurrence of *A. rugulatus* is in the upper part of the Rewan Formation, its introduction being followed by *A. strigosus* and finally *A. tenuispinosus* in the uppermost part of the Rewan Formation. *A. tenuispinosus* ranges into the base of the overlying Clematis Formation, whilst *D. playfordi* ranges up to occur rarely in the Moolayember Formation. *A. wollariensis* and *L. limatulus* disappear 685 m to 792 m respectively above the base of the Moolayember Formation of Middle Triassic age. De Jersey (1970*a*) considered the upper Rewan Formation and possibly the basal Clematis Formation to be of late Scythian age. Too little data is available for Tasmania to equate the *A. wollariensis* - *A. rugulatus* occurrence (prior to the *A. tenuispinosus* occurrence) to their respective peaks in the Rewan Formation.

The TRm assemblage belongs to the *Aratrisporites tenuispinosus* Assemblage described from the Sydney Basin (Helby, 1973). Helby noted that *D. playfordi* ranged up to the *A. tenuispinosus* Assemblage. Dolby and Balme (1976) suggested correlation of the base of the *'Tigrisporites playfordii'* zone with the base of the *A. tenuispinosus* Assemblage. In summary the microflora in the lower half of TRm suggests an age of mid-Smithian to early Anisian.

The macroflora belongs to the mid-Smithian to mid-Anisian *Dicroidium zuberi* Oppel zone of Retallack (1977). *Dicroidium dubium* var. *australe* and *Cylostrobus* are restricted to this zone. *D. dubium* var. *australe* first occurs in the Newport Formation which lies in the upper zonule of the *A. tenuispinosus* Assemblage Zone (Helby, 1973). *D. zuberi* var. *zuberi* ranges from mid-Smithian to Norian.

In New South Wales *Skilliostrolbus* occurs in the Terrigal Formation (Gosford Formation) assigned to the *A. tenuispinosus* Assemblage, and in the Camden Head Claystone which is believed to be of late Early Triassic age (Ash, 1979; Holmes and Ash, 1979). The macroflora suggests an age of mid-Smithian to mid-Anisian whilst the lack of *Xylopteris,* which is common higher in the sequence, suggests an age not as young as Anisian (based on Retallack, 1977). The microfloral and macrofloral data indicate a mid-

Smithian to early Anisian age, although a pre-Anisian age is more probable.

Mixed lutite-quartz sandstone sequences overlying or occurring at the top of quartz sandstone sequences have been reported from the Derwent Valley (Jennings, 1955), the Hobart and Brighton Quadrangles (Leaman, 1976, 1977), the Coal River area (TRlm and TRlf in part of Leaman, 1971), Mt La Perouse (Davidson, 1969), the St Clair Quadrangle (Gulline, 1965), and along the Western Tiers - the Cluan Formation at Poatina (McKellar, 1957) and its probable correlates in the Quamby Bluff area (Wells, 1957; Pike, 1973) and at Mother Cummins Peak (Burns, *in* Jennings, 1963).

The Cluan Formation lutite is predominantly a dark grey shale (McKellar, 1957) and its microflora is unknown. The middle of the overlying Tiers Formation contains a microflora (Playford, 1965) correlatable with that which occurs towards the middle of the muddy fluvial plain facies (TRm). However, the Tiers Formation is quite distinct lithologically, as it contains lithic sandstone (McKellar, 1957). Playford (1965) reported *D. playfordi* and *Thymospora ipsviciensis* from the Ross Formation at Poatina, and *A. strigosus* and *A. tenuispinosus* from the Tiers Formation, *A. strigosus* extending into the Brady Formation and *L. limatulus* from the top of the Tiers Formation. The TRm microflora is intermediate between that of the Ross Formation and the Tiers Formation and perhaps could be expected to occur in the Cluan Formation.

From unit 52 in a red bed-lutite-sandstone sequence about 226 m above the base of the La Perouse Formation, Davidson (1969) recorded *Krauselisporites cuspidis, Protohaploxypinus samoilovichi, Punctatisporites?* sp. A, *Lundbladispora* sp. *A*, *Aratrisporites banksi*, and *A. strigosus*. Six metres above this horizon, in unit 56, Davidson recorded *A. strigosus, A. tenuispinosus, Alisporites* sp. *A., Biretisporites, Osmundacidites fissus, O.* sp. *cf. wellmanni*, and *O.* sp. *A.* occurring with *Equisetites* roots, *Cylostrobus sydneyensis, Cladophlebis australis, Pterrorachis barrealensis, Dicroidium feistmanteli*, and *Lepidopteris madagascariensis*.

Unit 56 is considered to be a biostratigraphic correlate of the horizons about 20 m above the base of TRm. Unit 52 may correlate with the base of TRm, but the microflora is slightly older. On gross lithological characters, unit 52 to unit 56 may be correlated with TRm.

Camp and Banks (1978) recorded the identification by J.A. Townrow of the frond *Pterrorachis barrealensis* Frenguelli, *Dicroidium zuberi* (Szajnocka), and *Cylostrobus sydneyensis* (Walkom) Helby and Martin in the Poets Road Member at Crisp and Gunn's quarry, Knocklofty. *D. zuberi* and *Cylostrobus* also occur in the sandstone-carbonaceous shale-red bed sequence between Impression Bay and Prices Bay on Tasman Peninsula (M.R. Banks, manuscript). The rocks containing *D. zuberi* and *Cylostrobus* are biostratigraphically correlated with TRm. The massive quartz sandstone (TRlm) in the Brighton Quadrangle also contains *Skilliostrolbus australis* (Ash, 1979).

In the absence of palaeobotanical data, the relationship of other lutite-quartz sandstones to TRm cannot be ascertained, although some of these horizons show gross lithological similarities to TRm. Until detailed lithological characters are comprehensively studied, correlation based on lithology will remain doubtful. The range of vertebrate fossils with respect to microfloral changes has not yet been established in Tasmania.

## QUARTZ AND LITHIC-FELDSPATHIC SANDSTONE AND INTERBEDDED MUDSTONE AND SILTSTONE (Ꞧs)

The Rs symbol has been used to depict rock sequences occurring above the muddy fluvial plain sequence (Ꞧm) and below the characteristic volcanic lithic arenite-lutite-coal measures sequence (Ꞧg) of Late Triassic age. Following the classification system of Williams, Turner, and Gilbert (1954), rocks mapped as Ꞧs contain quartz arenite, feldspathic and/or lithic arenite (and intergrading lithologies), and lutite. In contrast to the volcanic lithic arenite of Ꞧg, Ꞧs contains a lesser proportion of fine-grained acid igneous grains, while very fine igneous grains with feldspar laths set in an unresolvable dark groundmass are rare to absent. Most hand specimens lack the grey to black lithic grains characteristic of the volcanic lithic arenites.

In thin section, quartz is more common in the lithic arenite of Ꞧs (25-45%) than in the volcanic lithic arenite of Ꞧg (5-30%, commonly 15-25%). To emphasise the difference between the two types of lithic arenite, that type occurring in Ꞧg is referred to herein as volcanic lithic arenite, the main criteria for its recognition in hand specimens being the abundance of grey to black grains. Both the lithic arenite and the volcanic lithic arenite may appear to be more feldspathic in hand specimens than is evident in thin section, possibly because weathered felsic lithic fragments resemble weathered feldspar grains.

The lutite of Ꞧs contains a higher proportion of grey to black carbonaceous rocks than in Ꞧm. Not uncommonly, the lutite (and occasionally some arenite layers) contains macrofossils including *Dicroidium odontopteroides, Xylopteris, Johnstonia,* and *Sphenobaiera,* recognisable in the field as being of different aspect to the macrofloras occurring in Ꞧm. One lutite rock type present in Ꞧs but not recorded from Ꞧm consists of interlaminated grey-green weathering mudstone and buff weathering siltstone to very fine-grained sandstone. The laminae vary from less than one millimetre up to a few centimetres thick, with the coarser silt or sand usually forming the thicker beds. Flame and load cast structures and isolated small burrows 10-20 mm long occur in this rock type (Plate 19).

Other features observed in Ꞧs, but not in Ꞧm, include sandstone with leaf fragments and carbonaceous grains, and sandstone with flasers and wavy laminae defined by carbonaceous mudstone. Mica is concentrated on the bedding planes of some rocks. A change in the chemistry of the lutite appears either at or near the base of the lithic arenite (Ꞧs). The lutite of Ꞧm is usually grey to light blue-grey when fresh, weathering with an orange tinge when not particularly carbonaceous. The light to dark grey lutite of Ꞧs rapidly weathers with a greenish-grey tinge, whilst the quartz-rich lithic arenite and siltstone weathers to buff colours on prolonged exposure. No red or purple lutite has been observed in Ꞧs. Quartz arenite weathers white or cream, rarely pink, and some black shale layers remain black after weathering. The consistency of palaeocurrent directions, directed on average towards the north-east, east, or south-east in Ꞧp and Ꞧm, is not maintained in Ꞧs.

In some areas sequences comprising beds showing the above listed characters and occupying the interval between Ꞧm and Ꞧg have been mapped as Ꞧs, while in other areas distinctive assemblages of Ꞧs lithotypes have proved mappable. Unfortunately the relationship between these litho-assemblages was not known in detail during mapping, mainly because of inadequate exposure and lack of suitable natural sections or borehole data, and partially because of the lack of continuity of litho-assemblages.

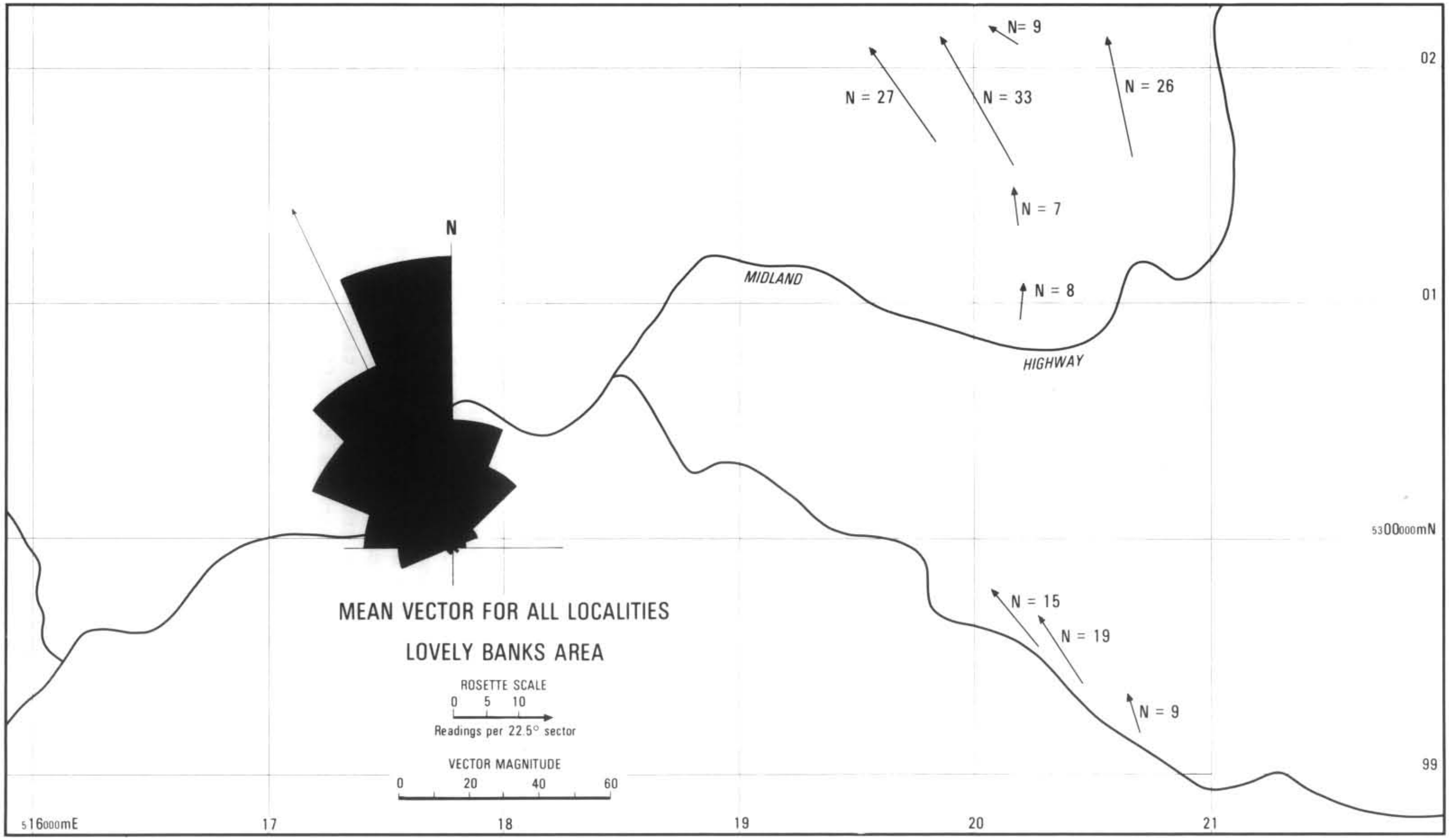



Figure 10. *Palaeocurrent vectors for basal sandstone bed with granules (lithological unit TRs), Lovely Banks area. Mean vector for each outcrop area calculated from individual measurements of festoons, tabular cross-bedding, and ripples.*

To some degree this has since been rectified (see page 68). The litho-assemblages mapped are quartz arenite and lutite (Ꞧsq), quartz arenite and lutite with carbonaceous beds (Ꞧsq'), and quartz-rich lithic arenite containing lutite with carbonaceous beds (Ꞧsf). In most areas the basal beds of Ꞧs belong to the Ꞧsq assemblage.

*INTERBEDDED QUARTZ ARENITE AND LUTITE (Ꞧsq)*

In the Melton Mowbray-Spring Hill area, east of 'Lovely Banks' [for example EN210990], the fluvial plain facies (Ꞧm) is overlain by a conspicuous 3-5 m thick coarse to medium-grained arenite with quartz granules (indicated by mappable coarse-grained sandstone symbol on the map). Granules are variably dispersed in sandstone, concentrated in thin laminae, or form granule conglomerate. The sandstone is primarily composed of quartz and other siliceous grains with 2-15% feldspar and contains mud pellets. Broken surfaces are often coloured yellowish brown to red, particularly where ferruginous silty traces of matrix or labile grains remain. Euhedral overgrowths on quartz grains enclose dirty margins of the original grains.

The base of the granule sandstone is well exposed [EP207017, EP200016] where scouring of the underlying Ꞧm lutite has been observed. The granule sandstone exhibits large scale festoon cross-bedding, occasionally with basal erosive surfaces which rise at angles up to 25° down-current, and smaller scale tabular cross-bedding forming sets 100-200 mm thick. A consistent current direction to the west of north has been obtained for the granule sandstone throughout the area (fig. 10), which is markedly different from that obtained from most underlying sandstones. Granule sandstone occupying the same stratigraphic position occurs north of Melton Mowbray [EP146000] but granules were not observed in DDH Kempton 1 at 'Stockman' [EN174951]. If any horizon in DDH Kempton 1 is a finer-grained equivalent of the granule sandstone, it is most probably the scouring arenite at 116 m. This sandstone is 2.2 m thick, quartzose, medium to coarse-grained at the base, rapidly fining upwards to medium-grained and contains some mud pellets. A few centimetres of lutite separate this unit from a further overlying fine-grained rippled sandstone 1.4 m thick (Appendix 4).

East of Lovely Banks the most complete sequence consists of a basal sandstone with granules, overlain by a thin (∿20 m) sequence of inter-bedded quartz arenite and lutite. Where most complete, this sequence consists of three fine-grained quartz units separated by lutite units of similar thickness. The lutite consists of variably micaceous orange (weathered) shale and massive siltstone and occasionally some grey carbonaceous siltstone. The quartz arenite is fine to very fine-grained and well sorted. It is usually white or cream with zones of pink and red colouration and in some areas black manganese? stains. The rock is tough and usually weathers with a knobbly surface and appears to be partially silicified. The partial silicification could be due to thermal metamorphism by a dolerite sheet now eroded from the area, but the possibility that the silicification is an early diagenic phenomenon related to the depositional environment cannot be ruled out. Restriction of the silicification to thin (100-200 mm) layers in some quartz arenite outcrops supports the latter possibility. The arenite contains mud pellets forming lag deposits a few centimetres thick and some accentuation of laminae by compositional and textural changes occurs. The arenite exhibits festoon cross-bedding, with festoons from several metres to less than 0.5 m across, ripple marks, and rare bars. A bar is composed of tabular individual beds [EP202009] 100-200 mm thick which are cross-bedded (fig. 11). The direction of dip

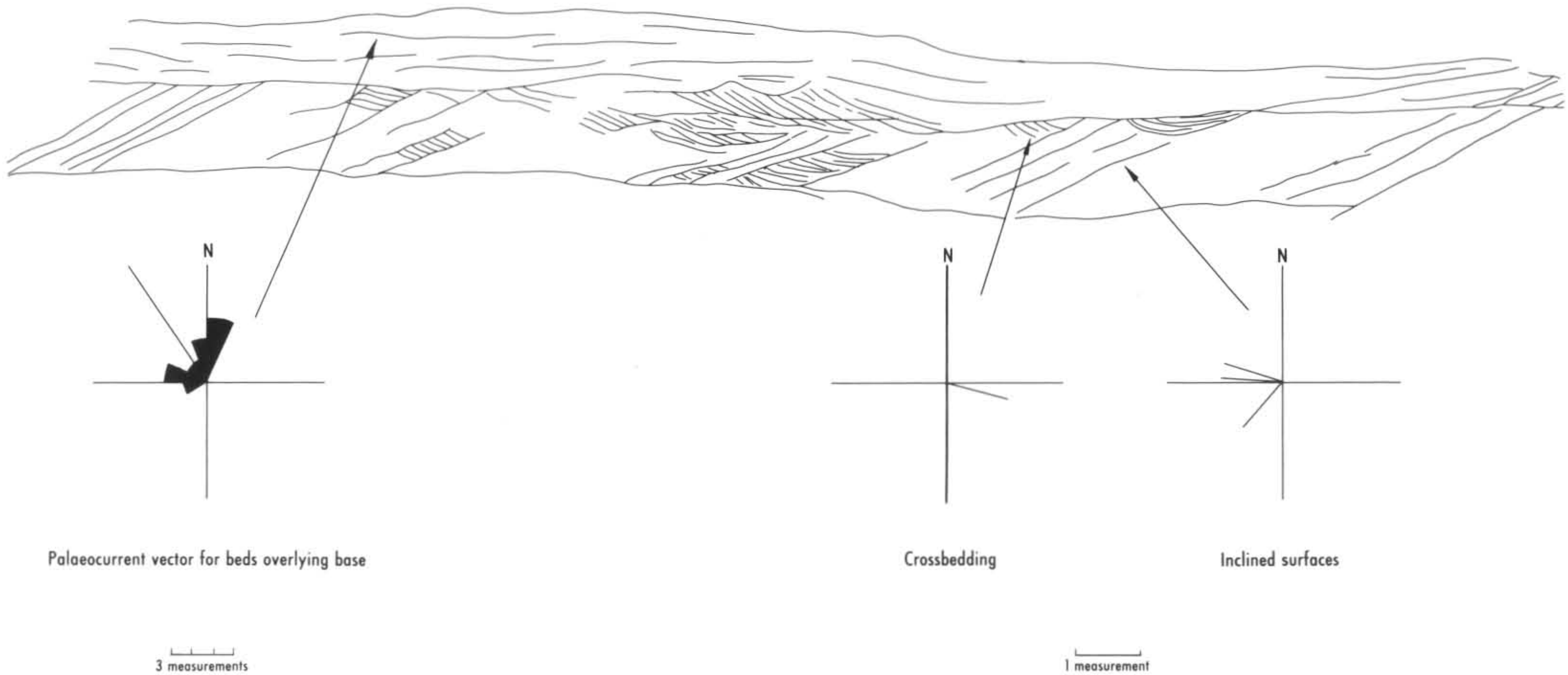
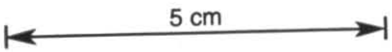



Figure 11. *Bar structure in the interbedded quartz-arenite and lutite litho-assemblage (Rsq). Azimuths of dip of inclined accretionary surfaces and crossbedding are indicated.*



of the tabular beds is completely opposed to the direction of current flow indicated by the cross-bedding. The bar structure passes upward into festoon cross-bedding. The structure resembles point bars of small high sinuosity streams (Puigdefabregas, 1973). From a diagram by Puigdefabregas, it appears that the direction of dip of the accretionary surfaces and the dip of the cross-bedding may differ by up to 150°.

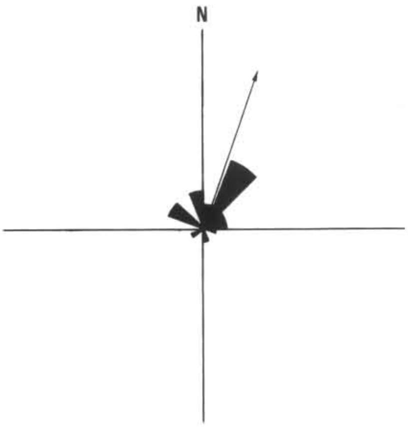
Current direction analysis of the quartz arenite overlying the basal sandstone with granules indicates currents were of variable azimuth and yield an average vector towards 288° (fig. 12). Foresets are commonly steeper (perhaps oversteepened) and cross-bedding structures are more variable than in TRp and TRm. The high maturity of the quartz arenite, accentuation of laminae, nature of cross-bedding and current direction, and the occurrence of arenite and lutite in similar proportions enables recognition of this assemblage. Field exposure has not permitted an assessment of the depositional environment of the lutite rocks, but presumably they are overbank deposits to the fluviatile channel quartz arenite. Fossils are rare in the TRsq unit.

Away from the Lovely Banks area, similar quartz arenite beds have been recorded at Woods Quoin and on the 'Stockman' property [EN186949]. Near Northumbria Hill [EP210094] quartz sandstone with granules occurs at several horizons above the TRm sequence. The assemblage has also been intersected in DDH Jericho 1, where a seven metre thick interval contains several horizons with white, pink, and red quartz granules and some mud pellets (Appendix 4). This seven metre thick interval is exposed along the banks of the Jordan River west of Northumbria Hill [EP204092 to EP215086]. Unlike the granule sandstone overlying TRm, several kilometres north-west of Northumbria Hill, this granule sandstone shows affinity to quartz sandstone of TRs and has been depicted on the map as TRs? and TRsq?. The granule sandstone is cross-bedded with individual cross-sets up to one metre thick. Average current vectors derived from outcrops north and south of the Jordan River are similar, with an average current direction for this area towards 305° (fig. 12). This direction is comparable to the current vector of 335° obtained from the granule sandstone at the base of TRs in the Lovely Banks area. The average current direction obtained from outcrops of granule sandstone on the north bank of the Jordan River and the average current direction obtained from overlying fine-grained quartz arenite are both towards 313°.

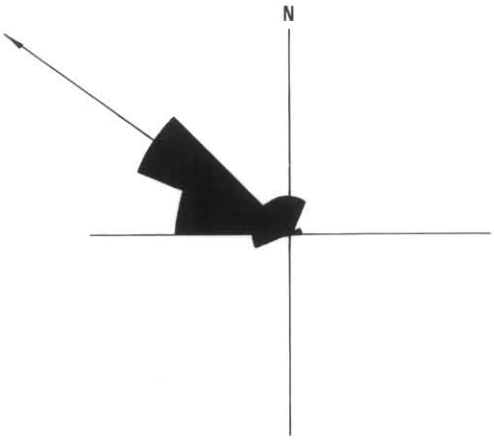
Several kilometres north-west of Northumbria Hill sandstone with granules overlies TRm but this sandstone resembles sandstone of the Early Triassic quartz sandstone TRp and has been tentatively assigned to TRp? The current directions of TRp? contrast with those described above. At four localities the granule sandstone (TRp?) has yielded current directions of 358°, 66°, 85°, and 137°, giving an average vector towards 77° (fig. 12).

Subsequent to the publication of the map, new road cuttings on the realigned Midland Highway at Spring Hill have exposed a sandstone with granules including pink quartz [EP213033]. This horizon lies within TRs, but not at the base.

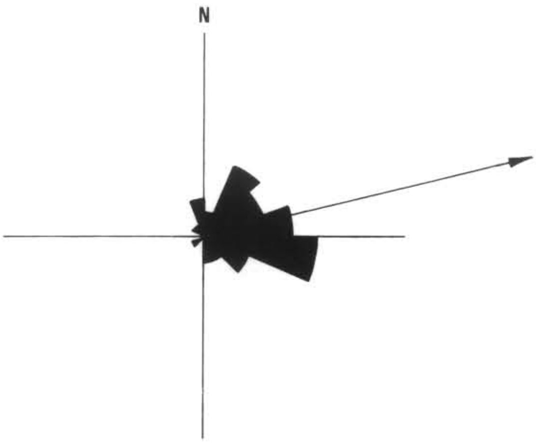
North of Big White Hill [EP168023] a unit shown as TRsf on the map includes at the lowest exposure a very coarse to coarse-grained sandstone and 'feldspathic' quartz sandstone. The feldspar content is greater than in rocks of TRp or TRm. This rock is considered to be a possible correlate of the sandstone with granules of TRsq in which labile grains have not been excessively weathered.



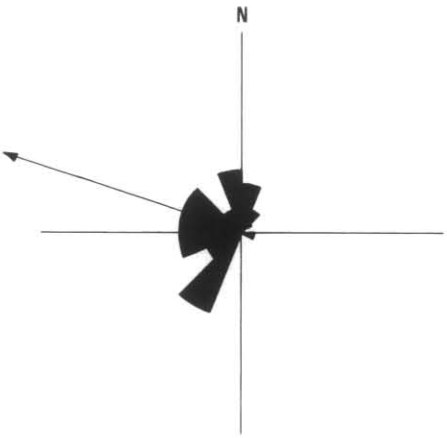

Vector mean from quartz-rich lithic arenite and lutite (Rsf, lower).




Vector mean from the quartz and lithic-feldspathic sandstone and interbedded mudstone and siltstone sequence (Rs), basal sandstone with granules, west of Northumbria Hill.

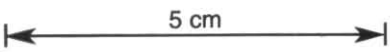


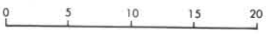

Vector mean from quartz sandstone (Rp?) overlying the muddy fluvial plain sequence.




Vector mean from Rsq horizon near base of Rs, excluding data from basal sandstone with granules.

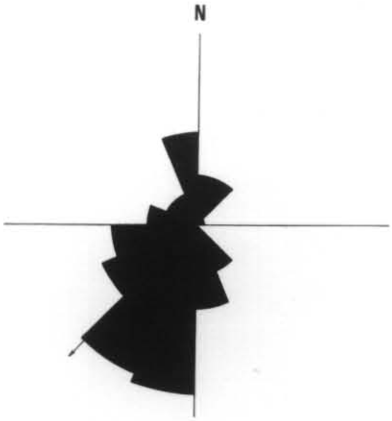

ROSETTE SCALE
Readings per 22.5° sector



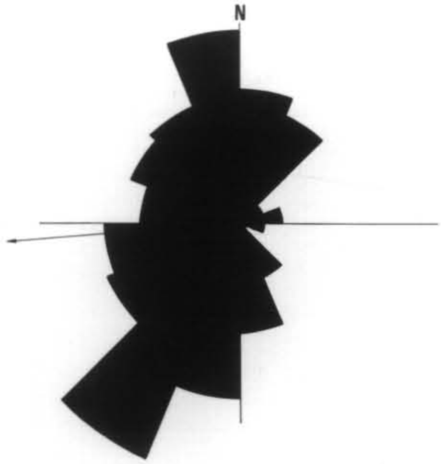




VECTOR MAGNITUDE SCALE

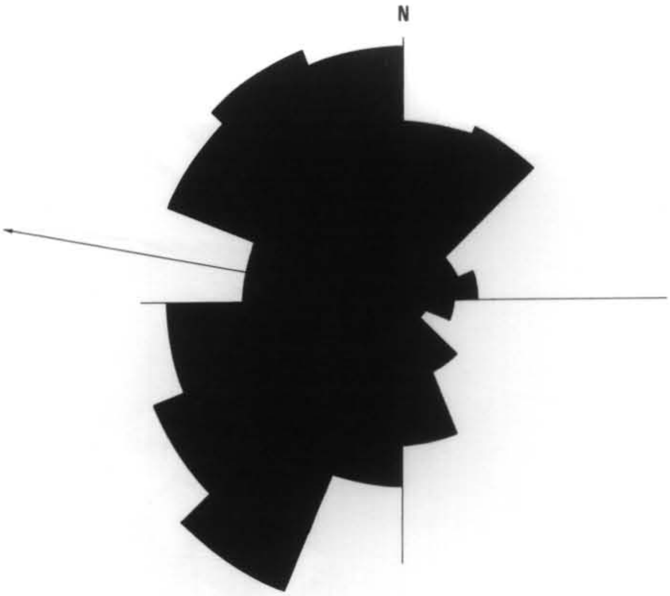
Figure 12. *Palaeocurrent vectors from the quartz and lithic-feldspathic sandstone and interbedded mudstone and siltstone (Rs) and quartz sandstone (Rp?) overlying the muddy alluvial plain sequence (Rm).*




Vector mean for interbedded quartz arenite and lutite with carbonaceous beds (Rsq').




Vector mean for all localities in the quartz and lithic-feldspathic sandstone and interbedded mudstone and siltstone (Rs).




ROSETTE SCALE
Readings per 22.5° sector

VECTOR MAGNITUDE SCALE

Vector mean for all localities of the quartz and lithic-feldspathic sandstone and interbedded mudstone and siltstone (Rs), and the volcanic lithic arenite, lutite and coal measures (Rg).

5 cm

Figure 13. *Palaeocurrent vectors from the quartz and lithic-feldspathic sandstone and interbedded mudstone and siltstone (Rs) and the volcanic lithic arenite, lutite and coal measures (Rg).*

Plate 20. *Basal view (vertically up) of exfoliating sandstone bed of the carbonaceous interbedded quartz arenite and lutite litho-facies (Rsq') [EP214034].*

Plate 21. *View from below of cross-bedded carbonaceous sandstone laminae at left, transitional with wavy lenticular laminae at right.*

Subordinate sandstone rich in lithic grains occurs beside the Lovely Banks Road [EN204992] and west of Lovely Banks [EN154999]. The quartz arenite is less well developed at the latter locality and appears to be absent from the base of Rs in some areas. Granules are also absent in DDH Spring Hill 1 at Lovely Banks.

Recent mapping by the author in the adjacent Interlaken Quadrangle has shown that rocks similar to Rsq and containing granule-rich horizons occur near Table Mountain in a similar stratigraphic position.

*INTERBEDDED QUARTZ ARENITE AND LUTITE WITH CARBONACEOUS BEDS (Rsq')*

This assemblage is defined by the presence of fluviatile quartz arenite with a wide variety of sedimentary structures and the occurrence of significant carbonaceous rock types, which often contain diverse macrofloras and a distinctive microflora. The carbonaceous rocks range from black and dark grey, slightly micaceous, muddy siltstone; to light grey, grey-green, and brown mudstone and siltstone; and to carbonaceous sandstone. Grey and black mudstone as pellets, wisps and stringers and less commonly coalified wood occurs in the sandstone. Coalified wood is also present in dark grey mudstone. All rock types may contain plant fossils and reasonably diverse and well preserved floras have been obtained from several localities (Appendix 3).

This assemblage was first recognised in road cuttings at EP215035; this cutting is described in Appendix 4. The arenite beds are composed predominantly of quartz (sometimes sparkling), with 2-15% well rounded feldspar and sometimes sufficient red garnet to be visible in hand specimens. Zircon, muscovite, and rutile are also present. Lamination is often conspicuous and is defined by grain size changes, micaceous, graphitic or carbonaceous partings, or occasionally feldspar concentrations. Superficially resembling the arenite of Rp, the Rsq' arenite is distinguished by the presence of carbon, the style of sedimentary structures, current directions, the associated lutite layers, the macroflora, and the less ferruginous appearance. Structures range from bars or microdeltas (Plate 22) several metres in thickness, scour and fill structures and festoon cross-bedding a few to several centimetres thick to very elongate straight crested 'longitudinal sand ripples' up to ten millimetres high and several centimetres wide (Plate 20, 21). Outcrops show that the 'longitudinal ripples' occur down the foresets of cross-bedding and down the axes of troughs. These may be large scale examples of primary current lineation defined by partings of flakey minerals and perhaps exaggerated by loading. Some ripples resemble extremely down-current elongated linguoid ripples. Convolute bedding with cylindrical and cuspate-shaped folds and large sandstone masses with compressional square wave-shaped open cast folds occur (Plate 23). Fold wavelengths are a few centimetres for most types. Oversteepened cross-bedding may be caused by loading or further intrastratal compression. Only one example of overturned cross-bedding has been recorded.

Three or four continuous benches of well-exposed quartz arenite separated by poorly exposed lutite and thin arenite beds usually occur where this assemblage crops out. Outside of the Spring Hill-Lovely Banks Road area, Rsq' has been mapped on the banks of the Jordan River south-east of Black Marsh [EP121038], beside the Lake Highway near Melton Mowbray [EP133985], and on the northern flanks of Big White Hill [EP170033]. There

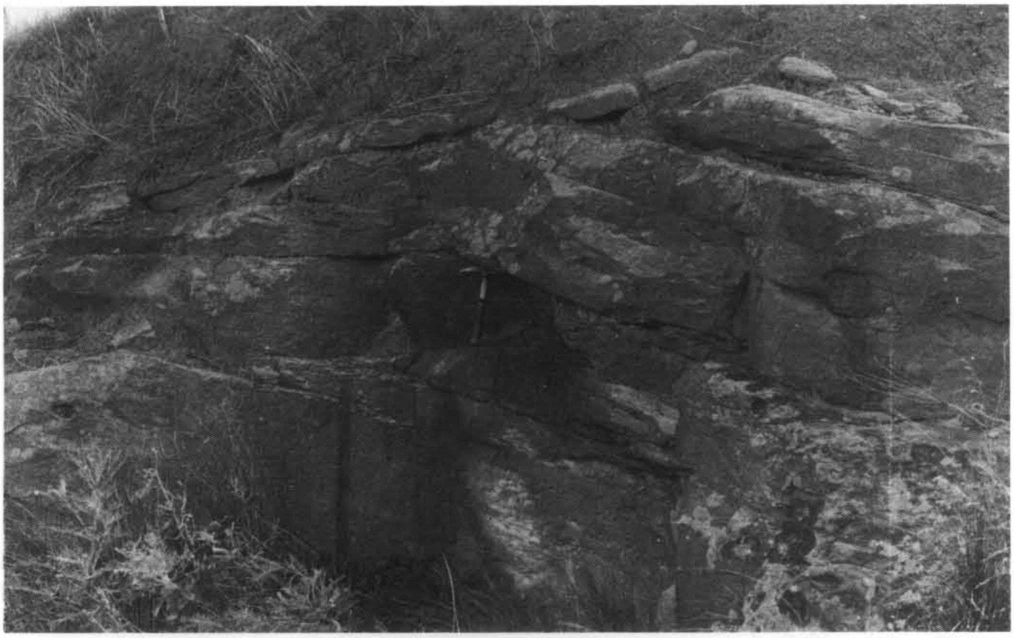


Plate 22. *Large bar structure in quartz arenite of carbonaceous quartz arenite and lutite facies (Rsq'). Avalanche face progrades and climbs from left to right. Old Midland Highway, south of Tedworth [EP211017].*

Plate 23. *Intrastratal box-folding in quartz arenite of carbonaceous interbedded quartz arenite and lutite litho-facies (Rsq') [EP210016].*

is supportive palynological evidence at the latter locality and also east of Northumbria Hill [EP235090]. Other outcrops occur at Mt Mercer [EN229975] and at York Plains [EP350198]. The inverval from 21.0 m to 43.6 m in DDH Kempton 1 probably belongs to TRsq'.

Certain sedimentary structures are common to both the quartz arenite beds of TRsq' and TRsq. These structures include well-defined lamination, sand bars of amplitude greater than one metre, and the variety and style of cross-bedding. An excellent example of the unusual 'longitudinal ripple' structure found in arenite layers of TRsq' has also been found in TRsq. Structures resembling rudimentary 'longitudinal ripples' occur commonly in TRsq.

*INTERBEDDED QUARTZ-RICH LITHIC ARENITE AND LUTITE (TRsf)*

This assemblage consists of buff-coloured quartz-rich lithic arenite and siltstone and quartz-rich feldspathic arenite with lesser yellow, grey, and grey-green mudstone. Some mud pellets have orange or red skins; variations of colours are partly due to weathering. Both laminated and massive lutite occurs. Although some sandstone units are several metres thick, most sandstone beds are between 0.1 m and 1.0 m thick and consist of fine to medium-grained fining upward cycles overlain by siltstone or silty mudstone. Cross-bedding is not conspicuous, but does occur either as festoons or very low angle sets. Sandstone layers consisting of numerous cosets are uncommon. Those that do occur usually scour underlying rocks and sometimes contain carbonised wood and mud pellets, particularly near the base. Some of the thinner sandstone beds are strongly lenticular and some show the mutual wedging out of paired beds similar to that seen in the type 1 assemblage of TRm. Flame and load structures, soft sediment deformation, and microfaults have been observed. Scattered vertical and inclined sand filled burrows are present in some areas but rarely is there evidence of intensive bioturbation. Beds with leaf debris occur, but well preserved leaf fossils are not common.

The unit TRsf was originally used to include poorly exposed beds at Spring Hill that overlie the quartz arenite and lutite with carbonaceous beds assemblage (TRsq') and which pass up transitionally into the volcanic lithic arenite, lutite, and coal measures sequence (TRg) [EP21500365]. Quartz-rich lithic arenite and lutite exposed in road cuttings on the old Midland Highway [EP213030 to EP212025] was regarded during mapping as being from an equivalent horizon, but further work has shown these outcrops to be of upfaulted beds from an horizon in TRs below TRsq'. The unit TRsf was extended during mapping to include similar lithological assemblages regardless of their stratigraphic position within TRs and notable single outcrops of lithic arenite in the quartz arenite dominated portions of TRs.

In the wider sense, TRsf has been applied, for example, to the sequence south of Little White Hill where quartz sandstone is rare [EP150010], to rocks above TRsq at Woods Quoin [EP075169], and to rocks north of Beddingdown Hill [EN105993]. TRsf is exposed in road cuttings within a graben near Lovely Banks. Subsequent to mapping, the southern boundary fault of the graben near Lovely Banks has been exposed in a road cutting [EP189011] and additional exposures of TRsf now exist along the graben. Further new exposures of TRsf along the realigned Midland Highway include the first road cutting south of the Lovely Banks Road [EP182007] and the two long cuttings at and south of the access road to Lemon Springs [EP277115].

In DDH Kempton 1 numerous upward fining cycles of lithic sandstone to muddy siltstone, generally from one to five metres thick, occur underlying that part of the sequence correlated with Rsq'. These cyclic rocks are also correlated with Rsf.

Diamond drilling and new road cuttings have further elucidated the sequence at Spring Hill. The major cutting immediately south of the crest cutting in dolerite at Spring Hill exposes quartzose sandstone (Rsq') near the base [EP21430388]. The highest quartz sandstone is overlain in the cutting by about 40 m of dominantly mudstone and siltstone with less lithic sandstone and some thin bituminous coal horizons (Appendix 4). The lutites are light to dark grey in colour, with some mudstone weathering to greenish grey and some coarse silt laminae and beds weathering to buff colour. A few large ellipsoidal concretions occur at particular horizons. Most of this sequence was not exposed on the old highway. The limited exposures on the old highway and beds sampled in a shallow diamond drill hole (DDH Spring Hill 3) sited on the old highway [EP21450392] probably correlate with the beds near the top or above the sequence now exposed on the realigned highway.

An interval of about 100 m of the lutite and quartz arenite with subordinate lithic arenite sequence and including a thin coal seam and numerous carbonaceous beds, separates the upper sequence of Rsf at Spring Hill from a lower sequence of Rsf. Most of the intervening interval is included in the quartz arenite and lutite with carbonaceous beds assemblage (Rsq') and has been cored in DDH Spring Hill 5.

The cuttings on the old highway at Spring Hill expose part of the lower sequence of Rsf [EP213030 to EP212025]. The southernmost cutting was enlarged during highway realignment and shows lateral changes from sandstone beds to interdigitating sandstone and silty mudstone and carbonised logs 1.5 m long embedded in sandstone. Some calcareous concretions and calcite cement occur in the lower sequence of Rsf. Water escape structures are common in the basal lutite beds. Lithologically similar rocks are exposed nearby in a cutting on the realigned highway [EP213032] and palynological evidence indicates that these rocks belong to the lower sequence of Rsf. Notable features in this cutting include the presence of rare *Dicroidium odontopteroides* near the base, pink quartz granules in a multistorey cross-bedded sandstone, and a capping, uniform, very fissile, medium grey mudstone at least four metres thick. It is possible that the top mudstone unit is part of the Rsq' sequence.

Current directions derived from an exposure of the lower sequence of Rsf on the old highway yielded an average vector towards 73° [EP213028], whereas a multistorey cross-bedded sandstone exposed nearby on the realigned highway yielded an average vector towards 21°. Three solitary sets of cross-bedding exposed on the realigned highway at Lemon Springs yielded current vectors towards 348°, 348°, and 243° respectively [near EP278109]. An outcrop of Rsf near Lovely Banks, most probably belonging to the lower sequence of Rsf, gave current directions towards 303° and 313° [EP195010].

### *LITHOSTRATIGRAPHIC SUMMARY OF Rs*

Although the rocks of Rs have been mapped as lithological assemblages without any stratigraphic ordering implications, new exposures and continuing stratigraphic drilling, combined with the mapped distribution of the litho-assemblages Rsq, Rsq', and Rsf, suggests a regional stratigraphic ordering may exist (fig. 14,15).

In the area east of Lovely Banks [around EP203000] the basal beds of Ꞧs consist of the litho-assemblage Ꞧsq, commencing with a granule sandstone. Such quartzose basal beds may be regionally widespread but do not necessarily always appear to be present. The granule sandstone is of local development, but may extend as a single or number of shoestring deposits. No carbonaceous beds were observed at this horizon during mapping but some new exposures contain subordinate carbonaceous light grey to medium grey mudstone. Medium grey to dark grey mudstone is rare and only known from drill core. It is possible that some minor occurrences of the litho-assemblage Ꞧsq', for example west of Apsley [EP112012], may occupy this stratigraphic horizon. Such uncertainty arises where the stratigraphic relationships of isolated outcrops cannot be established and no supporting palaeontological information is available. No carbonaceous sandstone, as is sometimes found in Ꞧsq', has been found in the basal beds of Ꞧs. Silicification of sandstone layers has been observed at this horizon.

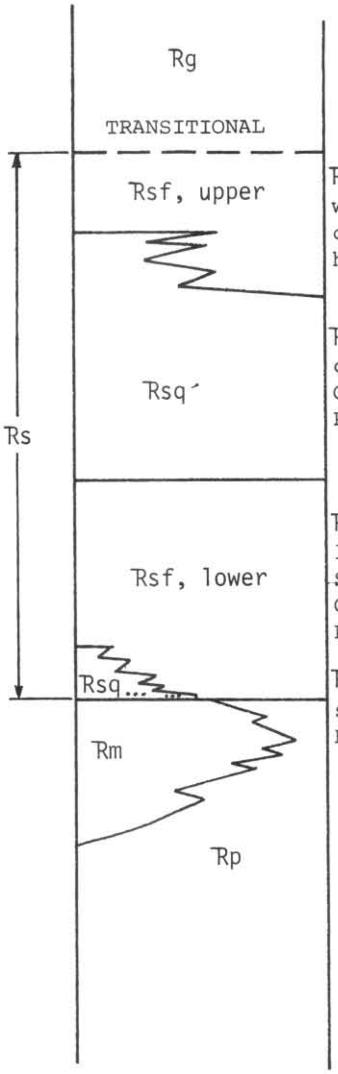
Overlying the basal part of Ꞧs with quartz arenite, or possibly in some areas forming the base of Ꞧs, is the lower succession of the litho-assemblage Ꞧsf, hereafter referred to as Ꞧsf, lower. This succession is present in all available sections and is probably distributed throughout the entire quadrangle. The succession contains no quartz arenite, although lithic arenite is usually quartz-rich. Medium grey and dark grey mudstone forms a subordinate portion of the lutite. Coalified vegetative matter occurs as individual logs in sandstone or concentrated in mudstone, but coal seams have not been recorded. Macroflora is sparse.

Overlying Ꞧsf lower is a sequence about 100 m thick containing quartz arenite. This sequence contains rocks of the litho-assemblage Ꞧsq'; subordinate lithic arenite, coalified vegetative remains, and rare thin coal seams. Medium grey to dark grey lutite is common and some sandstone beds are carbonaceous. Areas in which sandstone is non-carbonaceous and lutite is not exposed may have been mapped as the litho-assemblage Ꞧsq. In some cases this is immediately obvious on the map, either by the presence of the underlying litho-assemblage Ꞧsf, or by lateral transition into Ꞧsq', for example north of Big White Hill [EP171033] and near DDH Kempton 1 [EN180949]. Plant fossils occur commonly at several horizons. This sequence probably occurs across the southern and eastern portions of the quadrangle.

Overlying the sequence with quartz arenite is at least 40 m of lutite with subordinate, mostly quartz-rich lithic arenite. This is the upper succession of Ꞧsf at Spring Hill, hereafter referred to as Ꞧsf, upper. The lutite is mostly carbonaceous, light medium grey to medium dark grey in colour, and with thin coal seams in the sequence. Plant fossils are common at a few horizons. As this sequence appears to be transitional into the younger volcanic lithic arenite, lutite, and coal measure sequence (Ꞧg), it may eventually prove to be better regarded as a lutite dominated facies of Ꞧg.

It is unlikely that the boundaries between the sequences comprising Ꞧs would everywhere occur at precisely the same stratigraphic level, as wedging-out of quartz arenite beds has been observed. Migration of the depocentres of rivers depositing quartzose or lithic deposits into different areas at different times may have also resulted in diachronous boundaries between such deposits.

The informal stratigraphic subdivision of the Ꞧs sequence of quartz-rich lithic sandstone, quartzose sandstone, and interbedded lutite is shown diagrammatically in Figure 14. A composite stratigraphic column for the Parmeener Super-Group in the Oatlands Quadrangle is shown in Figure 15.




Ʀsf, upper. Predominantly carbonaceous lutite with quartz-rich lithic arenite beds. Thin coal seams. Plant fossils common on some horizons.

Ʀsq´. Quartz arenite and lutite with common carbonaceous beds. Subordinate lithic arenite. Coalified plant matter and rare thin coal seams. Plant fossils common on several horizons.

Ʀsf, lower. Quartz-rich lithic arenite and lutite forming thin fining upward cycles. Subordinate medium grey to dark grey mudstone. Coalified plant remains but no coal seams. Plant fossils generally uncommon.

Ʀsq. Quartz arenite and lutite ± granule sandstone at base. Rare carbonaceous lutite. Fossil plants rare.

Figure 14. *Informal stratigraphic subdivision of Ʀs sequence of quartz-rich lithic sandstone, quartzose sandstone and interbedded lutite.*

5 cm

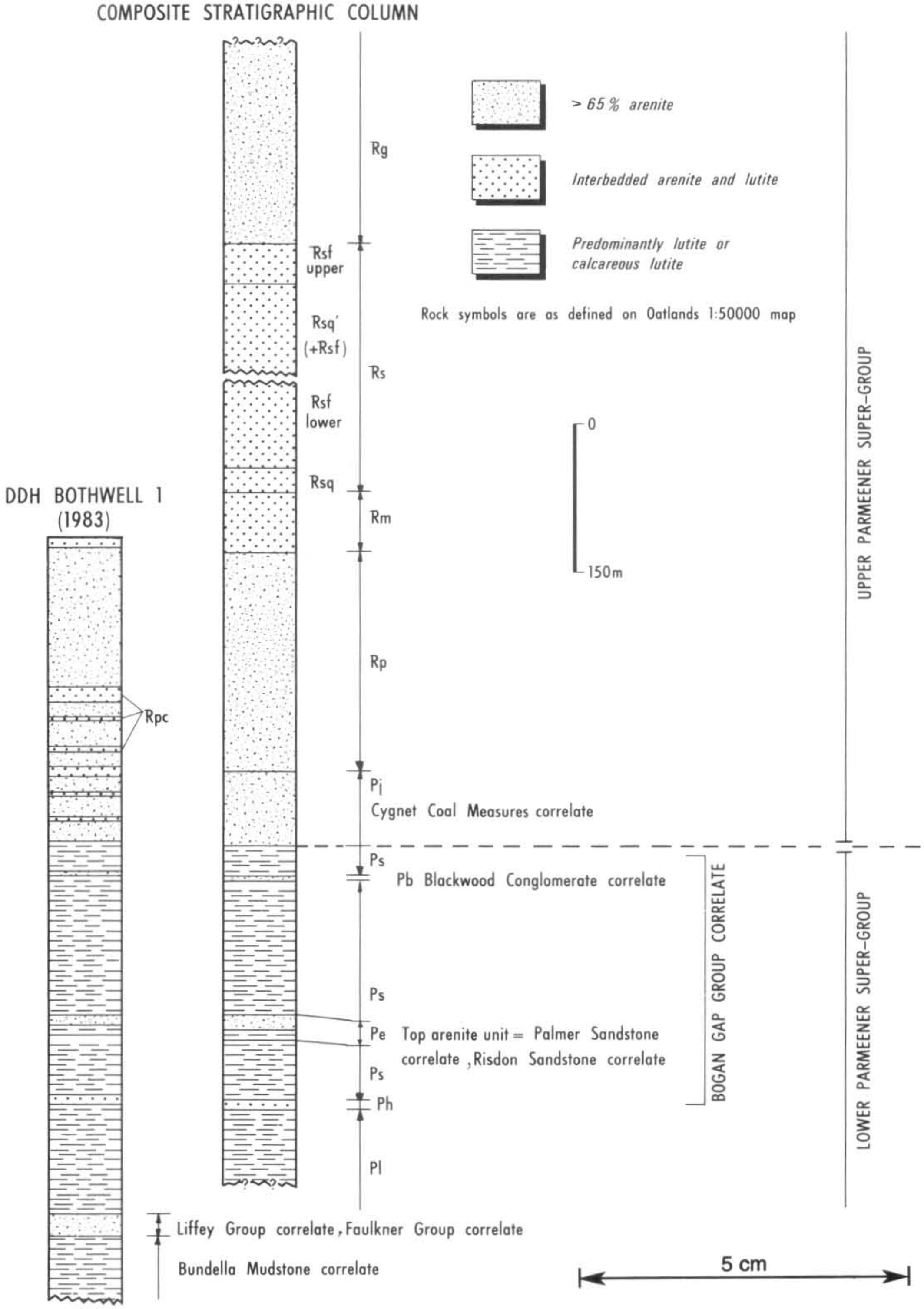



Figure 15. *Composite stratigraphic column for Parmeener Super-Group, Oatlands Quadrangle.*

## *DISCUSSION*

The change in current directions from TRp and TRm to TRs and the change in characteristics of the sandstone layers suggests that TRs commences a major new cycle of deposition, partly of different provenance to the underlying sequence. The change in macroflora abundance from TRm to TRs and the change in oxidation state of the lutite above the base of TRs suggests the new cycle of deposition may also be accompanied by a climatic change. The lack of dessication features and reduction of burrowing suggests that much of the environment may have remained constantly damp. The presence of many carbonaceous rocks indicates anaerobic conditions which may have reduced subaqueous animal life, while thick mudstone units devoid of sand suggest the presence of large swamps or abandoned channels.

The quartz arenite is clearly of fluviatile origin, and in some areas is intimately related to carbonaceous lutite. Unfortunately the exposures are inadequate to determine the nature of the relationship, but presumably the carbonaceous lutite represents ponded areas in which plant remains accumulated, possible oxbow or flood basin lakes. The presence of oxbow lakes is supported by contacts in which lutite overlies deep erosional surfaces cut into quartz arenite. The arenite units usually have basal erosional surfaces where they overlie lutite. Preservation of stoss side laminae and climbing cosets suggest that some arenite beds were formed under conditions of high nett sand deposition by rivers which contained large scale bars. The prominent lamination of some arenite suggests pulsed flow which may have been caused by regular antidune collapse.

In comparison, the more lithic arenite layers, particularly in DDH Kempton 1, are much thinner and form the base of fining upward sequences in which lutite predominates. The basal contacts are not noticeably erosive, and in some cases sand fills burrows in the top of the underlying cycle. With the exception of the thicker, coarser units, mud pellets or cross-bedding are not common. Ripples and wavy lamination are present. Common horizontal mud and silt partings indicate the arenite to be thinly bedded. The lutite sometimes contains interbedded arenaceous beds from a few up to a 100 mm thick. These cycles are believed to have been deposited by sluggish water passing through muddy swamps.

The thicker erosive based lithic arenite units with cosets of cross-bedding indicate the presence of some larger channels. The disrupted frame work of some siltstone layers may have been caused by soil formation. Well preserved leaves (mostly sphenopsid reeds and *Phoenicopsis elongatus,* but also seed ferns and ferns) densely crowded on restricted mudstone horizons indicate some vegetated areas. Logs may have been introduced or have grown on levees or high ground.

It is not known whether the fluviatile quartz arenites were an integral part of the environment or were the result of short lived incursions, possibly of a different provenance of possibly earlier deposited Upper Parmeener Super-Group sandstone. Some glistening white arenite layers fine upward with an increase in lithic and feldspathic content.

## *AGE AND CORRELATION*

### *Microflora*

The microflora of the lithic arenite, quartz arenite, and lutite sequence (Rs) is known from surface outcrops exposed particularly in the

Spring Hill area [EP212030] and from DDH Kempton 1 [EN174951]. Macrofloral lists are given in Appendix 3.

In DDH Kempton 1 the oldest microfloras studied came from rocks correlated with the muddy alluvial plain facies (Ꞧm), the rock unit which occurs immediately below Ꞧs. At 139.5 m and between 122.5-122.8 m depth, common *Aratrisporites wollariensis* Helby, 1967, rare *Aratrisporites tenuispinosus* Playford, 1965 and *Osmundacidites* spp. occur. These are the only species present in the older sample, but the microflora of the younger sample is more diverse with *Calmnospora* sp., *Limatulasporites* sp. cf. *L. limatulas* (Playford) Helby and Foster, *Aratrisporites* sp. cf. *A. banksi* Playford, 1965 being present together with rare incomplete specimens possibly of *Limatulasporites fossulatus* (Balme) Helby and Foster, 1979, *Playfordiaspora crenulata* (Wilson) Foster, 1979, *Falcisporites australis* (de Jersey) Stevens, 1981, and *Protohaploxypinus* sp.

The interval 92-116 m in DDH Kempton 1 contains quartz arenite, quartz-rich lithic arenite, and lutite including micaceous carbonaceous laminated mudstone. This interval is considered to be the basal quartzose beds of the sequence Ꞧs and at 109.0 m contains several species which occur persistently at most other horizons sampled above this datum in both DDH Kempton 1 and equivalent surface exposures. These species include:

*Calamnspora* spp.
*Osmundacidites* spp.
*Falcisporites australis*
*Cycadopites follicularis*
*Cycadopites crassimarginis* (de Jersey) de Jersey, 1964
*Lophotriletes novicus* Singh, 1964 (somewhat rarer and less persistent)

The genus *Aratrisporites* is represented by;

*Aratrisporites plicatus* de Jersey and Hamilton, 1967
*A.* sp. cf. *A. strigosus* Playford, 1965
*A.* sp. Plate 6, fig. 12 de Jersey and Hamilton, 1967

and a population of specimens with large (40-62µm) broadly elliptical to subcircular, frequently folded or crumpled exoexines and relatively small intexines. Some specimens of this population are comparable to *Aratrisporites banksi* Playford, 1965; some resemble *Aratrisporites fischeri* (Klaus) Playford and Dettmann, 1965, whereas others resemble *A. plicatus* but with clearly defined intexines. A monosaccate form *?Cordaitina* sp. is present and possibly *Grebespora concentrica* Jansonius, 1962 and *Rugulatisporites stonecrofti* de Jersey and Hamilton, 1967.

*Protohaploxypinus* sp. cf. *P. jacobi* (Jansonius) Plate 3, fig. 1 Helby, 1973 is present at 99.0 m in DDH Kempton 1. In addition a surface outcrop of the quartz arenite and lutite litho-assemblage (Ꞧsq) [EP184007] yielded a fragmentary trilete spore with sculpture identical to a species recorded from younger strata. This species is regarded as conspecific with spores recorded from Queensland as *Clavatisporites* sp. cf. *C. hammenii* (Herbst) de Jersey, 1971.

Above the basal beds of Ꞧs in DDH Kempton 1 occurs a sequence of lutite and quartz-rich lithic arenite (Ꞧsf, lower). A microflora from 90.0 m in DDH Kempton 1 is from the base of Ꞧsf, lower. *Horriditriletes* spp. begin their range here and occur sporadically in microfloras from higher horizons in Ꞧsf, lower. Other species also found in other samples from Ꞧsf, lower include:

*Limatulasporites fossulatus*
*Aratrisporites banksi*
*Aratrisporites* sp. Plate 6, fig. 12 de Jersey and Hamilton, 1967
*Playfordiaspora crenulata*

The dominant *Aratrisporites* forms lie within the range of variation of the population of larger forms in the sample from 109.0 m discussed above. One form, resembling *A. strigosus*, has relatively smaller intexines compared to *A.* sp. cf. *A. strigosus* from 109.0 m. Other species present in the sample from 90.0 m include:

*Stereisporites antiquasporites* (Wilson and Webster) Dettmann, 1963
*Lunatisporites pellucidus* (Goulbin) Helby *in* de Jersey, 1972
*Pilasporites* sp. and possibly *?Cordaitina* sp.

The microflora from the upper half of the sequence (Rsf, lower) includes the following species:

*Clavatisporites* sp. cf. *C. hammenii* (Herbst)
*Horriditriletes ramosus* (Balme and Hennelly) Bharadwaj and Salujha, 1964
*Lophotriletes* sp. aff. *L. novicus*
*Apiculatisporis* sp. cf. *A. globosus* (Leschik) Playford and Dettmann, 1965
*Uvaesporites verrucosus* (de Jersey) Helby, 1971
*Cadargasporites senectus* de Jersey and Hamilton, 1967
*Triplexisporites playfordii* (de Jersey and Hamilton) Foster, 1979
*Rugulatisporites* sp.
*Limatulasporites limatulus* (Playford) Helby and Foster, 1979
*Limatulasporites fossulatus* (Balme) Helby and Foster, 1979
*Densoisporites* sp. cf. *D. playfordii* (Balme) Plate 2, fig. 8 de Jersey, 1972
*Aratrisporites strigosus*
*Aratrisporites paenulatus* Playford and Dettmann, 1965
*Aratrisporites* sp. aff. *A. goulburniensis* Helby, 1967
*Aratrisporites banksi*
*Platysaccus queenslandi* de Jersey, 1962
*Lunatisporites pellucidus*
*Protohaploxypinus* sp. cf. *P. jacobi*
*Equisetosporites* sp. *A.*
*Equisetosporites* sp. *B.*
*Cycadopites follicularis*
*Circulisporites* sp.
*?Debarya* sp.

The dominant species of *Aratrisporites, A.* sp. aff. *A. goulburniensis* possesses stout, well spaced coni, baculi, and spines less than 2 µm long.

Approximately the upper half of the lutite and quartz-rich lithic arenite sequence (Rsf, lower) is exposed in a road cutting at EP213032 and additional exposures of the top part of this sequence occur in the next road cutting to the south [EP212027]. *Clavatisporites* sp. cf. *C. hammenii* and *Horriditriletes ramosus* occur near the base of the cutting sequence probably at a slightly older horizon than their first occurrence in DDH Kempton 1. *Clavatisporites* sp. cf. *C. hammenii, L. novicus, Horriditriletes* spp., *L. limatulus, L. fossulatus* and *Aratrisporites* sp. Plate 6, fig. 12, de Jersey and Hamilton, 1967, although not present in all samples, occur throughout the sampled portion of the upper half of Ʀsf, lower. A sample collected about 30 m below the top of the sequence is unusual in that it contains abundant *Protohaploxypinus* sp. cf. *P. jacobi* but only rare *Falcisporites australis*. This sample contains several species also occurring in DDH Kempton 1 at 69.8 m, including:

*Cadargasporites senectus*
*Densoisporites* sp. cf. *D. playfordii*
*Rugulatisporites* sp.
*Aratrisporites paenulatus*
*Aratrisporites* sp. aff. *A. goulburniensis*

In contrast to the drill hole succession, *Uvaesporites verrucosus* was not recorded from any of the road cutting samples taken from Ʀsf, lower. The oldest of these samples, approximately 36 m below the top of the sequence, contains rare *Matonisporites* sp. A sample from 11 m below the top of the sequence contains the first record in Ʀsf, lower of the following species:

*Converrucosisporites* sp.
*Punctatosporites walkomi*
chordate bisaccates
*Circulisporites* sp.

*Circulisporites* sp. is present in four samples (drill hole and surface) collected from near the top of Ʀsf, lower and is particularly abundant in one sample [EP212026]. This particular sample and/or the beds immediately above contain:

*Converrucosisporites cameroni* (de Jersey) Playford and Dettmann, 1965
*?Retitriletes* sp.
*Duplexisporites* sp. cf. *D. problematicus* (Couper) Playford and Dettmann, 1965
*Aratrisporites plicatus*
*Reticuloidosporites* sp.
*Vitreisporites signatus* Leschik, 1955
*Chordasporites australiensis* de Jersey, 1962
*Lueckisporites* sp.
*Equisetosporites* sp. *A*.
*Equisetosporites* sp. *B*.
*Grebespora magna* de Jersey, 1970
*Pilasporites crateraformis* Jain, 1968

Pseudo tetrasaccate forms of *Falcisporites* are present and large elliptical monosaccate pollen may also be an aberrant *Falcisporites*.

The earliest occurrence of *Uvaesporites verrucosus* from the surface samples was from a >4 m thick uniform, fissile medium to dark grey carbonaceous mudstone bed capping the Ʀsf, lower sequence. This mudstone is believed to be the basal bed of the quartz arenite and lutite with carbonaceous beds sequence (Ʀsq'). A significant change in the microflora occurs at about this horizon with the introduction of *Foveosporites* sp. cf. *F. moretonensis* de Jersey, 1964 and *Semiretisporis denmeadi* (de Jersey) de Jersey, 1970 which occur commonly in assemblages from Ʀsq'. Some specimens from this horizon closely resemble *S. denmeadi* and possess bifurcating radial ridges but also with small spines on an equatorial flange. Some specimens of *Foveosporites* sp. cf. *F. moretonensis* tend to possess a more open sculpture like *Camarozonosporites rudis* (Leschik) Plate 3, fig. 7 de Jersey, 1970 and either a thicker equatorial exine or narrow, uniform cingulum. *Aratrisporites parvispinosus* Leschik *emend.* Playford and Dettmann, 1965 is present but of somewhat less frequent occurrence. The long ranging Permian and Triassic form *Quadrisporites horridus* Hennelly reappears at this horizon and has been noted in several samples from the TRsq' sequence. Other species occurring first at this horizon and sporadically at higher horizons include:

*Granulatisporites* sp. *B.*
*Stenozonotriletes* sp.
*Thymospora ipsviciensis* (de Jersey) Jain, 1968
*Aratrisporites* sp. cf. *A. flexibilis* Playford and Dettmann, 1965
*Alisporites parvus* de Jersey, 1962
*Vitreisporites microsaccus* de Jersey, 1964

Several species which have only been recorded from this horizon are:

cf. *Polypodiaceosisporites* sp. nov. Helby, 1973
*Rugulatisporites trisinus* de Jersey and Hamilton, 1967
*Tuberculatosporites aberdarensis* de Jersey, 1964
?*Falcisporites* aberrant trisaccate
monosaccate (29-43 µm, alete) aff. *Accintisporites ligatus* Leschik, 1955

The *Aratrisporites* group includes forms comparable with:

*A. strigosus*
*A. paenulatus*
*A. tenuispinosus*
*A. wollariensis*
*A.* sp. Plate 6, fig. 12 de Jersey and Hamilton, 1967.
*A. banksi*
*A.* sp. aff. *A. goulburniensis*
*A.* sp. cf. *flexibilis*

Some species recorded from the underlying sequence (TRsf, lower) do not range up into the TRsq' sequence *e.g. Cadargasporites senectus, Limatulasporites fossulatus, Rugulatisporites* sp., *Equisetosporites* sp. *A., Equisetosporites* sp. *B.*, and *Circulisporites* sp. A single specimen of *Limatulasporites limatulus* was found at the base of the TRsq' sequence but none were found above this horizon. The exact stratigraphic position of a sample obtained from a cutting on the old Midland Highway (topographically above the uniform grey mudstone capping the TRsf, lower sequence) is not known, but it certainly is from near the base of TRsq'. This sample contains *F.* sp. cf. *F. moretonensis*, and *S. denmeadi* with *L. novicus, T. playfordii*, and *Grebespora* sp. *A.* de Jersey, 1970.

An obliquely compressed specimen, probably *T. playfordii* was also observed from the uniform grey mudstone capping the TRsf, lower sequence, and a rugulate to reticulate spore, possibly *T. playfordii*, was recorded from near the base of TRsq' in DDH Kempton 1.

Typical forms found in samples from the quartz arenite and lutite with carbonaceous bed sequence (TRsq') include:

*Calamnospora* spp. including *C. tener* (Leschik) de Jersey, 1962
*Dictyophyllidites mortoni* (de Jersey) Playford and Dettmann, 1965
*Horriditriletes* spp. including *H. ramosus*
*Converrucosisporites* spp. including *C. cameroni*
*Osmundacidites* spp. including *O. wellmanii* Couper, 1953
*O. fissus* (Leschik) Playford, 1965 and coarsely granulate forms
*Foveosporites* sp. cf. *F. moretonensis*
*Lophotriletes novicus*
*Uvaesporites verrucosus*
*Semiretisporis denmeadi*
*Aratrisporites parvispinosus*
*Playfordiaspora crenulata*
*Falcisporites australis*
*Cycadopites follicularis*
*Cycadopites crassimarginis*
*Quadrisporites horridus*

Forms of less frequent occurrence include:

*Stereisporites* spp. including *S. antiquasporites*
*Concavisporites tumidus* Playford, 1965
*Baculatisporites* sp.
*Apiculatisporis* spp.
*Densoisporites* sp. cf. *D. poatinaensis* Playford, 1965
*Aratrisporites* sp. aff. *A. goulburniensis*
*Aratrisporites banksi* and related rugulate or conate to infragranular only forms
*Aratrisporites* sp. aff. *A. granulatus* (Klaus) Playford and Dettmann, 1965
*Aratrisporites wollariensis-strigosus-paenulatus* group
*Aratrisporites* sp. cf. *A. flexibilis*
*Sulcosaccispora alaticonformis* (Malyavkina) de Jersey, 1968
*Vitreisporites microsaccus* de Jersey, 1964
*Platysaccus queenslandi* de Jersey, 1962
*Protohaploxypinus* sp. cf. *P. jacobi*
*Discisporites* sp. cf. *D. psilatus* de Jersey Plate 4, fig. 2 de Jersey 1971
*?Debarya* sp.
*?Maculatasporites* sp.

Although several samples from the Ꞧsq' sequence have yielded microfloras, their relative stratigraphic ordering is not always known. In DDH Kempton 1, three productive samples span only 25 m of the basal part of the sequence, that is approximately the basal one quarter of the sequence. A sample from a locality rich in macrofossils approximately midway through the Ꞧsq' sequence contains rare *Annulispora folliculosa* (Rogalska) de Jersey, 1959. Knowledge of the distribution of this species in Ꞧsq' must await palynological study of DDH Spring Hill 5.

The microflora of the lutite and quartz-rich lithic arenite sequence (Ꞧsf, upper) above Ꞧsq' is also only poorly known. In the 14 m interval between the youngest quartz arenite of Ꞧsq' and the oldest thin coal seam of Ꞧsf, upper, the most common forms are *Calamnospora* spp., *Osmundacidites* spp., *Falcisporites australis*, and *Cycadopites* spp. [EP214039]. At the top of this 14 m interval, below the oldest coal seam, *Stereisporites antiquasporites*, *Rogalskaisporites cicatricosus* (Rogalska) Danze-Corsin and

Laveine, 1963, *Annulispora folliculosa* and *Semiretisporis denmeadi* are present. In the next 7 m thick interval between the first and second thin coal seams one sample yielded a microflora consisting almost entirely of *S. denmeadi*. A further 8 m thick interval separates the second and third thin coal seams and has yielded a microflora similar to that contained in a sample from a culvert on the old Midland Highway [EP215037]. Significant species from the culvert sample include:

- *Cyathidites minor* Couper, 1953
- *Rogalskaisporites cicatricosus* (Rogalska) Danze-Corsin and Laveine, 1963
- *Apiculatisporis* sp. cf. *A. globosus* (Leschik) Playford and Dettmann, 1965
- *Anapiculatisporites* sp. cf. *A. pristidentatus* Reiser and Williams, 1969
- *Foveosporites moretonensis*
- *Annulispora folliculosa*
- *Semiretisporis denmeadi*
- *Cycadopites* sp. cf. *C. tivoliensis* de Jersey, 1970
- *Pilasporites crateriformis* Jain, 1968

*Correlation*

The microfloras of the lower portion of the quartz arenite, lithic arenite, and lutite sequence (TRs) are similar to those described from the Clematis Sandstone and Moolayember Formation of the Bowen Basin and the Esk Beds of the Esk Trough (de Jersey and Hamilton, 1967; de Jersey 1968, 1972) and those described from the upper part of the Narrabeen Group, Hawkesbury Sandstone, and Wianamatta Group of the Sydney Basin (Helby, 1973). Precise correlation with these basins is hampered as the nature of the boundary between the *Aratrisporites tenuispinosus* Assemblage Zone and the *Aratrisporites parvispinosus* Assemblage Zone is not known in detail (Helby, 1973), and because a hiatus probably exists between the youngest microfloras of the *Duplexisporites problematicus* microflora and the younger *Craterisporites rotundus* Zone (de Jersey, 1975).

In the Oatlands sequence *Cycadopites follicularis* (=*C. nitidus* (Balme) de Jersey, 1964) re-appears in the sequence near the base of the unit TRs, whereas *Cycadopites crassimarginis* and *Aratrisporites* sp. Plate 6, fig. 12 de Jersey and Hamilton, 1967 appear first at this level. In the Sydney Basin *C. follicularis* occurs first in the *A. parvispinosus* Assemblage Zone. In the Bowen Basin *C. follicularis* extends from Permian units through the Rewan Formation before becoming more prolific in the Clematis Sandstone and Moolayember Formation. *C. crassimarginis* appears first in the Moolayember Formation and *A.* sp. Plate 6, fig. 12 de Jersey and Hamilton, 1967 is a very rare form in the Clematis and Moolayember Formations. As some specimens of *Cycadopites* have been observed in which only one side of the colpus is thickened in the characteristic fashion of *C. crassimarginis*, and most specimens of *C. follicularis* show a slight degree of marginal thickening, it is possible that these two species may intergrade. Consequently less significance is attached to the presence of *C. crassimarginis*, that is, its presence is not accepted as necessarily indicating that the basal part of TRs is as young as the Moolayember Formation.

*Clavatriletes* sp. cf. *C. hammenii* may be present near the base of TRs; it is certainly present about midway up the lower sequence of lutite and quartz-rich lithic arenite (TRsf, lower). In the Bowen Basin *C.* sp. cf. *C. hammenii* first appears in the Clematis Sandstone. Other species that make their first appearance in the Oatlands sequence near the base of

TRs include *Lophotriletes novicus* and *Protohaploxypinus* sp. cf. *P. jacobi* Plate 3, fig. 1 Helby, 1973. *L. novicus* is known from Permian and Triassic strata but is particularly abundant in the upper zonule of the *A. tenuispinosus* Assemblage Zone of the Sydney Basin. In the Sydney Basin *P.* sp. cf. *P. jacobi* is restricted to the *A. parvispinosus* Assemblage Zone. Apart from Permian occurrences, *P. jacobi* occurs in the lower Moolayember Formation in the Bowen Basin. *Horriditriletes ramosus* (=*Neoraistrickia taylorii* Playford and Dettmann, 1965) first appears midway up the TRsf, lower sequence. In the Triassic of the Bowen Basin *H. ramosus* first appears in the Moolayember Formation, although a comparable form is present in the Clematis Sandstone. *H. ramosus* is also present in the Narrabeen Group of the Sydney Basin.

In the upper half of the TRsf sequence, *Uvaesporites verrucosus, Cadargasporites senectus, Foveosporites mimosae, Densoisporites* sp. cf. *D. playfordii* Plate 2 fig. 8 de Jersey, 1972, *Tuberculatosporites* sp. cf. *T. aberdarensis, Chordasporites australiensis* and *Pilasporites crateraformis* are present. A single specimen compared to *Duplexisporites problematicus* was also recorded. The species *T.* sp. cf. *T. aberdarensis* differs from *T. aberdarensis* in having predominantly conate rather than spinulate processes and may be conspecific with *T.* sp. cf. *T. aberdarensis* recorded from the Moolayember Formation (de Jersey and Hamilton, 1967). *T. aberdarensis* occurs in the Esk Beds and younger strata in Queensland, but in the Sydney Basin it has also been recorded by Helby from the older Narrabeen Group (de Jersey, 1971*b*). *C. australiensis* and *F. mimosae* occur first in the Clematis Sandstone, whereas *U. verrucosus, C. senectus,* and *D. problematicus* appear first in the Moolayember Formation. In the Sydney Basin these last three species occur first in the *A. parvispinosus* Assemblage Zone. *Pilasporites crateraformis* appears first in the Esk Beds and *D.* sp. cf. *D. playfordii* is confined to the Esk Beds.

It has already been established (p.55) that the microflora of the muddy alluvial plain facies (TRm) underlying TRs belongs to the *A. tenuispinosus* Assemblage Zone and there is little doubt that the microflora of the upper part of the lutite and quartz-rich lithic arenite sequence (TRsf, lower) belongs to the *A. parvispinosus* Assemblage Zone or its equivalent the *Duplexisporites problematicus* microflora as developed in the Esk Beds and Moolayember Formation. Exactly where the boundary between the *A. tenuispinosus* and *A. parvispinosus* Assemblage Zones should be drawn in the sequence is less certain, partly because the exact nature of the transition between the two zones is not known in the Sydney Basin (Helby, 1973). Assessment of the usefulness of *Aratrisporites* species for correlation must await more detailed determination of the variability in morphology and in distribution of the species present. It appears possible to assign the end members of some populations to more than one species, and members of different populations sometimes lie within the range of variation of a single described species. Members of the extended concept of *A. tenuispinosus* (Helby, 1973) occur in TRsf, lower, but *A. tenuispinosus* s.s. was not recorded from this interval, although it occurs in older and younger strata. *A. paenulatus* has been recorded from the upper half of TRsf, lower and a form resembling *A. goulburniensis*, but with considerably finer sculpture, is present. *A. paenulatus* and *A. goulburniensis* were included in the extended concept of *A. parvispinosus* (Helby, 1973).

There is a significant microfloral change at the base of the quartz arenite and lutite with carbonaceous beds sequence (TRsq'). Although the change may be in part environmentally controlled; for example the re-introduction of *Quadrisporites horridus, Maculatasporites* sp., and the presence of possible spinose acritarchs, other species, such as *Semiretisporis denmeadi, Foveosporites* sp. cf. *F. moretonensis, Rugulatisporites trisinus,* and *Aratrisporites parvispinosus* s.s. make their first appearance. In eastern Australia *S. denmeadi* is restricted to the *Craterisporites rotundus* Zone (de Jersey, 1975) as developed in the Ipswich Coal Measures and their biostratigraphic correlates. A hiatus probably separates the Queensland occurrences of the *Craterisporites rotundus* Zone from the *Duplexisporites problematicus* microflora and it is possible that rocks spanning this hiatus may also contain *S. denmeadi*. In Western Australia *S. denmeadi* is present in older horizons, perhaps as early as the Anisian stage (Dolby and Balme, 1976).

In the basal portion of Ʀsq', *S. denmeadi* co-occurs with several species which do not range up into the *Craterisporites rotundus* Zone. These species are:

*Rugulatisporites trisinus*
*Triplexisporites playfordii*
*Limatulasporites limatulus*
*Aratrisporites wollariensis*
*Aratrisporites strigosus*
*Aratrisporites* sp. Plate 6 fig. 12 de Jersey and Hamilton, 1967

Possibly added to the above list could be forms tentatively identified as *Polypodiaceosporites* sp. nov. Helby, 1973 and *Accinctisporites ligatus*. A population of small monosaccate pollen resembling *A. ligatus* Plate 3, fig. 3 de Jersey, 1972 is also present.

*S. denmeadi* also co-occurs with *T. playfordii* and *L. limatulus* in the top of the Tiers Formation at Poatina (Playford, 1965) but this association does not appear to have been reported from elsewhere in Australia. This could indicate that the beds forming the base of Ʀsq' and the top of the Tiers Formation were deposited during a time interval equivalent to part of the hiatus between the Moolayember Formation - Esk Beds and the Ipswich Coal Measures. Alternatively, *S. denmeadi* may occur earlier in Tasmania than elsewhere in eastern Australia. This is supported by the absence of *R. trisinus, T. playfordii, L. limatulus,* and *A. wollariensis* in the upper part of both the Moolayember Formation and the Esk Formation. With the disappearance of these species within the basal part of Ʀsq', there remains little evidence to indicate that the microflora is as old as the *Duplexisporites problematicus* Zone. Although *Lophotriletes novicus* is present above the base of Ʀsq', its presence does not indicate a pre-*Craterisporites rotundus* Zone, as *L. novicus* has recently been recorded from the Late Triassic Callide Coal Measures (Stevens, 1981). The introduction of *Annulispora folliculosa* within Rsq' gives support to the possibility that the microflora is younger than the *D. problematicus* microflora, as *A. folliculosa* first appears in the *C. rotundus* Zone.

A microflora obtained from the dominantly lutite with quartz-rich lithic arenite sequence (Ʀsf, upper) which occurs above the youngest known quartz arenite in the Oatlands Triassic sequence contains:

*Rogalskaisporites cicatricosus* (Rogalska) Danze-Corsin and Laveine, 1963
*Apiculatisporis* sp. cf. *A. globosus* (Leschik) Playford and Dettmann, 1965
*Anapiculatisporites* sp. cf. *A. pristidentatus* Reiser and Williams, 1969

*Annulispora folliculosa*
*Semiretisporis denmeadi*
*Cycadopites* sp. cf. *C. tivoliensis* de Jersey, 1970

These species, or the species to which they are compared, appear first in the *Craterisporites rotundus* Zone. *Foveosporites moretonensis* de Jersey (identification confirmed by J.L. McKellar), a species which appears first in the Bundamba Group (*Polycingulatisporites crenulatus* Zone) (de Jersey 1970*b*, 1975), and *Cyathidites minor* Couper, 1953, which in Queensland first appears in the Jurassic (McKellar, 1974), are both present. *Pilasporites crateriformis* Jain, 1968, a form ranging from the Esk Beds into the Ipswich Coal Measures (de Jersey, 1972), is also present. In Queensland *C. tivoliensis* and *S. denmeadi* are not known above the Ipswich Coal Measures. Consequently the bulk of the data suggests that this microflora belongs to the *Craterisporites rotundus* Zone and that *Foveosporites moretonensis* appears earlier in Tasmania than in Queensland.

Full appraisal must await a more detailed study of the Tasmanian sequence. In South Victoria Land, the ranges of *S. denmeadi* and *C. minor* also overlap in probably younger strata containing a microflora of sub-zone D, which has been correlated with the lower *Polycingulatisporites crenulatus* Zone (Kyle, 1977).

No microfloras from the volcanic lithic arenite, lutite and coal measures sequence (Ꞩg) have been studied from the Oatlands Quadrangle. However Playford (1965), Dettmann (*in* Threader, 1968*b*), Forsyth (1977; and unpublished work) have studied about fifty samples from lithological correlates of the sequence Ꞩg. Few if any of these samples yield microfloras which could be correlated with the Bundamba Group in preference to an Ipswich correlation. *Polycingulatisporites crenulatus, Classopollis,* and most species characteristic of the *Polycingulatisporites crenulatus* Zone are absent. The only exceptions are *Retitriletes austroclavatidites* and *Lycopodiacidites kuepperi* recorded by Dettmann from the Mount Nicholas mine. *R. austroclavatidites* appears first in the *P. crenulatus* Zone; however a similar form has also been observed in Middle Triassic rocks in Tasmania. *L. kuepperi* occurs in the Karnian of Europe and is not a characteristic species of the *P. crenulatus* Zone, but a comparable species has been recorded from the Jurassic Helidon Sandstone (de Jersey, 1971*a*). At the Mount Nicholas mine, *L. kuepperi* occurs with *Aratrisporites flexibilis*, which does not range above the *Craterisporites rotundus* Zone.

Away from the Spring Hill area some sequences mapped as lithological correlates of the quartz arenite, lithic arenite and lutite sequence (Ꞩs) have, in general fashion, proved to be palyno-correlates of Ꞩs. At Big White Hill [EP169032] rocks mapped as Ꞩsq' have yielded a very meagre microflora, including *U. verrucosus*. East of Northumbria Hill [EP235090] Ꞩsq' contains *H. ramosus, Foveosporites* sp. cf. *F. moretonensis* and possibly *S. denmeadi*. Undifferentiated rocks of Ꞩs from near The Peak [EP204068] contain *Aratrisporites coryliseminis,* Klaus, 1960, reported by Helby (1973) from the *Protohaploxypinus samoilovichi* Assemblage to the *A. parvispinosus* Assemblage but also known from younger strata (Playford and Dettmann, 1965); *Aratrisporites flexibilis,* reported from the *A. parvispinosus* Assemblage and the *Craterisporites rotundus* Zone; *U. verrucosus* and possibly *Foveosporites* sp. cf. *F. moretonensis*. A sample considered to come from near the boundary of Ꞩs and the underlying muddy alluvial plain facies (Ꞩm) at EP212097 contains *Cycadopites crassimarginis, Playfordiaspora crenulata, Aratrisporites strigosus, Clavatisporites* sp. cf. *C. hammenii, Protohaploxypinus* and probably *Aratrisporites plicatus*. This assemblage is consistent with that occurring near the base of Ꞧs, but several unusual features of the geology of this area indicate that undetected faulting may be present and that the sample may come from a higher stratigraphic horizon than shown on the map. One poorly preserved specimen also present in this assemblage may be *Uvaesporites verrucosus*. Should *U. verrucosus* be present, based on the known distribution of this species in Ꞧs, it would indicate that lutite beds of Ꞧs have been incorrectly mapped as part of the muddy alluvial plain facies (Ꞧm).

A microflora occurring at Webber Falls [EQ962019; St Marys Quadrangle] near St Marys on Tasmania's east coast contains *Uvaesporites verrucosus* and *Duplexisporites problematicus,* and ten species which in Queensland cease their range before the Ipswich Coal Measures. This microflora is attributed to the *Duplexisporites problematicus* microflora and the *Aratrisporites parvispinosus* Assemblage Zone and occurs interbedded and below basalt flows dated as 233± 5 m.y. (Calver and Castleden, 1981). Based on the revised Triassic time scale proposed by Webb (1981), a Ladinian age seems most likely. The best correlation with the Spring Hill sequence is with the upper half, perhaps the uppermost part of the lutite and quartz-rich lithic arenite sequence (Ꞧsf, lower). This correlation is based on the following species common to both microfloras;

*Clavatisporites* sp. cf. *C. hammenii*
*Triplexisporites playfordii*
*Horriditriletes ramosus*
*Uvaesporites verrucosus*
and possibly *Duplexisporites problematicus*

and the absence of *Semiretisporis denmeadi, Foveosporites* sp. cf. *F. moretonensis,* and *Aratrisporites parvispinosus* from the Webber Falls microflora. *Rugulatisporites trisinus* and *Concavisporites tumidus* are present at Webber Falls but do not appear until the beds overlying Ꞧsf, lower at Spring Hill. Both species are known from older strata in Queensland (de Jersey, 1968).

In summary, the microfloras of the basal quartzose beds of Ꞧsf, lower belong to a younger portion of the *Aratrisporites tenuispinosus* Assemblage Zone or a transitional interval near the *A. tenuispinosus* Assemblage Zone - *A. parvispinosus* Zone boundary. The upper half of Ꞧsf, lower belongs to the *A. parvispinosus* Assemblage Zone and the beds above the basal portion of the quartz arenite and lutite with carbonaceous beds sequence (Ꞧsq'), belong to either the *A. parvispinosus* Assemblage Zone (or *Duplexisporites problematicus* microflora) or a transitional zone between the *Duplexisporites problematicus* microflora and the *Craterisporites rotundus* Zone. The major part of Ꞧsq' is probably pre *Craterisporites rotundus* Zone and although *A. folliculosa* enters the sequence within Ꞧsq', it is not until the overlying lutite and quartz-rich lithic arenite sequence that a more fully developed *C. rotundus* Zone microflora is found.

By comparison with microfloras in Queensland (de Jersey and Hamilton, 1967; de Jersey, 1968, 1970*a*; 1970*b*; 1971*b*; 1972; 1975) the base of Ꞧs is late Early Triassic or Anisian, and the upper half of Ꞧsf, lower is Anisian or Ladinian. Should the microfloras of Ꞧsq' represent an intermediate stage between the *Duplexisporites problematicus* microflora and the *C. rotundus* Zone, then Ꞧsq' is Ladinian. The microflora of Ꞧsf, upper is probably Karnian or possibly Norian in age. The radiometric date of the Webber Falls basalt further supports a Ladinian age for beds near the top of Ꞧsf, lower.

The microflora reported by Playford (1965) from near the top of the Tiers Formation, with the dominance of *A. banksi* at the expense of *A. strigosus* and *A. tenuispinosus*, the appearance of *S. denmeadi*, reduction in *Protohaploxypinus samoilovichi* and the partial replacement of *Osmundacidites fissus* by *O.* sp. cf. *O. wellmanii*, is of younger affinity than the lower sample from the Tiers Formation. Based on the range of these species in the Sydney Basin (Helby, 1973), the Bowen Basin (de Jersey, 1970*a*), the Ipswich Coal Measures (de Jersey, 1970*b*), and the Esk Trough (de Jersey, 1972), the higher Tiers assemblage is regarded as being of Middle Triassic age (*Aratrisporites parvispinosus* Assemblage Zone), whereas the Brady Formation microfloras are best regarded as belonging to the *Craterisporites rotundus* Zone (see also de Jersey, 1970*b*, p. 21).

Based on Playford (1965), the basal beds of Rsq' are best palynologically correlated with the Tiers Formation by either direct biostratigraphic correlation or correlation *via* New South Wales and Queensland sequences.

A quartz arenite and lutite with carbonaceous beds sequence exposed in cuttings on the Midland Highway at Constitution Hill (Brighton Quadrangle), immediately north of a dolerite dyke, contains *Semiretisporis denmeadi* and *Horriditriletes ramosus* and appears to be a correlate of Rsq'.

In the Hobart area *S. denmeadi*, *Uvaesporites verrucosus* and *Quadrisporites horridus* occur in the matrix of a rich *Dicroidium odontopteroides* Oppel Zone macroflora collected from near the corner of Elizabeth Street and Wilson Street by C. Burrett (University of Tasmania) in 1977. As *Q. horridus* has not been observed above Rsq', the rocks containing the macroflora are tentatively correlated with Rsq'.

*Macroflora*

The macroflora is listed in Appendix 3. The range of most species, expressed by Retallack (1977) is Anisian or Late Anisian to Norian. A species from one locality in Rsq' [EP212022] is similar but not identical to *Dicroidium odontopteroides* var. *remotum* (Szajnocha) Retallack, 1977 for which a Late Anisian to Ladinian range is given. Retallack indicates a range of Karnian into Late Norian for *Sphenobaiera tenuifolia* (Johnston) Jain and Delevoryas, but more recently, Holmes (1982) has recorded this species from Anisian rocks. Of particular interest is the occurrence of *Dicroidium odontopteroides* at EP184007, as unless undetected faulting has occurred nearby to the east, this locality is believed to be near the base of Rs.

The macrofloral evidence therefore indicates that Rs is probably wholly younger than Early Triassic and pre-Rhaetian in age.

*D. odontopteroides* is present near the base of the road cutting exposing the lutite and quartz-rich lithic arenite sequence (Rsf, lower) at EP212032. A saw-tooth like sphenopsid sheath was noted in a cutting on the old Midland Highway [EP212026].

The most diverse macroflora of this part of Rsf, lower has been noted in DDH Spring Hill 2. This macroflora includes sphenopsids, *?Sphenopteris* sp., and species of the Corystospermaceae.

The macrofloras of the quartz arenite and lutite with carbonaceous beds (Rsq') preserved both in sandstone and lutite are dominated by *Dicroidium, Johnstonia,* and *Xylopteris* with *Sphenobaiera* occasionally common. Above Rsq' in the lutite and quartz-rich lithic arenite sequence (Rsf, upper), sphenopsids, *Phoenicopsis elongatus* and *Cladophlebis* dominate in lutite, often associated with narrow (∿5 mm) spathulate to linear shaped elongate leaves. Wood alone has been noted in the sandstone of Rsf.

Considering both macrofloral and microfloral evidence, Rs is probably Anisian at the base, Late Anisian or Ladinian near the boundary between Rsf, lower and Rsq', and Karnian at Rsf, upper.

### *CORRELATION IN TASMANIA*

Beds comparable with Rsq' and containing a Middle-Late Triassic macroflora have recently been mapped in the St Marys Quadrangle by C. Calver and R.H. Castleden and on Schouten Island by K.D. Corbett. The beds on Schouten Island also contain coal seams. An assemblage of white quartzose sandstone, feldspathic sandstone, shale and coal with *Zeugophyllites* (=*Phoenicopsis elongatus*) occurs at Triabunna (Hills *et al.*, 1922). The association of quartz sandstone and carbonaceous beds also occurs in the Sorell Quadrangle (A.B. Gulline, pers. comm.) and the Brighton Quadrangle (Leaman, 1977, p. 15), for example on the road between Campania and Colebrook near Wards Hill, on the Midland Highway at Constitution Hill [EN183848] where *Semiretisporis denmeadi* is present, and in the Hobart Quadrangle in cuttings along the Brooker Highway between Berriedale and Claremont.

Portions of Rlm on the Brighton 1:50 000 map (Leaman, 1975*a*) contain rocks broadly equivalent to Rs, including some rocks closely resembling rocks of Rs. Recent mapping by the author at Table Mountain [EP113239; Interlaken Quadrangle] has shown that overlying Rp or Rm type sequences is a thin interval of Rsq type lithologies with granules, overlain by Rsf grading up into a sequence with oxidised coals and Rg volcanic lithic arenite. At Poatina, the Tiers Formation resembles Rsf, lower with a coarser, more siliceous (quartz 30%) sandstone near the base (McKellar, 1957). The upper part of the Tiers Formation is a biostratigraphic correlate of the basal beds of Rsq', but no litho-stratigraphic correlate to Rsq' occurs at Poatina.

Should Rs represent a basin-wide new cycle of deposition, the quartz conglomerate containing pink and milky quartz reported from south of Dover and near Police Point by Hale (1953) may be a correlate of Rsq. These southern outcrops occur not far below the base of 'feldspathic' (lithic?) sandstone. Other beds south-east of Police Point contain cross-bedding indicating currents to the south-west (Hale, 1953).

### VOLCANIC LITHIC ARENITE, LUTITE AND COAL MEASURES (Rg)

Rocks mapped as Rg consist of distinctive coarse to fine-grained volcanic lithic arenite, siltstone, and claystone, with some coal seams. Quartz sandstone is absent. Silicified logs occur in some arenite beds and large ellipsoidal to tabular concretions are common at some horizons. Layers of cobbles of extra-basinal origin occur at several localities but are probably restricted to the higher parts of the sequence. Rare glass shards have been found and indicate distant penecontemporaneous volcanism. Leaf fossils are abundant at some localities and plant fragments are dispersed in some sandstone layers.

The main feature used to distinguish ₸g during mapping was the thick cross-bedded units of distinctive volcanic lithic arenite. ₸g crops out in grabens and other down-faulted areas and on hillsides protected by overlying basalt flows or dolerite intrusions and reaches 160 m thick at York Plains, but may be thicker. Most grabens have not been sufficiently eroded to expose the base of the unit and hillside occurrences, *e.g.* south of Jones Point [EP170110], Mt Mercer [EN238965], Sandhill Spur, Northumbria Hill [EP232089], and a recently located outcrop north of Big White Hill [EP168028] are not sufficiently well exposed to study in detail the transition between ₸sf and ₸g. Consequently during mapping, a somewhat arbitrary boundary has been used for the base of ₸g based on the first indisputable thick sandstone of the distinctive ₸g type. In many sequences it is only the arenite beds which are exposed and the proportions and types of lutite are unknown. In some sections arenite appears to dominate over intervals of up to about 70 m.

The field observation of thick sandstone units in ₸g has been largely confirmed by recent coal exploration drilling in ₸g in the York Plains area (Glenie *et al.*, 1981). Five holes, each about 50 m deep, have been drilled for Capricorn Mining Ltd at various horizons within ₸g, and the rocks comprise 67-84% arenite. The sequences drilled are composed of arenite units separated by mudstone, carbonaceous mudstone, coal, and lesser siltstone beds. Most sandstone units range from 10 m to 36 m thick, whilst the lutite and coal sequences range from 4 m to 10 m thick. Coal forms 3-11% of the total sequences, or 14-34% of non-arenite sequences. Most coal seams are between 0.1 m and 1.1 m thick and are usually interbedded with similar proportions of mudstone in the lutite units. The sediment proportions, by hole, are given below:

| Hole No. | Depth (m) | Arenite (%) | Lutite & coal (%) | Coal (%) | Coal, non-arenite (%) |
|---|---|---|---|---|---|
| 1 | 50.5 | 69 | 31 | 3.2 | 13.7 |
| 2 | 44.8 | 67 | 33 | 11.4 | 34.5 |
| 3A | 44.8 | 84 | 16 | 4.8 | 29.5 |
| 3B | 47.7 | 81 | 19 | 3.0 | 15.4 |
| 6 | 44.1 | 73 | 27 | 8.5 | 30.9 |

The volcanic lithic arenite consists of well rounded lithic and quartz grains and rounded to subangular feldspar. The lithic grains are mostly of volcanic, dyke, or shallow hypabyssal rock types and include dacite, alaskite (D.C. Green, pers. comm.), basalt, chert, mudstone, and quartzite. Quartz may form as little as 5%, but is usually 10-30% of the rock, is clear, with or without inclusions, sometimes embayed, and extinguishes over a narrow range. Some quartz is probably of volcanic origin. Feldspar (plagioclase and orthoclase) forms 5% to 10% of the rock. Mica (usually muscovite) is present. Some sandstone beds are quite carbonaceous. The sandstone commonly contains a calcite cement which may tend to replace some grains. Calcite concretions exhibit a greater degree of grain replacement and may consist essentially of quartz grains set in calcite.

The most complete sequence occurs at York Plains. The lowest part of the sequence exposed contains a predominance of siltstone or very fine-

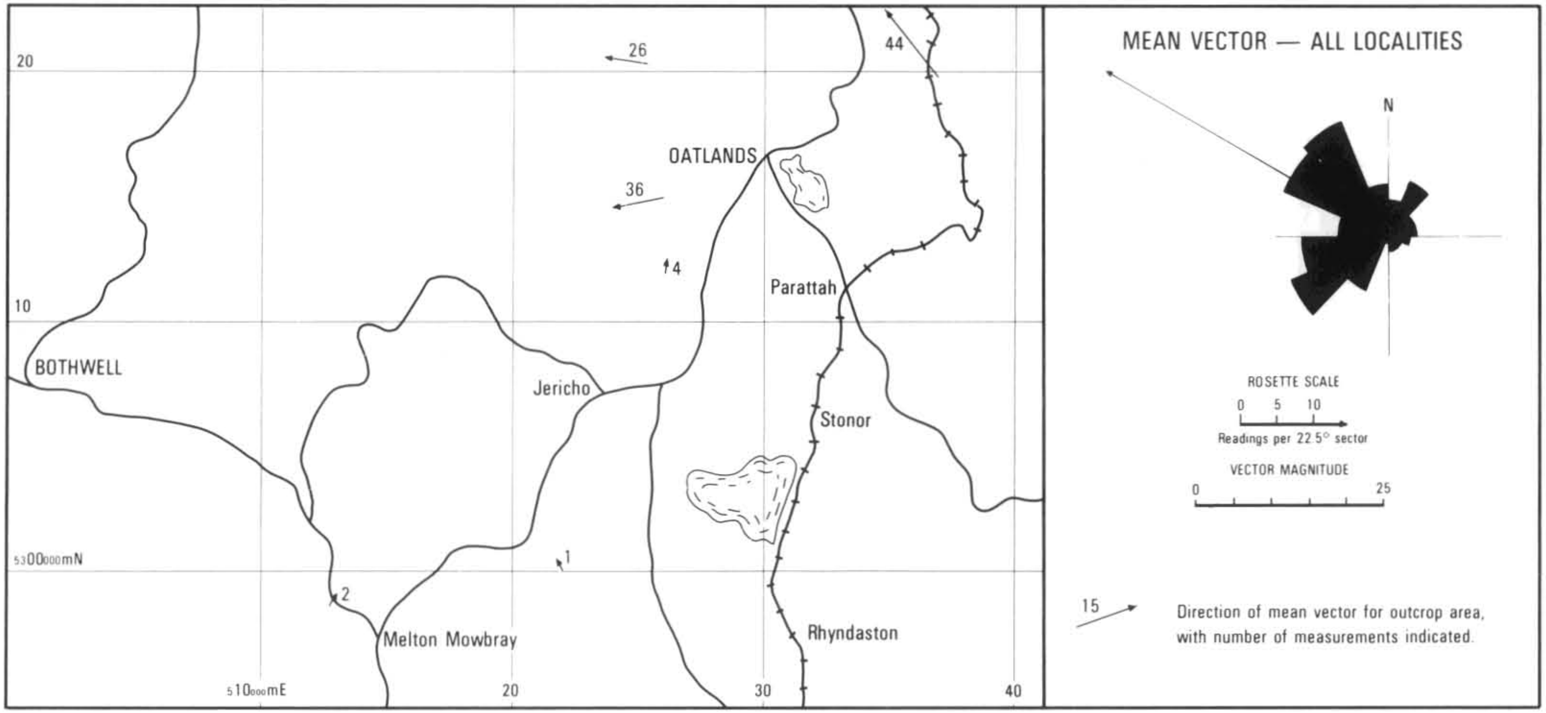
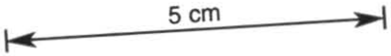



Figure 16. *Palaeocurrent vectors for the volcanic lithic arenite, lutite and coal measures (Rg). Mean vector for each outcrop area calculated from individual crossbedding and festoon axis measurements of relative unit magnitude.*



grained sandstone mixed with coarser arenite, and may grade down into TRsf. Tabular calcareous concretions are particularly common at this level. The coarser arenite units contain breccias of large mud clasts, some deposits consisting of 95% clasts and superficially appearing like mudstone beds. The exposed bases of some arenite beds are broadly erosive into underlying beds and consist of cosets with individual cross-bedded sets up to one metre thick. Some beds may contain grey or brown plate-like clasts of mudstone and coalified wood. The basal beds of the arenite units rapidly pass up into cosets of festoon cross-bedding of smaller scale and finally into ripple cosets and less commonly lutite before another cycle begins. Current directions are variable geographically (fig. 16) and show greater deviance in single cycles than cycles in TRp and TRm. Few current vectors towards the south-east quadrant were observed. Arenite often appears massive and lamination is difficult to discern, making current direction data hard to obtain.

The higher parts of TRg exposed on Mount Pleasant [EP404217] contain well rounded cobbles, particularly at the base of major cycles and usually in proximity to silicified logs. Some clasts up to 0.4 m diameter occur scattered around the northern side of Mount Pleasant and are believed to be derived from TRg. The clasts were first recorded by Nye (1921), who noted that some contained Permian fossils whilst others were of acid igneous origin. The largest clasts are mostly of one type of quartz feldspar porphyry in which the quartz phenocrysts are typically bipyramidal. In smaller clasts the proportion of quartz and feldspar and the groundmass grain size varies greatly between different clast types. Some contain biotite and rare clasts contain abundant chlorite-epidote. Typical rhyolitic-dacitic or andesitic textures are shown. Other rock types have spherulitic porphyry and myrmekitic textures. Quartzite, greywacke, granitic rocks, and fossiliferous Permian greywacke and silicified limestone are present. Permian fossils include crinoids, bryozoans, brachiopods, and *Keeneia*. One Permian clast contained a particularly high proportion of very fresh, fine-grained acid igneous rock types. A conglomerate clast included constituent pebbles of greywacke with fine-grained acid igneous fragments. Practically every rock type occurring as clasts could be matched with grains composing the volcanic lithic arenite at this and other localities. Similar clasts, but fewer in number, have been observed in outcrops elsewhere [EN119985 and near EP259147]. Certain clasts have close similarities to rocks of the Mt Read Volcanics (G.R. Green, A.B. Gulline; pers. comm.) and to dyke rocks from eastern Tasmania (N.J. Turner, M.P. McClenaghan; pers. comm.), but other unsheared rocks cannot be matched with known Tasmanian rocks.

A light grey, fine-grained silicified bed about 100 mm thick crops out in a coal-bearing sequence of TRg exposed in a creek [EN039974]. The bed contains numerous leaf and seed fossils well preserved as impressions marked by white clay on some laminae. The flora is listed in Appendix 3 An overlying sandstone contains rounded large pebbles of silicified siltstone of a similar type but not containing leaf fossils. This indicates silicification occurred soon after deposition. The silicified bed contains rare tricuspate shards(?) and is interpreted as being, in part, a distant volcanic ash deposit. The rock does not closely resemble tuff from near Bicheno [FP080630; Bicheno Quadrangle] described by Bacon and Everard (1981) (C.A. Bacon, pers. comm.). Other silicified rocks containing plant material have been observed elsewhere but not in outcrop. No evidence for a tuffaceous origin for these beds has been found.

*MACROFLORA*

The macroflora collected from ₸g and probable ₸g localities is listed in Appendix 3. In addition a frond preserved in sandstone at EN119985 is probably the conifer *Rissikia media* (Tenison-Woods) Townrow, 1967.

*AGE AND CORRELATION*

The lithic arenite, lutite, and coal measures sequence (₸g) overlies interbedded lutite and quartz-rich arenite (₸sf) which contains a *Craterisporites rotundus* Zone microflora indicating a Late Triassic Karnian to Norian age for ₸sf, upper. ₸g contains a macroflora including several species which do not range above the Norian (Retallack, 1977). Retallack indicates a pre Karnian age for *Rissikia* spp. If the field identification of *R. media* is correct, this may suggest a Karnian age in preference to a Norian age for at least part of ₸g.

₸g is a lithological correlate of the Brady Formation, the New Town Coal Measures, and similar coal measure rocks found throughout eastern and central Tasmania. The Brady Formation (Playford, 1965), the coal measures at South Cape Bay, and the middle and upper portion of the coal measures near St Marys (Dettmann *in* Threader, 1968) all belong to the *Craterisporites rotundus* Zone. The biostratigraphic correlation of the Ipswich Coal Measures and the Brady Formation has been discussed by de Jersey (1970*b*).

*DISCUSSION*

The major volcanic lithic arenite units are considered to have been deposited by major rivers which flowed through a flood plain supporting smaller channels and extensive swamps in which peat sometimes accumulated. The high deviation of current directions at outcrop and regional level indicates the rivers were meanderine. Similarly to ₸s, no evidence has been found for extensive dessication or intensive bioturbation. Townrow (1964) has suggested that the coal measure flora indicated a cool temperate climate.

The large size of the clasts (up to 0.4 m) suggests they probably were not water transported, but may have been rafted in tree roots. This is supported by the association of clasts with silicified logs. The concentration of rounded boulders of quartz feldspar porphyry at York Plains suggests some trees were probably rooted in hinterland boulder beds of monotypic composition. The provenance of the clasts appears to be mixed between eastern and western Tasmania and other areas unknown. The occurrence of Permian clasts suggests the possibility that some clasts may be recycled dropstones eroded from the Permian glaciomarine beds. That some fossiliferous Permian clasts are silicified suggests thermal (contact?) metamorphism or 'silcrete' formation may have occurred between Early Permian and Late Triassic time. Volcanic activity is known from eastern Tasmania during this interval (Calver and Castleden, 1981; Bacon, 1979). The occurrence of Middle Triassic rocks overlying Permian glaciomarine beds at Webber Falls (St Marys Quadrangle), their closeness to granitic basement near Cranbrook (Swansea Quadrangle), palynological (S.M. Forsyth; unpublished) and stratigraphic evidence (C.R. Calver, pers. comm.) from the St Marys area of erosion of Permian rocks before Middle-Late Triassic deposition, suggests eastern Tasmania as the more likely source area for ₸g. This is supported by the low frequency of currents towards the east in ₸g. Such a source area and palaeoslope is in contrast to that for ₸p and Rm deposition and indicates either local uplift or regional tilting during the Middle-Late Triassic, an interval for which basaltic extrusion and acid tuff events are known (Calver and Castleden, 1981; Bacon, 1979).

It is possible that the tectonic and volcanic event may have led to the ponding of river systems, whilst an improved climate and evolution of the flora resulted in peat deposition as has been suggested by Gould and Shibaoka (1980).

## Tertiary system

No thick Tertiary sedimentary sequences are known in the Oatlands Quadrangle although they may underlie areas obscured by Tertiary basalt or Quaternary deposits along the valleys of the River Clyde, the Jordan River near Melton Mowbray, and perhaps Jericho. In many outcrops Tertiary basalt directly overlies reasonably fresh Parmeener Super-Group rocks or dolerite, particularly where basalt is not confined to valleys. Silicified wood (coniferous?) on the northern side of Big White Hill [EP181025] suggests a soil had developed prior to basalt eruption, possibly on Tertiary sediments. Ferricrete, possibly underlying basalt, occurs at Bow Hill [EP190175]. The basalt-filled valley of the River Clyde contains numerous occurrences of Tertiary ferricrete and silcrete marginal to and probably underlying basalt.

The occurrence of many of the hill-capping lava flows at about 500 m at first suggests subsequent dissection of a once more extensive basalt plain. However, the basalts are of varied types and their detailed distribution suggests that much of the major drainage features had become established by at least the period of younger basalt extrusion. The lava flows in the vicinity of Bow Hill and at Sandhill Spur [EP220080] flow towards the valley of the Jordan River and to within 20 m of the present valley base (295 m) at Exe Sugarloaf [EP180148]. Abtmaier considers that the arcuate shape of the basalt near Exe Sugarloaf and the presence of underlying dolerite cobbles indicate that this basalt fills the bed of a Tertiary stream. This view of antiquity of the drainage system is reinforced by the fact that it is the older flow at Bow Hill which descends into the valley on the south-western side. Further down the Jordan Valley, the flows at Big White Hill and Little White Hill [EP150035] descend to the 360 m level, while ferricrete is found at an altitude of 260 m [EP125053]. Very hard brecciated siltstone (Ps) surfaces 1.5 km further west at 280 m may be sub-basalt pavements. It is not clear whether the Curzon Hill flow [EN127970] down to 260 m (80 m above the Jordan River) occupies an old valley of the Jordan River or a tributary valley.

### BASALT AGGLOMERATE AND ASSOCIATED ROCK TYPES (Ta)

The best exposed deposit of this type occurs in a quarry [EP112037] on the Lake Highway north of Apsley, occurring downslope from basalt necks and displaying a near-vertical contact with quartzose sandstone (Rp) on its lower side. The deposit contains up to boulder size pieces of basalt, dolerite, Triassic sandstone and mudstone, and small pieces of wood set in a basaltic matrix. Some wood pieces are soft, yellow, and fibrous. The deposit is steeply crudely bedded and jointed, the bedding steepening into the quarry. A specimen has been described as a sandy basaltic lapagonitic lapilli tuff by Everard (1968) and the deposit has been comprehensively described and its possible formation discussed by Butters (1970). Butters considered the deposit to be a zoned tuffisite pipe, dipping into a core basalt-rich zone immediately behind the quarry. The lateral extent of the deposit is unknown because of mantling dolerite talus.

No basalt clasts have been found by the author in further deposits mapped as tuffisite by Butters about one kilometre west along the Lake Highway. These deposits do contain some very fine-grained dolerite and resemble ferruginised and partially consolidated talus of uncertain age observed elsewhere. Butters however found some concentrations of basalt clasts in these deposits.

A small exposure of basalt agglomerate, which includes dolerite cobbles, occurs at York Plains [EP393192] about 1.5 km from the nearest mapped basalt.

A small, valley-floor outcrop of very scoriaceous basalt enclosing or intruding baked mudstone occurs at EP241142. Basalt cobbles in dolerite talus have been found about 700 m to the north along the line of a major N-S trending fault and ferricrete occurs close to the agglomerate. This outcrop has been interpreted as occurring near the base of an eroded flow.

Red clay and black clay with small weathered granules occur west of the Curzon Hill basalt flow and may be tuffaceous.

Dr F.L. Sutherland has drawn the author's attention to further basalt agglomerate containing dolerite clasts east of an un-mapped basalt capping Fernleigh Hill [EP266199], and another deposit directly underlying the basalt flow at Barwicks Hill [EP286188]. The latter occurence contains large boulders of dolerite and basalt enclosed in basaltic material and is thought to be very close to the site of a supposed kimberlite pipe.

Minor outcrops of basaltic breccia, sometimes enclosing Parmeener Super-Group clasts, occur marginal to some volcanic necks [*e.g.* EP142108; EP160137; EP197087] (plate 27).

## FERRICRETE (Tf)

Ferricrete has been mapped marginal to basalt, particularly in the River Clyde valley, but small occurrences have been found elsewhere. Isolated blocks and small lags of ferruginised sandstone were not mapped, but extend over much of the quadrangle, as do blocks of ferricrete in the toe of some Quaternary dolerite talus deposits. It is possible that a veneer of ferricrete and related rocks once extended over much of the quadrangle. Should the ferricrete predate the basalt, it would appear that the ferricrete had been stripped from some high ground prior to basalt extrusion, with further stripping taking place during the Pleistocene.

Rarely large pieces of compressed, ferruginised wood occur in the ferricrete. More common are small lozenge-shaped angular clasts with textures resembling wood which are probably replaced charcoal. Many of the ferricrete deposits contain common to rare quartz grains or granules indicating an initial sedimentary origin for the host rock which has been lateritised.

Several varieties of ferricrete have been mapped. Some ferricrete is clearly lateritised sandstone (Tfh) whilst pisolitic varieties (Tfc) also usually contain detrital quartz up to granule size. Other ferricrete is massive yellow and purple spotted rock possibly originally of igneous origin. In some cases the ferricrete occurs as concentric layered shells of ochrous character coloured red, orange, yellow, brown, and purple, occasionally with internal cavities lined with black mineral films. The ochrous deposits, including more massive varieties and box-work structured types, have been mapped as Tfo. The distribution of the ferricrete around Bothwell suggests that the ferricrete is older than the basalt but this has not been confirmed by direct stratigraphic observation.

Some dolerite has been lateritised, occasionally preserving the crystal outlines and cleavage cracks, whereas in other areas the original rock texture has disappeared. Some lateritised dolerite occurs in close association with pallid, deeply weathered dolerite.

#### GREYBILLY (Ts)

Greybilly occurs marginal to the basalt and ferricrete deposits in the Bothwell area. The most characteristic rock type forms low rounded light grey outcrops, breaks with a conchoidal fracture, and contains scattered quartz sand and granules set in a finer silicified matrix. Silicified plant remains, stems or roots of circular cross section a few millimetres to a few centimetres diameter, and cavities of similar size and shape occur. Near EP060110, crudely radiating structures resembling roots radiating from trunk bases occur, and the greybilly is pock-marked by numerous flute-like marks averaging about 10 mm wide and a few centimetres long. The marking could be produced by cobble impacts in streams, but the sense of direction is completely opposed to the current drainage system and to that which may have been expected during the mid-Tertiary. Basalt occurs within the area of greybilly outcrop and almost certainly overlies the greybilly. The 'flute' marks may be the result of thermal shock induced by basalt flows (E. Williams, pers. comm.). The contrasting composition of the basalt compared to the basalts further west in the River Clyde valley allows the possibility that the silcrete may have formed in association with the Clyde basalts and not necessarily the basalt which overlies the silcrete.

Some silcrete differs from the above type by possessing an equigranular saccharoidal texture.

#### SANDSTONE WITH ANGULAR CLASTS (Tx?)

These rocks range from poorly sorted sandstone with clasts to breccia deposits. Based on the presence of crude vertical joints which cut the matrix only, and their semi-lithified nature, a Tertiary age has been suggested, but a Quaternary age cannot be dismissed. Outcrops occur at EP135092 and EP123064, the latter having polygonal jointing.

### Quaternary deposits

#### MAPPING LIMITATIONS

Quaternary deposits are widespread throughout the quadrangle and conceal many boundaries between older rock types. Because of the unpredictability of dolerite structures, the common occurrence of faulting, uncertain relationships between some Upper Parmeener Super-Group rock units, and the difficulty in defining the base of basalt flows, many of the obscuring deposits have been depicted on the map. The alternative would have been to interpret boundaries between pre-Quaternary rocks or depict the obscured areas as undifferentiated rock types.

Dolerite talus flanking most dolerite hills has caused particular problems during mapping. Not uncommonly valley floors either expose Parmeener Super-Group rocks or themselves are covered by alluvium. Talus mantles the slopes, probably covering sedimentary rock types, and eventually fine-grained dolerite crops out up the slope, defining the edge of the intrusion, or alternatively coarser grained dolerite is exposed either some distance from the intrusive edge or at a fault boundary.

Rare sedimentary rock clasts in the talus and careful mapping of dolerite clast grain size distribution sometimes enables the sedimentary rock-dolerite boundary to be located, but usually the boundary can only be defined to within a few hundred metres. In such cases the map depicts the highest sedimentary rock outcrops or floater occurrence and the lowest definite evidence of dolerite, separated by talus deposits. In some cases either the sedimentary rock is known only from clasts in the talus or the distance to the nearest sedimentary rock outcrop is so great that it has been found convenient to depict such talus as composed of mixed lithologies. Examples exist where the sedimentary clasts may constitute only a very small part of the mixed talus, but may be significant in locating dolerite boundaries. Magnetometers have not been used to locate obscured dolerite boundaries but would probably prove useful.

The concentration of mapping effort along older geological boundaries has led to an uneven mapping of Quaternary deposits; for example mapping of dolerite talus over dolerite has usually not been attempted.

In the areas mapped by Abtmaier (excepting Quaternary lag deposits (Ql) and sandy deposits of windblown origin (Qcsw)) superficial deposits have not been mapped on the ground and all other Quaternary deposits have been photo interpreted. In some cases Abtmaier interpreted the position of dolerite contacts beneath talus. Where additional information has become available it has become apparent that some areas mapped as dolerite are in fact dolerite talus blanketing soft Upper Parmeener Super-Group rocks (see Appendix 1). Some areas considered to be dolerite, but which are possibly dolerite talus, have been shown as Jdl? on the map.

## TALUS DEPOSITS (Qt)

### *Dolerite clasts (Qtd)*

Extensive dolerite talus deposits are typically composed of angular and subrounded boulders and finer grained material of dolerite origin, and form even slopes to hummocky terrain with or without modern landslides. Occasional depressions in hummocky terrain may support swamps. Natural sections are rare, but road cuttings sometimes indicate minimum thicknesses of several metres of matrix-supported clasts set in a red-brown or orange clayey matrix. Clasts range in size from pebbles up to boulders several metres across. Clast size is determined not only by proximity to source, but also jointing in the parent material and topographic height of the parent material. Occasional layers a single clast thick occur in some exposures, indicating more than one transportation mode. Minor alluvial deposits in talus have not been mapped separately.

Thin platy dolerite sheets produce a particular type of talus containing large platy slabs; for example at Woods Quoin [EP075188] slabs over one metre in length occur over one kilometre from their source. Rotated blocks over six metres in diameter also occur close to their source at Woods Quoin.

Some difficulty has occurred west of Apsley distinguishing between talus derived from coarse-grained dolerite and *in situ* dolerite. Some areas believed to be talus contain rounded boulders up to several metres across set in a matrix containing occasional small sandstone clasts. These deposits have been mapped as Qtd, whilst outcrops of similar boulders without supporting evidence have been depicted as Qtd? [EN110998] and Jdl? [EP114025] where no source for coarse-grained rocks could be located in the ridge of dolerite immediately above. Some of these 'deposits' are essentially cut off from the dolerite terrain of Den Hill, and should Den Hill prove to be the source of the boulders, then it is implied that a considerable portion of the initial slope has been eroded. Alternatively the boulders may be derived from the virtual *in situ* weathering and collapse of a former dolerite sheet. Should this be the case, then it appears that coarse-grained dolerite occupied the basal part of a sheet, and this is regarded as extraordinary. Such an occurrence would imply the maintenance of high temperatures by magma flow, remobilisation of partially cooled magma, or a more granophyric composition of the magma.

Many smaller deposits, mostly of lower altitude source, consist of angular to subrounded cobble-size dolerite. Although forming thin veneers occasionally less than one metre thick, these deposits may completely obscure less resistant rocks such as Upper Parmeener Super-Group mudstone.

*Lower Parmeener Super-Group clasts (Qtp)*

The main deposits mapped occur along steep scarps flanking the Jordan River north of Apsley [EP113050, EP135088]. Most clasts are angular and only a few centimetres diameter. The matrix tends not to be greasy when wet. The deeper portions of the deposits are partially consolidated and may exhibit clay-lined polygonal jointing. The jointing may arise by opening of similar joints in the underlying siltstone (Ps), to which the talus has adhered during partial consolidation.

*Upper Parmeener Super-Group quartzose sandstone clasts (Qtt)*

These deposits occur on steep slopes below sandstone cliffs. They possess a sand to sandy clay matrix supporting sandstone clasts ranging from small chips up to large boulders.

*Basalt clasts (Qtb)*

Some basalt flows with cooling joints about 0.5 m apart yield equi-dimensional boulders which contribute to basalt talus. Although the upper margins of the flow remnants are usually clearly defined by columnar out-crops and plateau landforms, the lower margins are commonly difficult to locate. This is particularly so adjacent to the northern boundary of the quadrangle [near EP185223] where areas of numerous large basalt boulders may be Quaternary talus or basalt outcrops. These boulder areas have been mapped as Tb?

*Mixed composition talus deposits*

The following types of mixed talus deposits occur:

- dolerite with notable amounts of Lower Parmeener Super-Group rocks (Qtdp);
- dolerite with notable amounts of Upper Parmeener Super-Group quartzose sandstone (Qtdt);
- dolerite with notable amounts of Upper Parmeener Super-Group lithic sandstone (Qtdv).

The dolerite portion of these deposits may range from 50% up to almost 100%. Colhoun (1977) considered that the bulk of the slope deposits in the adjoining Brighton Quadrangle were produced or remobilised during the Last Glacial stage.

*Scree deposits (Qs)*

The term 'dolerite scree' has been used for deposits composed mostly of sub-angular blocks with no matrix. These include boulder fields with no soil cover and direct cliff-fall debris. Deposits mapped at EP110118, EP232001, and EP227018 all occur above 460 m. That part of the deposit below 460 m near Rhyndaston [EP310980] may include dolerite talus.

BOULDER BEDS (Qb)

Water laid deposits of boulders and cobbles have been mapped under separate categories.

*Dolerite fan deposits (Qbfd)*

These deposits occur where short streams descending steeply from dolerite terrain reach lower gradients (1:12-1:20), usually on sedimentary rocks. The deposits fan out from the point where the stream gradient decreases and the deposits are normally coarsest at that point, with boulders 0.4-1.0 m diameter. With increasing distance down the fan, the dolerite clasts become more rounded and small spherical cobbles become common. Some deposits have channels radiating from the apex and a radial pattern of gravel bars are apparent in some fans. Alluvial fans bordering the River Derwent have been considered to have formed during glacial phases of the Late Pleistocene (Sigleo, 1979; Colhoun, 1977).

*Boulder beds composed of dolerite (Qbd)*

Boulder beds mapped as Qbd are similar to the alluvial fan deposits but are not fan-shaped nor necessarily situated at the point of emergence of steep streams from dolerite terrain. Such deposits normally occur in areas with a notable downstream gradient and were probably deposited on the extremity of fans and in braided streams with gradients of 1:50-1:500. Included are deposits particularly noticeable because of the large size of some clasts, for example dolerite slabs of 0.5 m diameter [EP020035]. A section of a deposit [EP115029] shows at least three metres of imbricated cobbles overlain by boulders.

*Boulder beds composed predominantly of sedimentary rock clasts (Qbs)*

These deposits are composed mostly of silicified sedimentary rocks, but usually include some dolerite clasts. Deposits north of Bothwell [EP001120] include clasts of conglomerate resembling the Blackwood Conglomerate correlate (Pb).

SWAMP AND MARSH DEPOSITS (Qc) AND SANDY DEPOSITS (Qcs)

This category includes swamp deposits and marsh deposits (Qc). The larger mapped areas of Qc are swamp deposits in small lagoons in quartzose sandstone (Rp). Some small deposits are associated with hummocky talus terrain. Submerged peat deposits overlying lacustrine sediments at Lake Tiberias [EP300020] have been cored and analysed palynologically and a $^{14}C$ date of 9550±200 BP (GaK-2239) has been given for a specimen from the base of the peat sequence (Macphail and Jackson, 1978). Macphail and

Jackson suggest that the cold and dry climate of the Late Pleistocene was succeeded by a wet and possibly warm climate during Early to Middle Holocene times. A subsequent reversion to drier conditions led to the modern sub-humid climate.

Sandy deposits (Qcs) are more widespread and encompass a range of depositional modes and compositions from clayey sand and sandy clay to clean, loose sand. Most deposits are derived from sandstone terrain or river plain environments and probably include alluvial, aeolian, and slope deposits. Where an aeolian deposit has been confirmed by aeolian cross-bedding or dune morphology, sandy deposits have been depicted as Qcsw. Some aeolian deposits are composed of clean sand but clayey sand and sandy clay are more common.

A driller's log of a borehole east of Lake Tiberias [EP315023] suggests that clay and sand may reach a thickness of ten metres in this area.

The most extensive deposits of Qcsw occur on the lee (eastern) side of Lake Tiberias and at Nala [EP374153]. It is likely that the extensive deposits of Qcs on the plains south of Melton Mowbray, the Dennistoun Plain, and near Bothwell are also of aeolian origin; certainly small portions of these deposits are aeolian. Sandy deposits occurring in sheltered gullies and on the lee side of sandstone hills, for example hills 5-10 km east of Woods Quoin, probably contain some windborne component, but probably also include alluvial and slope deposits as indicated by their absence on the interfluves.

Because of the similarity of sandy soils developed on both sandstone and sand deposits, sand deposits on sandstone are greatly under represented on the map.

No new evidence has been found to indicate the age of the aeolian deposits. Sigleo (1979) has studied similar deposits in adjoining areas to the north, east, and south and briefly summarised models of lunette formation. The favoured model for sand lunette formation is by the erosion of sandy shores of lakes with fluctuating high water level, whilst clay lunettes probably form by the deflation of clay aggregates from dried lake beds. Sigleo attributed a Late Pleistocene age to lunette clay and sand and aeolian sand sheets, which he considered formed at the end of each cold phase, and a Holocene age for some blanket sands, probably resulting from aboriginal and later European disturbances. Sand south of the Oatlands Quadrangle at Malcolms Hut Road has been $^{14}C$ dated at 15 740±700 BP (SUA-376) (Colhoun, 1975) whilst Sigleo (1979) considered increased summer temperatures at the end of the Last Glacial resulted in the drying out of lake beds resulting in the youngest clay dunes of neighbouring areas. The study of terrestrial dunes has led to the suggestion of a cool moist climate pre 20 000?BP (Sigleo and Colhoun, 1982).

ALLUVIUM (Qa)

Alluvial deposits are associated with most modern streams of moderate to low gradient. Typically, where gradients are about 1:50 or lower, thin cobble and pebble beds usually overlie the bedrock and are generally succeeded by silt and clay deposits 1-3 m thick, and less commonly by sand. Very coarse sand or fine pebbles of dolerite rarely occur in thick beds. Not uncommonly a black, organic-rich deposit caps the alluvial sequence, particularly on marshy flats. In these situations the lower cobble beds are often bleached white.

Cobble channel fills occasionally occur within the silt-clay-sand sequences and in channels now only occupied during floods. The major deposits are associated with the Jordan and Clyde Rivers. Except where bedrock is exposed, the thickness of alluvium is not known. Nine metres of dolerite cobbles drilled in a small stream [EP047076] without reaching bedrock is regarded as exceptional. Six metres of white clay drilled without bedrock intersection in Fordell Creek [EP061117] is also unusual. No core was recovered at this latter site and the possibility exists that Tertiary sediments could underlie alluvium here.

Deposits indicated as Qa? on Dennistoun Plain [EP018130] are known only by the accumulation of dolerite cobbles around holes dug for poles supporting a radio telescope at this locality.

Butters (1970) considered that the larger scale meanders of the Jordan River north of Apsley [EP115015] indicated a previous water flow much greater than that at present. The presence of basal cobbles and gravel in most alluvial deposits is consistent with earlier greater flow. The basal cobble beds are not strongly weathered and only rarely have ferruginous cementation. These deposits may be related to the wetter Early to Middle Holocene climate suggested by Macphail and Jackson (1978), or may be of Late Pleistocene age. Thick deposits occur in the vicinity of the Jordan River at Jericho [EP240080].

*Higher level alluvial deposits (Qah)*

Some alluvial deposits are noticeably higher than the current alluvial plains. These deposits grade into Qb-type deposits of finer (cobble) grain size. Qah deposits occur along the Jordan River, particularly in the Melton Mowbray area [EN145978] and in some cases [*e.g.* EN160958] were probably deposited by tributary streams. Deposits capping hills are most striking, for example dolerite cobbles at EN154968. Some deposits occur over 20 m above the present Jordan River [*e.g.* EP135099]. Basalt clasts occur at this locality, at EP117056, and possibly in unmapped deposits east of Black Marsh.

Gravel composed of siltstone chips and showing some alluvial cross-bedding occurs in pits on the Dennistoun Road [EP056175] overlying the Cygnet Coal Measures correlate (Pj). These deposits are not related to the present drainage.

LAG DEPOSITS (Ql)

Lag deposits are surface concentrations generally of silicified rock and wood. They occur primarily near Parattah [EP328095], Jericho [EP245075], and York Plains [EP385210]. The constituents have been regarded as being derived from Tertiary deposits, however a Rg origin seems as likely. A mixture of constituents from both sources probably occurs. One deposit [EP068068] includes silicified blocks with a black matrix containing cream and red angular, lozenge-shaped clasts 10-20 mm diameter that texturally resemble wood. The deposit at EP013035 is a lag of Lower?Parmeener Super-Group sandstone blocks.

UNDIFFERENTIATED DEPOSITS (Qu)

Many deposits mapped as undifferentiated Quaternary deposits are distributed along valleys. The major proportion of these deposits is probably of alluvial origin but this could not be conclusively shown. Included are deposits transitional between talus and valley floor alluvium and which are probably of sheet wash origin.

New exposures along the reconstructed Midland Highway north-east of Lovely Banks display mixed slope deposits which are partly alluvium, partly talus. Steep rock-choked valleys and talus are exposed in cuttings towards the top of Spring Hill [EP215040] and cobble beds are exposed north of Jericho [EP262076].

## IGNEOUS AND CONTACT METAMORPHIC ROCKS

### Jurassic dolerite

Dolerite is widespread throughout the quadrangle and occurs as sill-like bodies from one metre to >200 m thick, and as dykes from a few centimetres to tens of metres wide, intruding horizons from the oldest exposed to the youngest of the Parmeener Super-Group. Multiple dolerite intrusions also occur (Plates 24,25). No radiometric dating of dolerite from the Oatlands Quadrangle has been carried out, but dolerite from elsewhere in Tasmania is of an age close to the Early-Middle Jurassic boundary (Schmidt and McDougall, 1977). At least one sample of Irving's (1956) study of dolerite magnetisation comes from the Oatlands Quadrangle. Dolerite is remarkably uniform in composition; petrological descriptions are given by Edwards (1942), Spry (1962), Joplin (1958, 1964) and detailed chemical analyses by Ortez (pers. comm.). Leaman (1975*b*) has suggested that younger intrusive phases intrude at stratigraphically high levels. Sills at Woods Quoin and Mount Pleasant [EP403216] are therefore regarded as being younger than the sills underlying these areas.

During mapping, textural and some compositional variations have been noted, mainly to elucidate dolerite structures. Petrographical studies have been confined to unusual varieties of dolerite and to assist in distinguishing some very fine-grained dolerite dykes from similar basalt dykes.

Grain size has been depicted as follows:-

| | |
|---|---|
| 0-0.7 mm | vf |
| 0.7-1.5 mm | f |
| 1.5-3.0 mm | m |
| >3.0 mm | b |

These apply to the average grain size of equigranular rocks and the average grain size of phenocrysts of porphyritic rocks as determined on outcrops only.

Very fine (vf) dolerite has only been observed close to intrusive margins, and some contain dark euhedral crystals of orthopyroxene. Orthopyroxene tends to be more common at steeply dipping margins of major intrusions but also occurs at sill contacts and in some thin dykes. Thin sections of thin dolerite dykes intruding dolerite at Spring Hill are petrographically indistinguishable from thin sections of the margins of the main dolerite body which they intrude. A dyke about 80 mm wide intruding dolerite consists of 80% glassy groundmass with randomly disposed feldspar laths 0.2 mm long and spherulitic trichites forming a felted hyalopilitic texture enclosing incipient larger feldspar laths and euhedral orthopyroxene phenocrysts 0.5 mm long. Some aggregates of feldspar and pyroxene crystals (Section 83-14) occur.

A much larger dyke at Spring Hill has a chilled margin. This margin similarly possesses a felted groundmass with spherulitic trichites up to

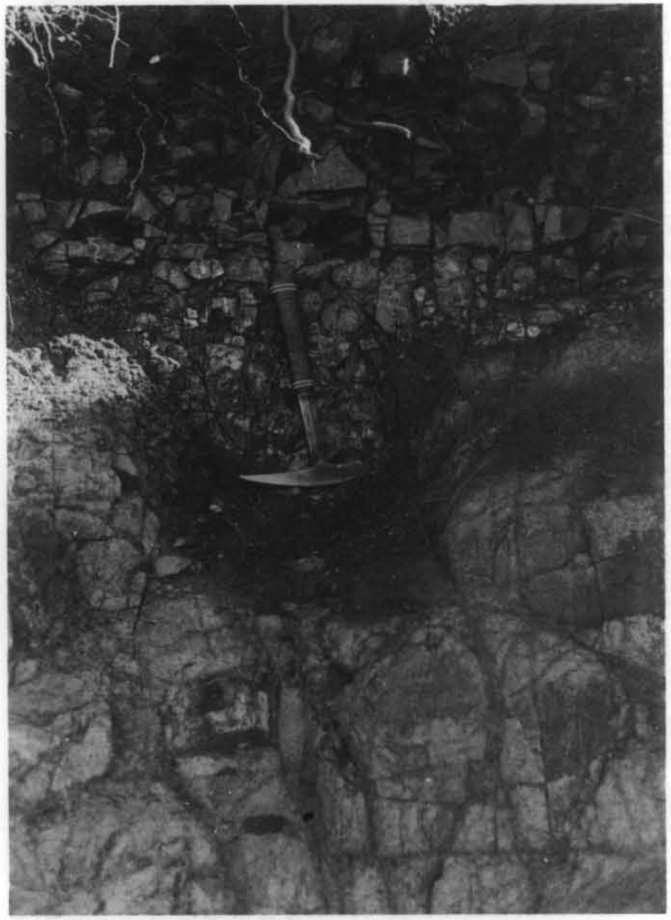


Plate 24. *Steeply dipping, very fine-grained glassy margin of fine-grained dolerite mass intruding coarser grained dolerite at bottom. The hammer lies against the excavated very fine-grained margin [EP214047].*

Plate 25. *Plan view of very fine-grained dolerite dilational dyke intruding coarse-grained dolerite, Bryans Creek [EP032177].*

0.1 mm long, orthopyroxene phenocrysts, and aggregates of feldspar and pyroxene one millimetre across which may be tiny xenoliths (Section 83-12). The crystals of feldspar rapidly coarsen to 0.5 mm and the pyroxene to 1.0 mm in Section 83-13 and form a subophitic texture or hyalophitic texture where patches of glass occur. The groundmass is greenish brown and contains quartz. Iron minerals form 2% of the rock. The grain size and mineral distribution is not even and areas of feldspar only and finer grained zones occur.

The texture some metres further away from the first contact resembles a megascopic version of the thin dyke. Randomly disposed feldspar laths are 0.3 mm to 0.5 mm long and are enclosed in an opaque to dark brown glassy mesostasis. Corroded phenocrysts of orthopyroxene, pigeonite, and sub-ophitic intergrowths of feldspar in pigeonite occur. A dyke at EP187106 is very similar (72-371). Rocks close to the south-west margin of the Spring Hill dolerite are also similar. Other rocks contain pigeonite pseudomorphs after orthopyroxene (83-16). This appears to occur close to margins, as these rocks contain about 15% glassy mesostasis with trichites and pyroxene crystals up to 0.4 mm long. Such rocks also contain small rounded quartz grains (83-17, 83-16) and hollow core-like plagioclase crystals which may possess dovetail extensions from the crystal corners. The best examples of the box-like crystals occur in Section 83-19 and are somewhat more skeletal than those figured by Lofgren (1974, Plate 1c). The length of box sides are sometimes unequal, leading to rectangular 'spirals' of plagioclase.

Glass in the dolerite from the margin of intrusions is usually devitrified brown to black with microlites and dispersed iron oxides. Some quartz is visible in hand specimens. The quartz mostly occurs as single anhedral round crystals or as composite bodies. The largest observed (83-20) was 1.5 mm diameter and consisted of several interlocking quartz crystals enclosed in radial fibrous quartz lining a vesicle.

Fine-grained dolerite intruding the Coal Measures Correlate (Pj) [EP052177] and Rg and Rsq? [EN045975] contains quartz (up to 30%), and occasionally calcite amygdales several millimetres across. Similar rocks have previously been reported from Rosegarland (Anand Alwar, 1960). Jointing of vf-dolerite tends to be irregularly platy at the margins of major intrusions and more cubic in very thin intrusions. With increasing grain size, as in f-dolerite, the orthopyroxenes become more rounded and finally totally absorbed. Before this occurs, augite, pigeonite, and orthopyroxene may co-exist in subophitic textures with labradorite. Jointing of f-dolerite tends to be platy and perpendicular to intrusion margins. Vertical platy jointing borders steeply dipping intrusions. Sills and dykes up to several metres thick contain no dolerite coarser than f-dolerite unless directly connected to larger intrusions as broadly based bosses.

With increasing grain size acicular crystals >1.5 mm are gradually replaced by more equidimensional crystals in m-dolerite. Sills, for example at Woods Quoin, composed of f-dolerite and m-dolerite tend to retain platy 'hour glass' jointing controlled by large scale columnar jointing through their entire thickness.

In larger sills there is usually a replacement of broad platy jointing by more cubic jointing, often with subhorizontal to inclined continuous jointing cutting through joints bounding large columns. The m-dolerite of this type tends to be equigranular and relatively mafic. This type of dolerite may coarsen into b-dolerite, but most outcrops of b-dolerite are

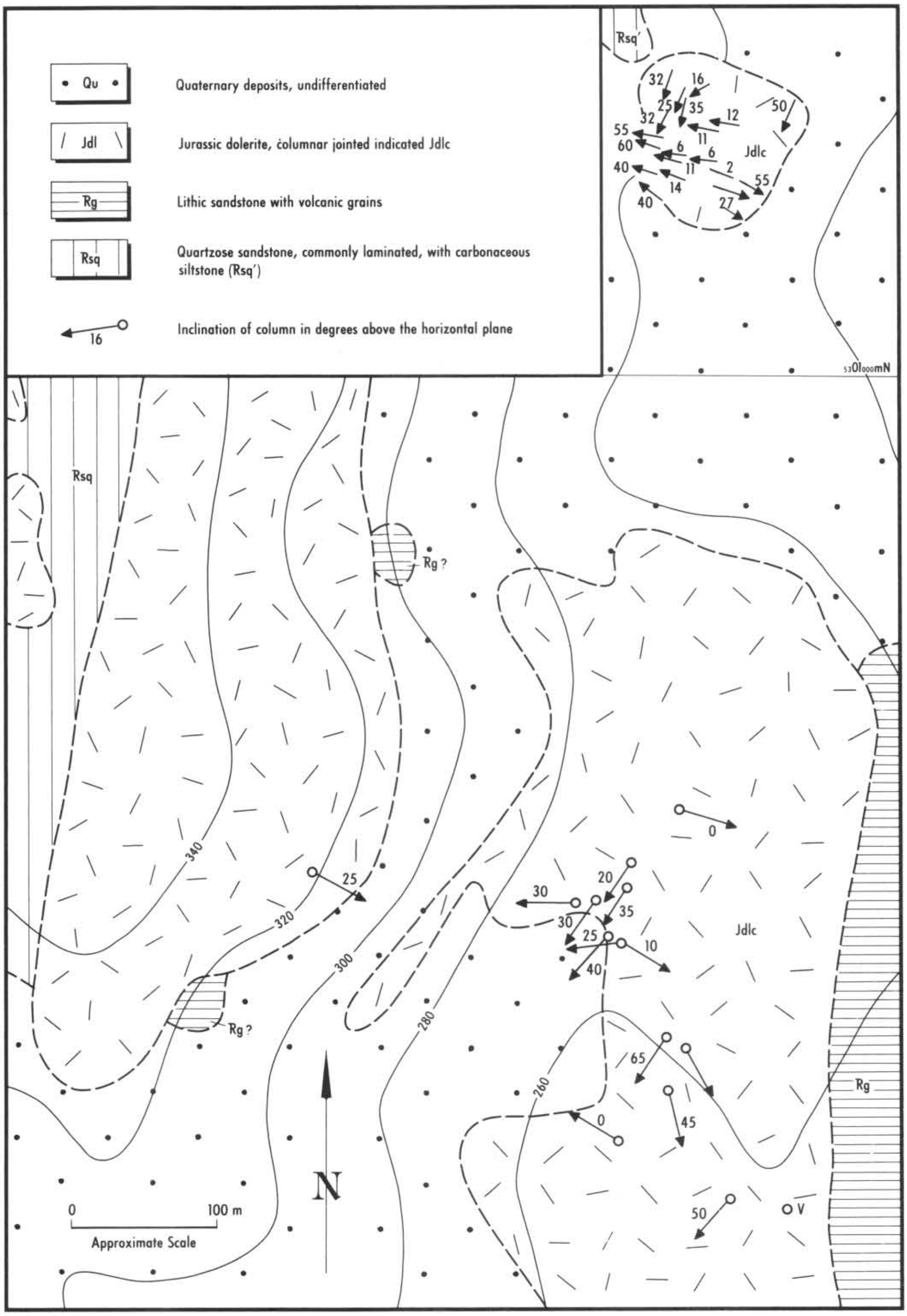



Figure 17. *Azimuth and inclination of columns in columnar dolerite (Jdlc), south-west of Apsley.*

porphyritic with large 3-12 mm pyroxene crystals set in a groundmass which weathers to light colours. Coarse dolerite such as this extends well below the upper portion of major sills, for example in the dolerite gorges of the River Clyde. Coarse-grained pegmatite with pyroxenes several centimetres long and granophyric rocks with quartz feldspar myrmekitic intergrowths and blocky crystals 2-10 mm diameter occur below the finer grained tops of major sills and may intrude the marginal zone. These intrusions occur both in clearly defined dilational dykes and as irregularly defined masses. The top of major sheets consists of uniform f-dolerite, but commonly below this is a zone where abrupt but diffuse boundaries occur between f-, m-, and b-dolerite masses of various sizes. Similar rapid transitions of grain size have been observed near EN119993, where pods of m-dolerite occur in f-dolerite in irregular intrusions probably arising from a major sill.

Several unusual varieties of dolerite have been noted. One variety contains in hand specimen prominent euhedral plagioclase laths set in a mafic groundmass. The most striking example [EP045181] is where feldspar crystals 1-10 mm long form rosettes. In thin section (76-834) the plagioclase laths form, in part, an ophitic texture with pyroxene up to 8 mm long, and elsewhere are set in mono-mineralic zones of much smaller interlocking plagioclase laths or brown coarse granophyric? mesostasis with 15% black opaque mineral.

Rounded composite quartz grains several millimetres across occur in a leucocratic rock which crops out in dolerite terrain on top of Bisdee Tier at EP237002. In thin section (73-249) the rock contains 15% elongate orange-brown altered crystals and quartz set in interlocking feldspar laths. The feldspar shows some simple twinning, but albite twinning is absent. It is not clear whether the rock is solely of igneous origin or whether it has formed from magma contaminated by sedimentary rocks. A somewhat similar rock was described by Anand Alwar (1966).

The fine-grained dolerite is frequently glassy. However, dolerite at EP173022 is unusual in possessing about 25% of undevitrified transparent light brown glass. Uncertainty regarding the age of this rock has led to its depiction as Jdl? on the map.

A fault breccia composed of calcite with embedded, very altered green dolerite occurs near EP057187. Iron sulphide nodules are common in this rock and zeolite may be present. Stilbite and laumonite (D.C. Green, pers. comm.) occur in fractures associated with dolerite dykes intruding dolerite at EP216042.

Glassy fine-grained columnar dolerite (Jdlc) is confined to grabens in lithic arkose (Ꝛg) at Apsley and between Mt Anstey [EP248136] and Rockton Sugarloaf [EP245220]. Thin sections closely resemble other glassy dolerites, but hand specimens differ by the presence of red weathered crystals. Unlike dolerite elsewhere, the columnar joints produce columns of small size, generally 100-250 mm diameter, that curve along their length. Mega-joints divide a mass of columnar dolerite into exposures in which column directions are uniform but differ from block to block [EP116012]. Some column directions are shown in Figure 17. Columnar dolerite appears to grade into normal dolerite at one locality [EP112005], whereas columnar dolerite may be chilled against a normal dolerite outcrop elsewhere [*e.g.* EN114981]. The distribution of columnar dolerite and the low inclination of many of the columns suggests that columns may occur marginally in upward projecting masses or pipes of dolerite.

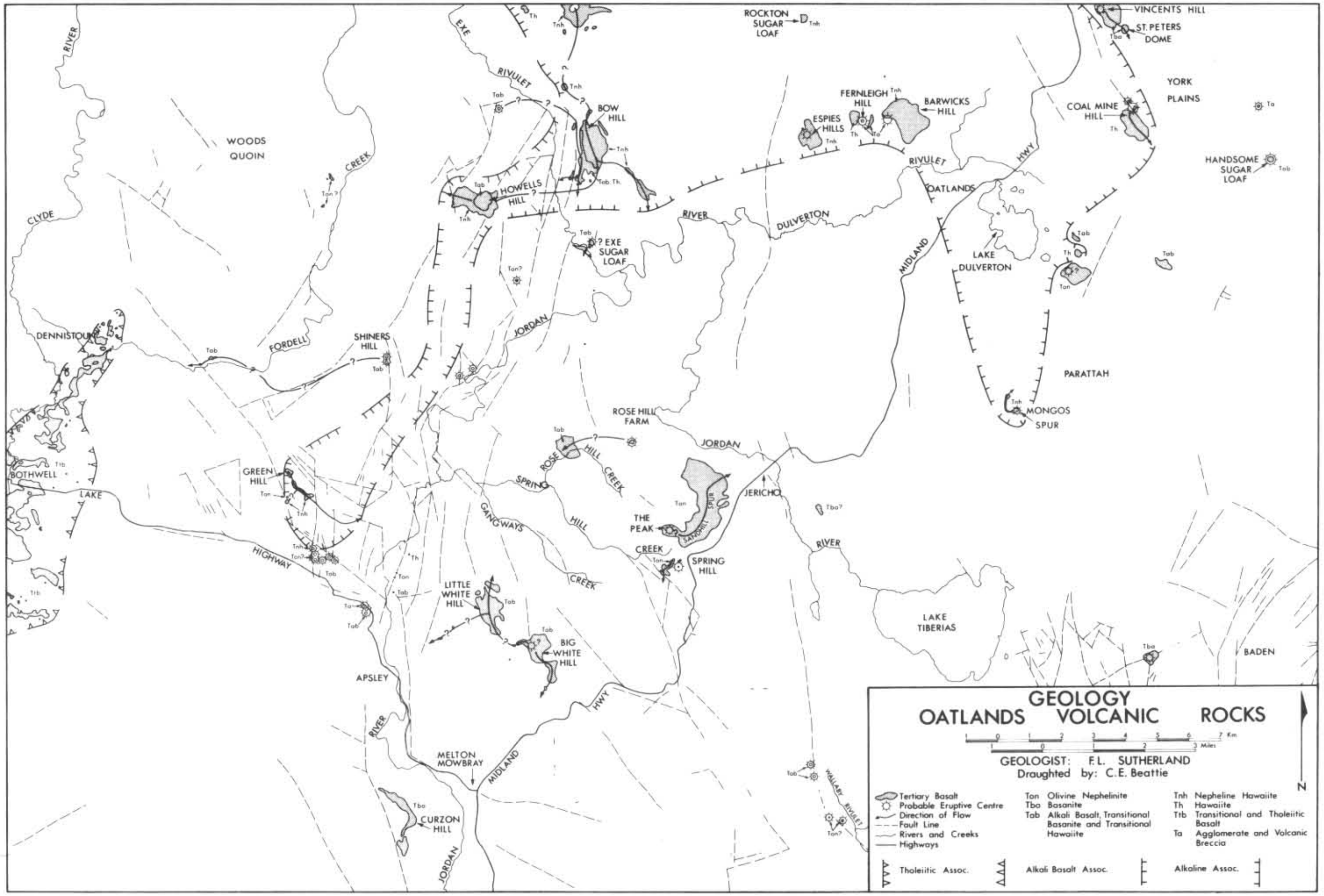



Figure 18. *Petrological distribution of volcanic rocks in relation to main drainage, fault lines, and eruptive centres.*

5 cm

METAMORPHIC EFFECTS OF DOLERITE

Metamorphic effects on Parmeener Super-Group rocks range from a slight baking and hardening to complete melting or recrystallisation. Thin layers of melted rock a few millimetres thick adhere to dolerite contacts at EP090019 and rare quartzite occurs close to dolerite contacts in quartz sandstone (Ꞧp) terrain. More commonly, a marginal zone a few metres wide with sub-quartzite and partially recrystallised sandstone occurs beside steep contacts of major intrusions. Lithic and feldspathic sandstone are commonly metamorphosed to particularly hard rocks which weather with thick, soft, brown sandy rinds. A baked carbonate concretion from near the contact between lithic arkose (Ꞧg) and dolerite at EP216028 consists of white recrystallised calcite enclosing euhedral fine corundum crystals.

The most intense and extensive metamorphism occurs above major dolerite sheets where lutite has been metamorphosed to hornfels several metres thick. Metamorphosed rocks at EP145222 have silt and sand grade grains clustered in granule size aggregates separated by irregular joints. Some of these rocks contain uniformly distributed cavities where unstable minerals have been weathered out.

Some metamorphic rocks resemble granophyre in appearance. Thin sections show these rocks to consist mainly of quartz, feldspar and lithic grains, and unidentified weathered crystals which in hand specimens reach a length of twenty millimetres.

## Cainozoic basalts

*F.L. Sutherland*

The Tertiary basaltic rocks form eroded remnants scattered over much of the Oatlands Quadrangle. Most of the exposures are isolated plugs, necks, and flows. Flow successions are only developed to any extent in the Clyde Valley near Bothwell [EP005074] and the Exe Rivulet valley around Bow Hill [EP185180]. A complex of plugs and necks of breccia occupy a downthrown fault block [EP090050] between Apsley and Bothwell. Separate flow sheets are preserved around Melton Mowbray [EN147978] and Jericho [EP233074]. Volcanic breccias are associated with some of the flows north-east of Oatlands [EP303165]. Contrasting petrologies in exposures near Lake Dulverton suggest separate sources. A prominent plug forms Handsome Sugarloaf [EP397175], south-west of York Plains and a dyke-like feeder crops out south-west of Parattah. A flow from a plug lies on a fault junction west of Baden [EP383022] and small plugs extend along a fault at Wallaby Rivulet [EN262968].

The degree of dissection of the volcanic remnants suggests that much of the activity was similar in age to basalts dated nearby on the Central Plateau and in the Hobart area (between 21 and 36 million years; Sutherland, *et al.*, 1973; Sutherland, 1976; F.L. Sutherland and P. Wellman, BMR unpublished data). This is confirmed by radiometric dating of the volcanic centre near Oatlands, a plug near Jericho, and a flow remnant near Melton Mowbray. The main flow at the Barwicks Hill centre [EP280190] gave a K-Ar minimum age of 25.0± 0.3 m.y. (Bureau of Mineral Resources, unpublished data). A similar minimum age is given for the higher flow capping the pyroclastic rocks under Fernleigh Hill [EP266189] on the west side of the centre (24.3 m.y.; unpublished data). This suggests a late Oligocene or slightly earlier eruption for rocks of the alkaline association (fig. 18).

The plug at Rosehill Farm [EP196087] has a similar age (27.6 m.y.;

unpublished data) and suggests that the alkaline association was accompanied by, and possibly fractionated from, these more primitive basanites. The oldest eruptive rock identified in the Oatlands Quadrangle is a porphyritic alkali basalt capping Big White Hill [EP163023] (36.3 m.y.; unpublished data).

## CLYDE VALLEY

These basalt flows extend from Fordell Creek, north-east of Bothwell, and follow the River Clyde valley to the south of Bothwell. The flow in Fordell Creek [EP060112] is fine-grained alkali olivine basalt, and probably erupted from where there are small plugs of similar basalt at Shiners Hill [EP119113]. The basalt contains small phenocrysts of olivine and sporadic fragments of disaggregated lherzolite, largely as olivine and partially reacted Cr-spinel. There are rare resorbed feldspar phenocrysts and quartzose fragments showing reaction effects. The basalt of the flow tends to contain a reddish brown glassy mesotasis and a more pronounced sub-fluidal texture compared to the plugs.

Small occurrences of basalt [EP102170] near the head of Fordell Creek, 2.5 km ESE of Woods Quoin, are probably unrelated to the Shiners Hill plugs. The rock contains glomeroporphyritic olivine and clinopyroxene in a partly glassy feldspathoidal base, and may represent an olivine nephelinite.

The flow filling the Clyde Valley north of Bothwell to Dennistoun is a transitional olivine basalt with an abundant darkish glassy mesostasis, partly crystallised into elongate prisms of clinopyroxene. A higher flow forms the hill under the reservoir west of Bothwell township. This flow is characterised by glomeroporphyritic clinopyroxene and olivine, and may approach a basanite in composition, as some nepheline may be present in the feldspathic groundmass.

Tholeiitic lavas enter the flow succession south of Bothwell. These range from relatively finer grained intergranular olivine tholeiites, some with dark glassy mesostasis, into coarser olivine-poor subophitic to ophitic rocks. The more vesicular lavas commonly contain infillings of opal and carbonate.

The only source identified for these Clyde Valley basalts are the plugs at Shiners Hill, which only gave a limited contribution to the succession. It is possible that most of the lavas were not erupted locally, but spilled into the Clyde drainage by overtopping from the Ouse drainage near Cawood Hill to the west (Sutherland, 1980).

## EXE RIVULET

The main basaltic filling of the ancestral Exe Rivulet drainage forms Bow Hill. At least three different basalts extend from an altitude of 568 m down to a base below 460 m. The lower basalts are fine-grained with blocky to irregular jointing. Microscopically, the groundmass shows fluidal textures. One type contains patches of pale brown glass and amygdales of greenish opal-chalcedony, and is an alkali olivine basalt or basanite. The other type is more feldspathic, with largely 'iddingsitised' olivine and amygdales of silica and carbonate, and approaches an oxidised hawaiite. The rocks contain sporadic xenocrysts of disaggregated lherzolite and sparse xenoliths of dolerite, some showing partial fusion.

The sources for these lower flows are uncertain. The basalt with interstitial brown glass may be derived from a small plug intruding

Triassic sandstone three kilometres WNW of Bow Hill. This is a similar basalt, and contains xenoliths of lherzolite and some banded gabbro-granulite, dolerite, and recrystallised quartzose country rock. The other basalt may have descended from Wild Pig Tier [EP162223], where a small knoll of hawaiite crops out 4.3 km north-west of Bow Hill. This rock contains abundant rounded xenoliths of Triassic sediment with thick rims of bluish-green alteration, and scarce xenoliths of lherzolite, spinel pyroxenite, and clinopyroxenite.

The upper part of Bow Hill is capped by nepheline K hawaiite (analysis 3, Table 1). This flow is up to 30 m thick and three rock varieties have been distinguished, either representing separate flows or textural variations within one flow. The lowest is a fine-grained dark grey rock containing abundant xenoliths dominated by peridotite. Xenocrysts and megacrysts are locally so abundant that the rock becomes picritic in appearance. The lowest unit is followed by a coarser rock in which late crystallisation of sodic plagioclase, with nepheline and alkali feldspar, gives the rock a poikilitic texture. This rock contains more 'doleritic' xenoliths than the underlying basalt. The capping rock is rough, somewhat vesicular, but fine-grained with 'iddingsitised' olivine.

Similar nepheline hawaiites form further exposures around Bow Hill. The flow remnant 1.5 km to the south-east is an extension of the highly mafic inclusion-rich base. A further possible exposure of such rock one kilometre WSW of the Exe Rivulet-Jordan River confluence suggests that this flow may have reached the Jordan River. Other remnants 1.5 km NNW of Bow Hill at 600 m elevation and three kilometres north at 720 m elevation suggest that the Bow Hill nepheline hawaiite descended from the plateau region to the north. The ultimate source is not yet identified, but one possibility is the prominent dyke of mafic nepheline-bearing rock forming Old Mans Head, east of Lake Crescent (Interlaken Quadrangle).

The abundant inclusions in these nepheline hawaiites mostly include lherzolite up to 85 mm diameter, gabbro, dolerite, country sedimentary rocks, and clinopyroxene megacrysts up to 60 mm diameter. The suite is notable for yielding rare garnet lherzolite and garnet pyroxenite, which are seldom found in flows and are described in more detail later.

Two basalts are represented at Howells Hill [EP150163], 4 km WSW of Bow Hill. The lower basalt is lherzolite-bearing and towards the base becomes fragmental, rubbly and scoriaceous. Thin sections show considerable xenocrystal material, mainly olivine from disaggregated lherzolite and quartz from Triassic country rocks. The rock resembles the Bow Hill nepheline hawaiite and may represent a further extension which spilled into the drainage system to the west. The overlying basalt forms a six metre thick capping of massive, irregularly jointed basalt lacking the inclusions of the underlying rock. Thin sections show that the rock is an alkali olivine basalt or transitional hawaiite containing abundant glomerophenocrysts of olivine and clinopyroxene in an intergranular groundmass. The source of this basalt is unknown.

A small flow descends from Exe Sugarloaf [EP193149] southwards into Exe Rivulet. The flow's southern extension contains patches of coarse basalt containing an abundant mesostasis, similar to more extensive examples described from valley fills in the River Tamar (Sutherland, 1971). These rocks may represent crystallisation from hydrous fluids developed in the lava.

A volcanic breccia forms a small but prominent neck [EP160138]

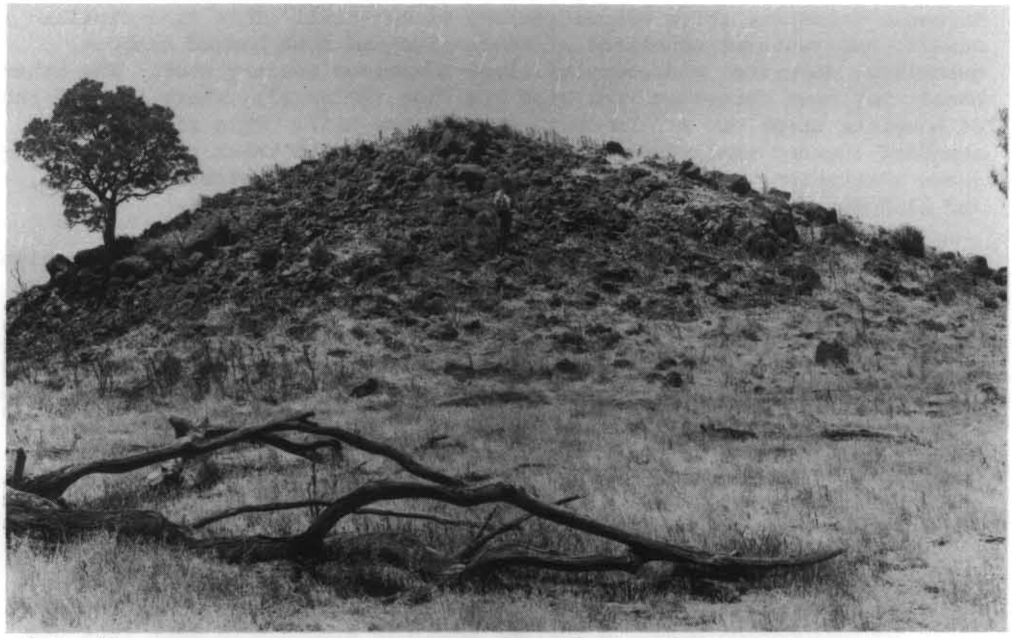


Plate 26. *Tertiary basalt neck near Exe Rivulet [EP160138].*

Plate 27. *Detail of part of Plate 26, showing clasts of basalt and Upper Parmeener Super-Group sandstone (light coloured) in basaltic agglomerate marginal to basalt neck.*

intruding Permo-Triassic beds, 3.3 km west of the confluence of Exe Rivulet and the Jordan River. The exposed part of the neck (Plate 26) is about 20 m in diameter, with a further tongue of breccia 20 m long extending from the south-eastern side (S.M. Forsyth, pers. comm.). The breccia (Plate 27) includes massive and vesicular basalt, thermally metamorphosed Upper Parmeener Super-Group sandstone and coarse siltstone, and dolerite. The clasts are mostly 40-100 mm diameter, but some siltstone blocks are up to 800 mm diameter. The larger siltstone clasts resemble siltstone from the structurally lower Cygnet Coal Measures Correlate. The breccia encloses zones of quite massive basalt. Basalt fragments within the breccia consist of fine-grained rock containing phenocrysts of olivine and clinopyroxene in a groundmass of nepheline and some alkali feldspar. This vent may be the source for a fragment of olivine nephelinite found in river gravel forming a high level terrace deposit beside the Exe Rivulet road to the east. Alternatively, the fragment may have been carried westwards from the olivine nephelinite of Sandhill Spur [EP220070] near Jericho. Remnant plugs, which include olivine nephelinite, also occur 5 km to the south-west of the gravel beds. These plugs could represent a further possible source for material in the gravel, but this is less likely as the transport would be in the opposite direction to the present drainage.

## APSLEY

The basalts in the Apsley area are associated with downthrown blocks and bounding faults located north of Apsley [EP120015]. The basalts form four separate groups. One group lies near the Lake Highway, 2.5 km NNW of Apsley, and includes at least three diatremes or breccia necks described as tuffisite by Butters (1970). The largest neck is exposed in an abandoned quarry [EP112036] and has intruded through massive Triassic sandstone. The tuffisite contains rounded to angular fragments of sandstone and siltstone to more than one metre diameter, mixed with fragments of vesicular basalt up to 200 mm diameter in a matrix of comminuted sediment and basalt. Basaltic plugs adjacent to the tuffisite necks and basalt in the tuffisite consist of a microporphyritic fluidal alkali olivine basalt.

Another group of at least twelve basaltic necks intrudes Triassic sandstone north of the Lake Highway [EP096052], about 4.5 km north-west of Apsley. The larger bodies form small conical hills. Butters (1970) investigated these basalts, which on geophysical evidence mostly represent plug-like forms. One plug [EP095054] has thermally metamorphosed adjacent Triassic sediments into buchite, which contracted forming columnar jointing in places (Spry and Solomon, 1964). Most of the basalt contains glomerophenocrysts of olivine and rosettes of clinopyroxene in a fine-grained groundmass. The rocks represent alkali olivine basalt or transitional hawaiite. Clinopyroxene phenocrysts in the coarse-grained plugs are up to 4 mm diameter in a medium-grained intergranular groundmass. In one of the westernmost plugs glomerophenocrysts of clinopyroxene and olivine lie in a groundmass containing small nepheline crystals and brownish glass. This probably represents a basanite or olivine nephelinite in composition. The plug associated with the buchite forms a distinctive rock. Clinopyroxene, olivine, and iron oxide rest in a poikilitic base of nepheline and zoned andesine-oligoclase, suggesting a nepheline hawaiite.

A further group of basalts form Green Hill [EP090074], about 7 km NNW of Apsley. The main ridge represents a flow remnant. Basalt talus occurs to the south-east for 1.5 km, suggesting that the flow originally extended down in that direction. Samples from the south end of Green Hill are nepheline hawaiite with 'iddingsitised' microphenocrysts of olivine and a fine-grained poikilitic groundmass with nepheline, zoned sodic plagioclase, and zeolites. Rock from the north end is similar, but olivine is not 'iddingsitised'. The groundmass shows ovoid fillings containing elongate and in some cases curved laths of sodic plagioclase intergrown with reticulate crystallites of iron oxides and grains of zeolite.

The source of the Green Hill flow is not completely certain, but it probably derived from a basaltic peak located on the fault line about one kilometre to the south-west [EP088068]. The rock at this peak is a coarser, more porphyritic variety. Conspicuous glomerophenocrysts and rosettes of clinopyroxene and olivine in some cases enclose feldspathic patches studded with squarish grains of iron oxide. Poikilitic nepheline and sodic plagioclase form crystals up to one millimetre diameter.

A small outcrop to the north [EP088070] is of a different rock. Microphenocrysts of olivine occur in a groundmass containing abundant small but prominent crystals of nepheline. This outcrop probably represents a small plug of olivine nephelinite.

The last group of Apsley basalts are small occurrences lying along a fault following the course of the Jordan River. Basalt 2.7 km north of Apsley is alkali olivine, with glomerophenocrysts of clinopyroxene, olivine and labradorite in a fluidal intergranular groundmass. Basalt 3.3 km north of Apsley is olivine nephelinite with 'iddingsitised' olivine and a nepheline-rich groundmass. Basalt 3.8 km north of Apsley is hawaiite, with olivine microphenocrysts in a fine-grained fluidal groundmass containing sodic plagioclase. It is not clear whether these occurrences represent small plugs or flow remnants that descended into the Jordan Valley from the lavas lying to the east and west.

## MELTON MOWBRAY

Basalt flows fill old drainage courses south-west and north of Melton Mowbray. The basalt two to three kilometres to the south-west forms a narrow, elongate fill over 60 m thick, in a valley cut mainly in dolerite. This may preserve an early course of the Jordan River which is now deflected to the east around this area. The rock contains sporadic xenocrysts and glomerophenocrysts of olivine and clinopyroxene in a fine-grained subfluidal base with zoned labradorite-andesine, partly poikilitic nepheline, and granular iron oxide. Rare coarse seggregations consist of prismatic clinopyroxene, nepheline, sodic plagioclase, and zeolite. The rock is a basanite and may have erupted from near the highest exposure on Curzon Hill.

The basalt four to six kilometres north of Melton Mowbray is preserved as two separate residuals, with inverted topography, forming Big White Hill and Little White Hill. The basalt is highest at Big White Hill, descending from over 560 m elevation to 420 m north of Little White Hill. The basalt probably flowed down an old tributary of the Jordan River. Some basalt spilled south of Big White Hill down to 370 m elevation and a little may have spilled eastward over a divide to where small basalt outcrops occur between 380-420 m elevation. Cooling columns are developed around Big White Hill and on the east side change in orientation from subvertical to near horizontal. This may suggest a feeder in this area. The basalt is commonly characterised by rosettes of clinopyroxene, readily visible in hand specimens. Thin sections show different percentages of olivine, clinopyroxene, and plagioclase phenocrysts in a fluidal feldspathic groundmass (Butters, 1970).

## JERICHO

The main basalts in this area cap Spring Hill [EP208049] and Sandhill Spur, south-west of Jericho. The smaller Spring Hill basalt descends south-west from over 560 m elevation to 500 m. The Sandhill Spur basalt descends north from 560 m elevation at The Peak [EP205059] towards the Jordan River, which has cut down below the basalt base to 360 m. The base is obscured by talus, but lies between 400-460 m elevation.

These rocks are olivine nephelinites. The Spring Hill rock is a mafic type with xenocrysts derived from lherzolite xenoliths, and probably erupted from small plug-like bodies exposed below the eastern side. The Sandhill Spur rock contains microphenocrysts of olivine and rare clinopyroxene in a groundmass in which squarish crystals of nepheline develop poikilitic texture in the coarsest rocks. In some sections olivine is 'iddingsitised' by a deuteric alteration. The source for the flow is uncertain, but it may have erupted from near The Peak. The relatively undissected form suggests that the flow might be one of the youngest in the Oatlands area.

A small remnant of massive basalt [EP255065] lies 1.5 km east of Jericho, and contains rare small lherzolitic xenoliths and xenocrysts. In thin section, microphenocrysts of olivine and clinopyroxene lie in a very fine-grained groundmass with small laths of zoned plagioclase and nepheline. The rock is an alkali basalt or basanite which erupted into a tributary of the Jordan, but the source is unknown.

A basalt plug [EP196087] crops out four kilometres WNW of Rosehill Farm. The plug is an alkali basalt approaching a basanite in composition (analysis 6, Table 1). Xenoliths include lherzolite and rare pyroxenites of unusual composition; these are discussed later. In thin section, the basalt shows a fine-grained fluidal texture. This plug may be the source for a similar basalt two kilometres to the west, which fills an old valley of Rose Hill Creek to a thickness of 80 m.

## OATLANDS

The main basalt exposure crops out on Barwicks Hill, 3.5 km north-west of Oatlands, and is over 40 m thick. The basalt shows slabby inclined jointing where it is exposed in the creek bed [EP279188] draining into Dulverton Rivulet. Volcanic breccia underlies the flow south-west of Barwicks Hill at 460 m elevation [EP276188]. This small exposure contains fragments of Jurassic dolerite up to 1.3 m diameter and baked Triassic shale up to 0.8 m diameter. One large piece of shale had developed radial prismatic jointing around its margin. The breccia also contains pieces of scoriaceous to dense basalt up to 0.6 m diameter and partly intermingles with the overlying basalt.

The Barwicks Hill basalt is nepheline K hawaiite (analysis 5, Table 1) and contains sporadic to common xenoliths of lherzolite up to 60 mm diameter. In thin section, xenocrysts of disaggregated lherzolite and phenocrysts of olivine and some clinopyroxene lie in a fine-grained to more coarsely poikilitic groundmass in which sodic plagioclase laths are up to 5 mm in length.

A basalt succession occurs one kilometre west of Barwicks Hill at Fernleigh Hill. The lowest unit forms a small sleeve of lherzolite-bearing basalt around 460 m elevation. This is probably an extension of the Barwicks Hill nepheline hawaiite. About six metres of dolerite-bearing breccia is exposed above this in an old landslip. The breccia contains fragments of wood, and is capped by at least 20 m of fine-grained, uniform, partly platy basalt forming the top of Fernleigh Hill. In thin section, this rock is an hawaiite or transitional mugearite, with microphenocrysts of olivine in a subfluidal feldspathic groundmass. The breccia probably marks the vent position and lies on the extension of a NNE-SSW linear that bounds a dolerite scarp in this area.

Kimberlite was recorded from this area (Stracke *et al.*, 1979), but may be related to the breccia intrusions. It may not represent a true kimberlite, as garnets with kimberlitic compositions are found in xenoliths in the Bow Hill nepheline hawaiite flow to the west.

Nepheline hawaiite, similar to the Barwicks Hill rock, with lherzolite xenoliths, also occurs at Espies Hills and Rockton Sugarloaf, 5.5 km WNW and 7.5 km north-west of Oatlands respectively. At Espies Hills, the basalt is massive, dense to vesicular, and lies within Jurassic dolerite. The basalt descends over 60 m on the north-west side, either forming a steep small valley fill or a plug-like feeder. Here the rock is fine-grained and contains conspicuous inclusions of the country dolerite and Triassic shale up to several centimetres diameter. The top of the hill, in contrast, consists of coarse poikilitic rock with pegmatoidal patches. These contain aggregates of partly curved laths of zoned sodic plagioclase up to 5 mm long, which are intergrown with bladed to tabular and partly graphic to finely arborescent titan-clinopyroxene. The Espies Hills rocks around 520 m in elevation are considerably higher than the Barwicks Hill basalt and probably represent a separate eruption. Rockton Sugarloaf lies over 560 m in elevation and represents an eruption on the edge of the central plateau.

## LAKE DULVERTON

Three outcrops of massive dense basalt lie between one and two kilometres south-east of Lake Dulverton. Each shows a different petrology, suggesting separate sources in this area. The largest (southern) outcrop is mostly mafic rock containing sporadic to common xenoliths of lherzolite up to 80 mm diameter. In thin section, xenocrystal debris from the lherzolites are scattered through the groundmass, which ranges from glassy and zeolitic to coarser with poikilitic nepheline.

Rock on the south side is less mafic, with only sporadic xenocrysts. Olivine phenocrysts lie in a fine-grained groundmass rich in grains of nepheline. This may represent a younger flow. Rock on the north-west side contains irregular veins and patches of coarse nephelinite suggesting the possibility of an underlying feeder. The nephelinite contains intergrowths of nepheline and prismatic titaniferous clinopyroxene up to 2 mm diameter, skeletal iron oxide, apatite, rare olivine, and an abundant mesostasis with laths and crystallites of zoned alkali feldspar, grains of sodic clinopyroxene, and zeolites.

The central outcrop lacks lherzolite xenoliths. It contains microphenocrysts of olivine in a fluidal groundmass of andesine-oligoclase and resembles a mugearitic hawaiite.

The northernmost outcrop is rich in lherzolite xenoliths and xenocrystal fragments. The fine-grained groundmass contains microporphyritic olivine and sporadic clinopyroxene. The rock represents an alkali olivine basalt or transitional hawaiite. Staining of thin sections suggests a K-rich type. Similar rock crops out four kilometres east of Lake Dulverton at a similar elevation and may be related in origin. The ultramafic xenoliths here include pyroxenite, and are detailed later.

## YORK PLAINS

Basalt caps Vincents Hill [EP344223], three kilometres north-west of York Plains, to a thickness of over 80 m. The rock is massive, contains numerous ultramafic xenoliths up to 80 mm diameter and rare Triassic sediment and Jurassic dolerite. The basalt appears to have erupted from the highest north end and flowed south to where St Peters Dome [EP352216] forms an isolated extension. Chemically the rock is basanite (analysis 1, Table 1). Thin sections show a fine-grained felted groundmass containing zoned oligoclase, alkali feldspar, nepheline, and zeolites. The rock is transitional to nepheline hawaiite. The ultramafic xenoliths are dominated by spinel lherzolite, but with sporadic spinel pyroxenites (detailed later).

Coal Mine Hill [EP355185], 1.5 km south-west of York Plains, is also basalt capped. The basalt was fed by plugs intruding a fault on the north side and the flow descends southwards. The rock contains common xenoliths of lherzolite and was studied by Piestrzeniewicz (1972). Chemically, the rock is K-rich hawaiite (analysis 9, Table 1), with a feldspathic groundmass rich in andesine-oligoclase. Flakes of biotite indicate the potassic nature of the rock.

Handsome Sugarloaf [EP397174] forms an isolated plug of K alkali olivine basalt (analysis 7, Table 1) four kilometres south-east of York Plains. The rocks contain fragments of Triassic sedimentary rocks and sparse xenoliths of lherzolite. Thin sections show a fine-grained groundmass with subfluidal labradorite and some late-stage patches of coarser alkali feldspar.

A small occurrence of basaltic agglomerate lies 1.8 km north of Handsome Sugarloaf.

## PARATTAH

A dyke-like body intrudes Triassic sedimentary rocks on Mongos Spur [EP315096], 2.1 km south-west of Parattah and basalt descends to the west as a narrow flow. The rock contains numerous lherzolite and some pyroxenite xenoliths up to 80 mm diameter, Triassic sedimentary rocks up to 150 mm diameter, and pyroxene xenocrysts. The lherzolite xenoliths were studied by Varne (1977). The rock is a nepheline K hawaiite (analysis 4, Table 1). It is mostly fine-grained, but contains some coarser trachytic patches dominated by laths of alkali feldspar, sodic plagioclase, and grains of clinopyroxene. The lower flow basalt is partly glassy with amygdales of radiating zeolites.

## LEMON HILL

Several narrow (<one metre), discontinuous basalt dykes were exposed in a road cutting on the realigned Midland Highway [EP276115] during 1981. The dykes are variably amygdaloidal.

The rock is a glomeroporphyritic basalt containing phenocrysts of altered olivine and some titaniferous clinopyroxene groups. The groundmass is dominated by large zoned sodic plagioclase containing titaniferous clinopyroxene and opaque iron oxides. Amphibole is developed in some of the late-stage mesostasis.

The rock is an hawaiite, and is less undersaturated than the basalt

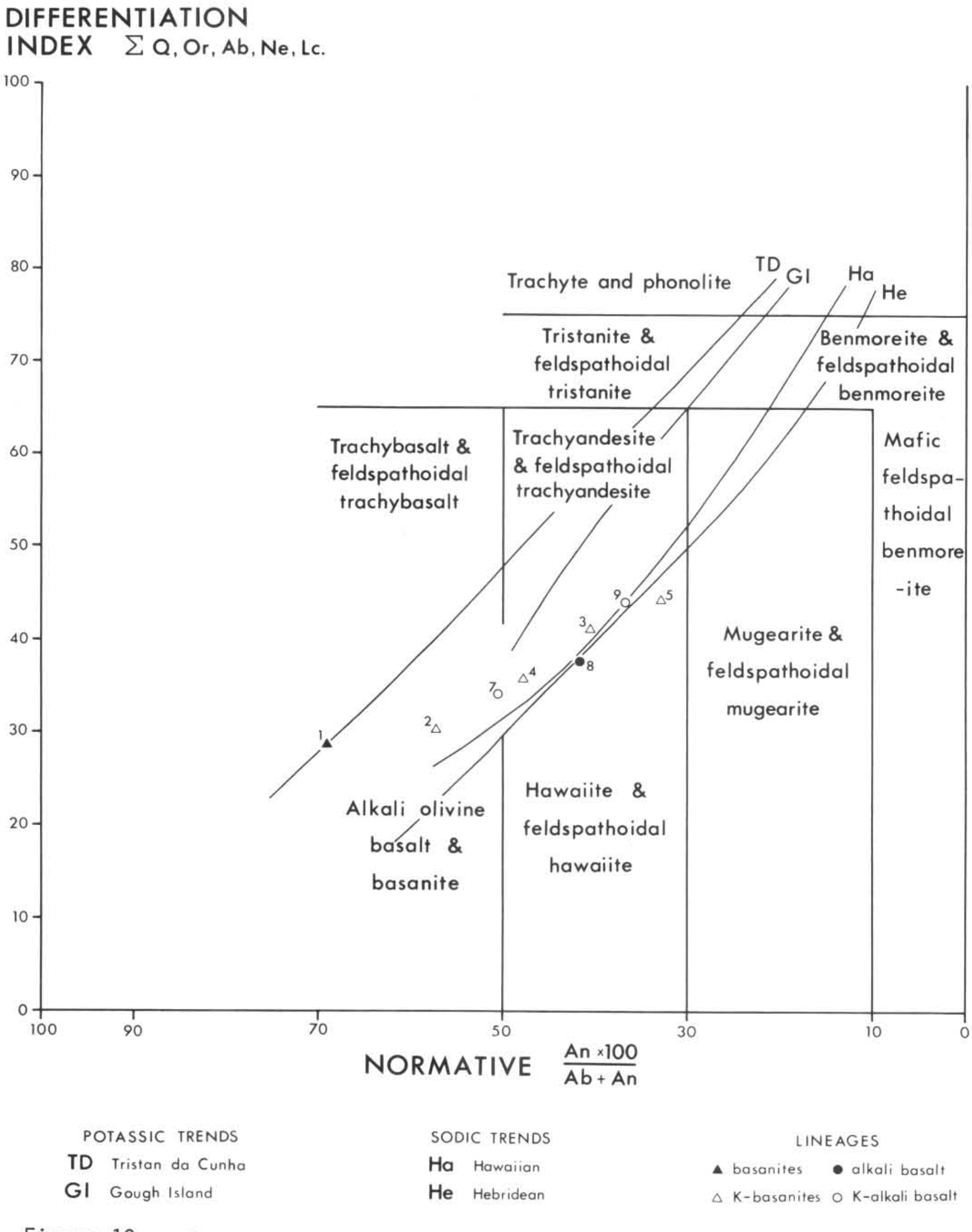



Figure 19. *Plots of Oatlands volcanic rocks on a Differentiation Index - Normative An diagram, based on analyses numbered in Tables 1 and 2.*

5 cm

at Mongos Spur four kilometres to the east. The dykes may be Tertiary in age and a later phase of the Mongos Spur eruption, in the same way that hawaiite follows nepheline hawaiite at Barwicks Hill.

## BADEN

Basalt lies at a fault junction [EP360020], two kilometres west of Baden. The rock is massive and amygdaloidal in places and contains common xenoliths of lherzolite up to 100 mm diameter. Chemically, the rock is a K-rich basanite (analysis 2, Table 1). Thin sections are glomeroporphyritic with phenocrysts of olivine and clinopyroxene, the latter showing spongy cores and inclusions of iron oxide and feldspar. The groundmass contains laths of labradorite and some interstitial alkali feldspar, nepheline, and zeolites.

## WALLABY RIVULET

Four separate small plugs lie along a north-south trending fault west of Wallaby Rivulet. The south-easternmost plug comprises minor agglomerate and vesicular basalt and contains small inclusions of lherzolite, sandstone, and quartz [EN262968]. Its companion plug is very small, less than three metres diameter, and consists of vesicular basalt with abundant small xenoliths of lherzolite, sandstone, and dolerite. Thin sections of these rocks contain microphenocrysts of olivine and clinopyroxene in a very fine-grained, partly glassy and feldspathoidal groundmass. The rock is probably basanite or olivine nephelinite.

The northern two plugs are petrologically similar. They are glomeroporphyritic basalt with phenocrysts of olivine, clinopyroxene, and zoned labradorite-andesine, and represent alkali olivine basalt or transitional hawaiite.

## PETROLOGY OF THE BASALTS

The distribution of the main petrologic types is shown in Figure 18. The rocks mostly include members of the basanite and alkali basalt lineages (Coombs and Wilkinson, 1969; Table 1, figure 19), with lesser occurrences of olivine nephelinite, transitional olivine basalt, and tholeiitic basalt. The rocks include K-rich types (figs. 19, 20) and show moderate evolution (Table 2). However they are relatively mafic types with low differentiation indices, as they plot with the sodic Hebridean and Hawaiian trends rather than with the potassic Gough Island and Tristan da Cunah trends.

Primary or near-primary magma types (Mg numbers 67-68; Green *et al.*, 1974) are represented by basalts approaching basanite in composition (Vincents Hill and Rosehill Farm; Table 2). These two rocks contain the highest Ni abundances (353-430 ppm; Table 3, fig. 21). These values are comparable with those of south-east Australian basalts identified as primary partial melts of peridotite (Frey *et al.*, 1978). The most evolved rocks are represented by the K-rich series of basanite-nepheline hawaiite and basalt-hawaiite (Mg numbers 53-62; Table 2). All these rocks show reduced compatible trace elements (<212 ppm Ni, <256 ppm Cr). Incompatible and semi-incompatible elements show little systematic variation with Mg number (figs. 20, 22, 23). As many of these rocks contain ultramafic xenoliths of mantle origin, this would suggest that their magmas were derived from melting of an inhomogeneous mantle (Kesson, 1973).

The basalts in the Oatlands Quadrangle can be grouped into three petrological associations, similar to the basalts of the Hobart Quadrangle

*Table 1. MAJOR ELEMENT ANALYSES AND CIPW NORMS, OATLANDS BASALTS*

| Analysis | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 42.02 | 43.59 | 43.49 | 44.33 | 44.77 | 43.7 | 44.36 | 44.73 | 46.85 |
| $TiO_2$ | 2.82 | 2.86 | 2.40 | 2.83 | 2.36 | 2.7 | 2.67 | 2.44 | 2.23 |
| $Al_2O_3$ | 10.55 | 12.35 | 12.38 | 12.03 | 13.07 | 13.2 | 13.72 | 13.21 | 14.13 |
| $Fe_2O_3$ | 4.32 | 3.03 | 4.38 | 4.35 | 3.49 | 2.5 | 3.49 | 2.13 | 3.21 |
| FeO | 8.39 | 10.22 | 8.25 | 7.54 | 10.17 | 10.8 | 9.23 | 10.33 | 9.42 |
| MnO | 0.22 | 0.20 | 0.18 | 0.21 | 0.21 | 0.17 | 0.19 | 0.18 | 0.13 |
| MgO | 12.95 | 10.03 | 8.90 | 8.25 | 7.22 | 12.5 | 7.91 | 9.47 | 8.57 |
| CaO | 10.37 | 9.67 | 8.16 | 10.35 | 7.56 | 7.9 | 9.05 | 7.85 | 7.03 |
| $Na_2O$ | 4.22 | 3.22 | 4.34 | 3.90 | 4.63 | 3.1 | 2.96 | 3.80 | 4.32 |
| $K_2O$ | 1.32 | 1.66 | 2.55 | 2.04 | 2.41 | 1.4 | 1.88 | 1.78 | 2.60 |
| $P_2O_5$ | 1.25 | 0.88 | 1.38 | 1.10 | 1.28 | 0.73 | 0.95 | 1.20 | 0.96 |
| Loss | 1.96 | 2.05 | 2.36 | 2.81 | 2.06 | 0.93 | 3.12 | 2.64 | 1.19 |
| Total | 100.39 | 99.76 | 99.75 | 99.74 | 99.23 | 99.63 | 99.53 | 99.58 | 100.64 |
| *CIPW Norm* | | | | | | | | | |
| Or | 7.92 | 10.10 | 15.77 | 12.53 | 14.71 | N.D. | 11.52 | 10.87 | 15.36 |
| Ab | 2.73 | 11.05 | 10.39 | 10.65 | 16.48 | N.D. | 19.08 | 20.03 | 19.81 |
| Ne | 18.22 | 9.18 | 15.18 | 12.79 | 13.06 | N.D. | 3.73 | 7.11 | 9.07 |
| An | 6.05 | 14.72 | 7.05 | 9.67 | 8.03 | N.D. | 19.32 | 14.14 | 11.49 |
| Di | 30.69 | 23.35 | 21.08 | 29.46 | 18.19 | N.D. | 16.90 | 15.48 | 13.88 |
| Ol | 23.49 | 21.42 | 20.10 | 14.46 | 19.23 | N.D. | 17.50 | 20.85 | 18.73 |
| Mt | 2.39 | 2.49 | 2.35 | 2.20 | 2.57 | N.D. | 4.39 | 4.32 | 4.65 |
| Il | 5.47 | 5.58 | 4.77 | 5.58 | 4.63 | N.D. | 5.26 | 4.79 | 4.23 |
| Ap | 2.94 | 2.09 | 3.34 | 2.66 | 3.08 | N.D. | 2.29 | 2.43 | 2.27 |

1. Transitional basanite, Vincents Hill, 3.5 km NNW of York Plains [EP345225].
2. K-basanite, north bank of Coal River 2.3 km west of Baden [EP360020].
3. Nepheline K-hawaiite, 540 m altitude, Bow Hill [EP188180].
4. Nepheline K-hawaiite, Mongos Spur, 2.1 km south-west of Parattah [EP315098].
5. Nepheline K-hawaiite, Barwicks Hill, west bank of creek 3.5 km north-west of Oatlands [EP277192].
6. Alkali olivine basalt from plug, 400 m level, south of Rosehill Farm, 4 km WNW of Jericho [EP196087].
7. K-alkali olivine basalt, Handsome Sugarloaf, 4 km ESE of York Plains [EP396175].
8. Transitional hawaiite, Exe Sugarloaf, 9 km north-west of Jericho [EP183150].
9. K-hawaiite, Coal Mine Hill, York Plains (Piestrzeniewicz, 1972).

Analyses 1-5, 7-8 by P. Beasley and E. Kiss, Australian National University.
Analysis 6 by J. Furst, Tasmania Department of Mines.
Analysis 9 by R. Piestrzeniewicz (from Piestrzeniewicz, 1972).

N.D. = not determined. Anhydrous mass percent norms at $Fe_2O_3/FeO = 0.15$

*Table 2. OXIDE AND NORMATIVE RATIOS, DIFFERENTIATION INDICES AND MAGNESIUM NUMBERS*

| Analysis | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| $Na_2O/K_2O$ | 3.20 | 1.94 | 1.70 | 1.91 | 1.92 | 2.21 | 1.57 | 2.13 | 1.66 |
| $\frac{100\ An}{An+Ab}$ | 68.9 | 57.1 | 40.4 | 47.6 | 32.8 | N.D. | 50.3 | 41.4 | 36.7 |
| $\frac{100\ Fo}{Fo+Fa}$ | 74.8 | 69.0 | 67.5 | 68.4 | 59.6 | N.D. | 69.4 | 72.7 | 61.4 |
| DI | 28.9 | 30.3 | 41.3 | 36.0 | 44.3 | N.D. | 34.3 | 38.0 | 44.2 |
| $\frac{100\ Mg}{Mg+Fe^{2+}}$ | 68.1 | 61.6 | 60.6 | 60.1 | 53.0 | 67.3 | 59.1 | 63.6 | 61.4 |

*Table 3. MINOR AND TRACE ELEMENTS, OATLANDS BASALTS*

| Analysis | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| *Item (ppm)* | | | | | | | | |
| Zn | 130 | 128 | 181 | 168 | 172 | 310 | 135 | 150 |
| Cu | 44 | 54 | 38 | 46 | 31 | 97 | 52 | 43 |
| Ni | 353 | 175 | 197 | 212 | 156 | 430 | 187 | 254 |
| Mn | 1375 | 1052 | 1137 | 1363 | 1237 | N.D. | 1219 | 1108 |
| Cr | 501 | 228 | 236 | 256 | 184 | N.D. | 181 | 290 |
| V | 162 | 148 | 94 | 149 | 72 | N.D. | 112 | 97 |
| Ti | 14878 | 13521 | 13013 | 16003 | 12438 | N.D. | 14307 | 13192 |
| Ba | 420 | 255 | 668 | 373 | 568 | 470 | 384 | 453 |
| Y | 42 | 30 | 42 | 35 | 42 | 38 | 44 | 37 |
| Sr | 1095 | 816 | 1485 | 1211 | 1275 | 791 | 941 | 1079 |
| Zr | 504 | 246 | 575 | 426 | 542 | 364 | 392 | 358 |
| U | 4 | 0 | 2 | 3 | 3 | N.D. | 2 | 0 |
| Rb | 30 | 36 | 56 | 41 | 53 | 28 | 43 | 46 |
| Th | 7 | 8 | 14 | 11 | 7 | N.D. | 6 | 10 |
| Pb | 7 | 10 | 11 | 9 | 6 | N.D. | 6 | 5 |
| Ga | 18 | 23 | 28 | 26 | 25 | N.D. | 21 | 23 |
| Zr/Y | 12.0 | 8.2 | 13.7 | 12.2 | 12.9 | 9.6 | 8.9 | 9.7 |

1. Basanite, Vincents Hill
2. K-basanite, Baden
3. Nepheline K-hawaiite, Bow Hill
4. Nepheline K-hawaiite, Mongos Spur
5. Nepheline K-hawaiite, Barwicks Hill
6. Alkali olivine basalt, Rosehill Farm
7. K-alkali olivine basalt, Handsome Sugarloaf
8. Hawaiite, Exe Sugarloaf
9. K-hawaiite, Coal Mine Hill

N.D. = not determined

Analyses 1-5, 7-8 by F.L. Sutherland, analysis 6 by J. Furst.

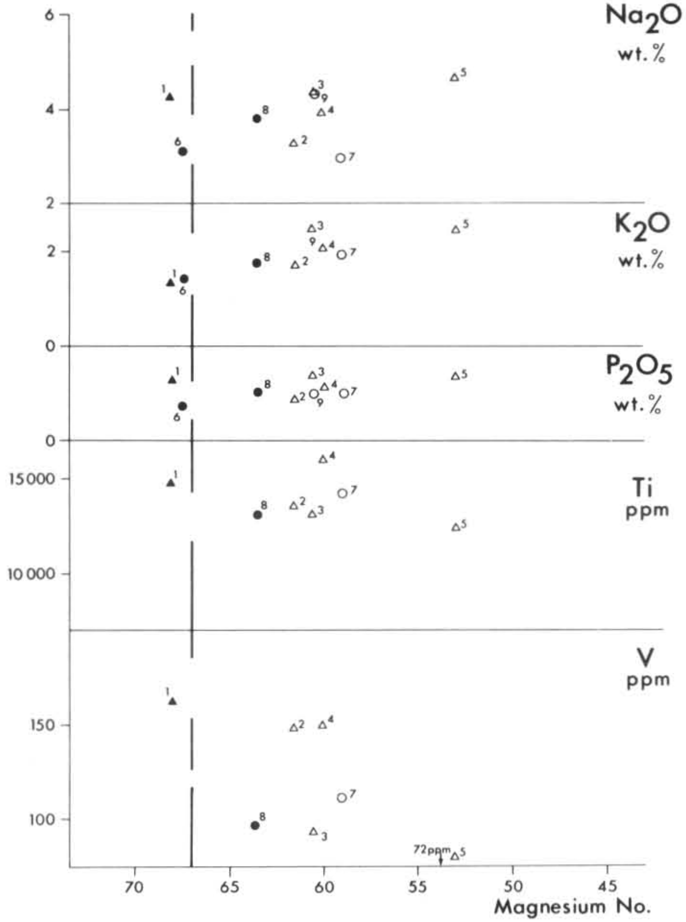



Figure 20. *Minor and trace element plotted values for Oatlands volcanic rocks, against magnesium number, based on numbered analyses in Tables 1-3.*

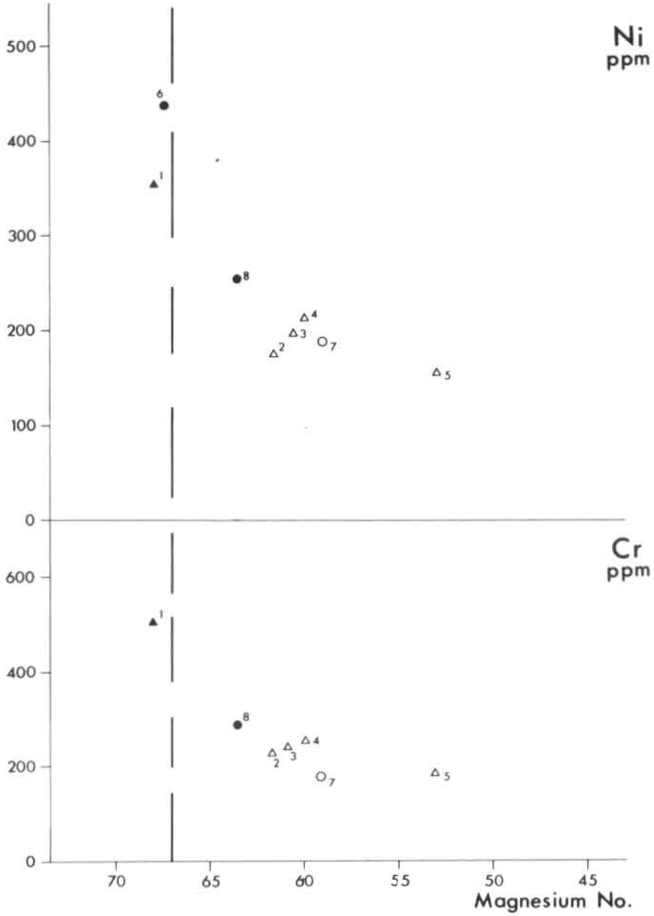



Figure 21. *Compatible trace element (Ni, Cr) plotted values for Oatlands volcanic rocks, against magnesium number, based on numbered analyses in Tables 2 and 3.*

5 cm

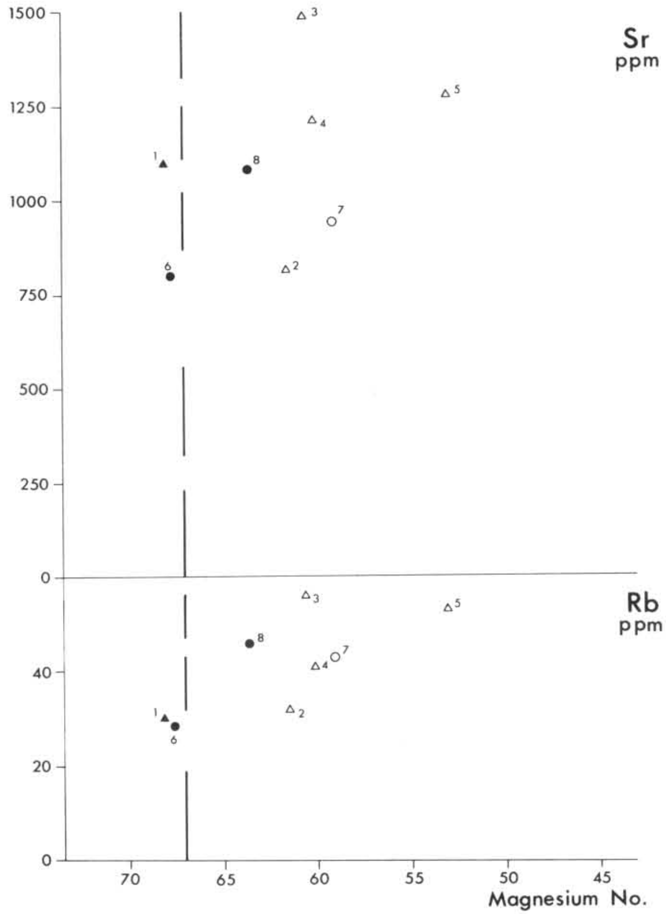



Figure 22. *Sr and Rb trace element plotted values for Oatlands volcanic rocks, against magnesium number, based on numbered analyses in Tables 2 and 3.*

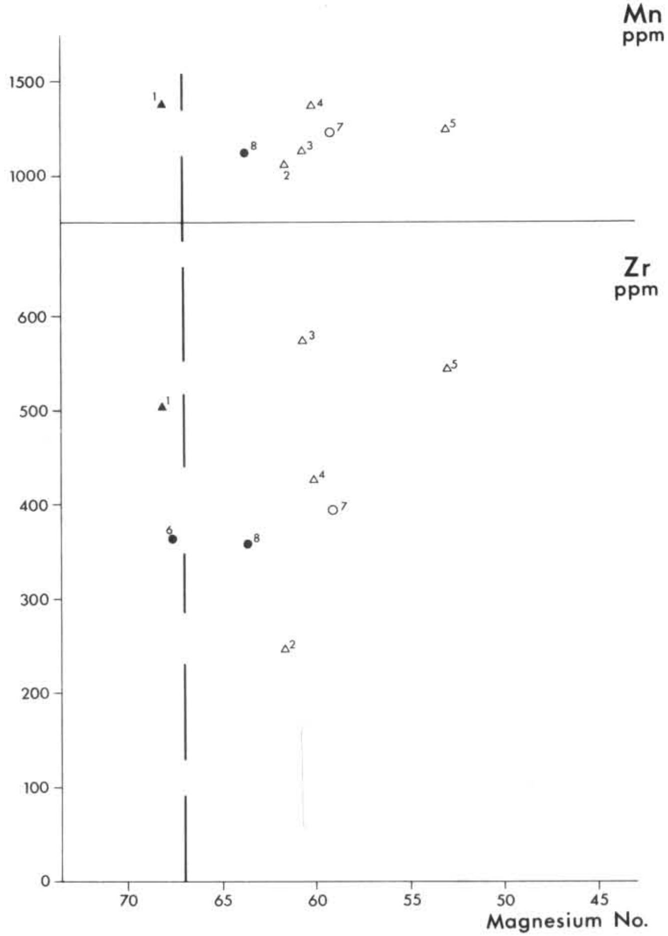



Figure 23. *Mn and Zr trace element plotted values for Oatlands volcanic rocks, against magnesium number, based on numbered analyses in Tables 2 and 3.*

(Sutherland, 1976). These are the alkali basalt, alkaline, and tholeiitic associations (fig. 19). The tholeiitic association is confined to the Clyde Valley in the vicinity of Bothwell. The alkaline association mainly occupies the northern region, but extends south towards Apsley and Parattah. The largest area is occupied by the alkali basalt association which extends southwards into the adjoining Brighton Quadrangle (Sutherland, 1977).

The tholeiitic association probably represents mantle regions which have undergone greater degrees of partial melting of peridotite. This would probably be of the order of 20-25% melting based on the studies of Frey *et al.* (1978) on south-east Australian basalts. The alkali basalt and alkaline associations would represent regions with lesser degrees of melting. For the alkali basalts and olivine nephelinites, comparison with the results of Frey *et al.* (1978) suggests melting in the range of 4-11%. Many of the alkaline rocks show high K and P and probably represent melting in the lower part of this range.

The origin of the alkaline association is uncertain. Two possibilities arise for the mantle xenolith-bearing rocks. They may represent melt produced from mantle peridotite and fractioned before eruption (Green *et al.*, 1974). The presence of clinopyroxene megacrysts in the Bow Hill nepheline hawaiite may be an indication of high pressure fractionation, if the megacrysts are cognate with the magma. Alternatively they may represent melt produced from depleted mantle peridotite (Wilkinson and Binns, 1977). No Fe-rich lherzolite has yet been identified in the xenolith suites from the Oatlands basalts.

The relative age of eruption of the alkaline association to the other associations is only partly established. At Bow Hill, nepheline hawaiite overlies alkali olivine basalt and at Howells Hill similar lava is overlain by glomeroporphyritic alkali olivine basalt. Thus alkali basalts have both preceded and succeeded alkaline lava. Hawaiite at Fernleigh Hill, lacking mantle xenoliths, appears to succeed lherzolite-bearing nepheline hawaiite, which suggests some higher level crustal fractionation for the hawaiites. Crustal fractionation was probably also involved in producing some of the alkali basalts and olivine nephelinites which lack mantle xenoliths. Some of these rocks contain glomerophenocrysts of olivine, clinopyroxene and, in some cases, plagioclase, typical of crystallisation in crustal magma chambers.

The alkali basalts, basanites, and K nepheline hawaiites of the analysed rocks all show relatively high Zr/Y indicator ratios (Table 3). This is typical of basalts derived by partial melting in equilibrium with garnet and suggests that these undersaturated lavas probably originated within the garnet lherzolite mantle (Frey *et al.*, 1978).

## INCLUSIONS IN THE BASALTS

Apart from fragments of Permo-Triassic sedimentary rocks and Jurassic dolerite country rock, many of the Oatlands basalts contain xenocrysts, megacrysts, and xenoliths of high pressure origin from the upper mantle and lower crust.

Amongst the inclusions are metaperidotite, garnet metaperidotite, metapyroxenite, garnet metapyroxenite, peridotite, pyroxenite, granulitic gabbro, and clinopyroxene and spinel megacrysts. The most widespread are fragments of mantle metaperidotite which have been recorded from about thirty localities. A detailed count of inclusions was made in the nepheline hawaiite at Bow Hill (J.D. Hollis, unpublished data). The basal part of this basalt gave a count of 60% metaperidotite, 5% metapyroxenite, 11% clinopyroxene megacryst, 19% sedimentary rocks, and 5% other inclusions. Rare garnet peridotite and garnet pyroxenite together make up much less than 0.5% of the inclusions. Garnet peridotites are extremely rare inclusions in basaltic flows compared to their more common occurrence in kimberlite (Carswell, 1980).

Mineralogical data is available from studies on a number of inclusions and provides information on the composition of phases in the mantle and lower crust under the Oatlands district.

The metaperidotites are mostly lherzolites and were studied in detail from Parattah (Varne, 1977) and Bow Hill. They consist predominantly of olivine ($Mg_{88}$), Al enstatite ($Mg_{87}Fe_{10}Ca_3$, up to 5.4% $Al_2O_3$), Al diopside ($Mg_{48}Ca_{47}Fe_5$, up to 7.5% $Al_2O_3$), and Cr pleonaste (up to 9.8% $Cr_2O_3$). The garnet lherzolites show olivine ($Mg_{90}$), Al enstatite ($Mg_{89}Fe_9Ca_2$, 5.5% $Al_2O_3$), Al endiopside ($Mg_{54}Ca_{40}Fe_6$, 6.6% $Al_2O_3$) and pyrope ($Mg_{74}Ca_{12}Fe_{14}$).

The metapyroxenite and pyroxenite are mostly websterites and were studied in detail from the Bow Hill nepheline hawaiite, the Andover alkali basalt [EP363142], Vincents Hill basanite, and Rosehill Farm alkali basalt.

Four types of websterite were recognised:

(1) Magnesian websterite and spinel websterite (Bow Hill, Vincents Hill), containing Al diopside ($Mg_{43-45}Ca_{47-51}Fe_{6-9}$, 8.1-9.5% $Al_2O_3$), Al bronzite ($Mg_{82-85}Fe_{14-18}Ca_{1-2}$, 5.6-6.7% $Al_2O_3$), and pleonaste ($Mg_{64-74}Fe_{26-35}Ca_{0-1}$).

(2) Garnet websterite (Bow Hill), containing Al endiopside ($Mg_{52}Ca_{38}Fe_9$, 7.4% $Al_2O_3$), Al bronzite ($Mg_{83}Fe_{14}Ca_3$, 5.3-6.2% $Al_2O_3$), and pyrope garnet ($Mg_{70-79}Fe_{17-19}Ca_{2-12}$).

(3) Less magnesian websterite (Bow Hill, Andover) containing Al augite ($Mg_{46-50}Ca_{34-42}Fe_{12-15}$, 5.9-9.7% $Al_2O_3$), Al bronzite ($Mg_{76-79}Fe_{18-20}Ca_{3-4}$, 4.5-5.9% $Al_2O_3$) and magnetite.

(4) Subcalcic websterite (Rosehill Farm), containing bronzite ($Mg_{78}Fe_{18}Ca_4$) and subcalcic augite ($Mg_{60}Ca_{24}Fe_{16}$). This is a most unusual assemblage amongst xenolith suites in eastern Australia (Wass and Irving, 1976).

A granulitic microgabbro was studied from the plug three kilometres WNW of Bow Hill. This rock contains salite ($Mg_{40}Ca_{47}Fe_{13}$), hypersthene ($Mg_{63}Fe_{36}Ca_1$), and labradorite ($Na_{33}Ca_{65}K_2$).

Clinopyroxene megacrysts at Bow Hill consist of Al diopside ($Mg_{46}Ca_{44}Fe_{10}$, 8.4% $Al_2O_3$), and with the spinel ($Mg_{65}Fe_{35}$) may represent high pressure crystallisation from basaltic magma. A small fragment of spinel peridotite contains clinopyroxene and spinel of these compositions, with olivine ($Mg_{82}$), and probably represents a cumulate of this nature.

The inclusion suites in the Oatlands basalts suggest that the host magmas rose up through a spinel lherzolite mantle, which contained patches of magnesian websterite. The rare pieces of garnet lherzolite and garnet websterite amongst the other inclusions at Bow Hill indicate an origin from the garnet lherzolite layer. This supports the high Y/Zr indicator ratios which suggest melting of a garnet-bearing source rock for these magmas. The Oatlands area falls within the region of high heat flow in eastern Australia (Cull and Denham, 1979), so that the garnet lherzolite layer in the mantle would be expected at depths greater than 60-65 km (from the data of Jenkins and Newton, 1979). Preliminary pressure determinations from co-existing pyroxenes in the garnet-bearing xenoliths give pressures around 30-32 x $10^5$kPa, suggesting depths of 90-100 km maximum (from the method of Herzberg, 1978; L.M. Barron, pers. comm.).

These mantle suites are typical of the Cr diopside suite of Wilshire and Shervais (1975) and contrast with the less magnesian pyroxenites which resemble their Al augite suite. The latter inclusions probably represent cumulates precipitated from basaltic magmas, either within the mantle or lower crust. The unusual subcalcic websterite may represent precipitation from a tholeiitic magma and probably represents a crustal intrusion, based on the lower Al content of the pyroxenes. One metawebsterite from Parattah shows exsolution lamellae of orthopyroxene in coarse grains of clino-pyroxene, with replacement of this fabric by a granular mosaic of smaller clinopyroxene and orthopyroxene grains. This indicates some of the complexity of unmixing and replacement events that are probably represented in these high pressure rocks. The felsic lower crust is probably largely composed of two pyroxene granulites and gabbros which are represented in the Bow Hill nepheline hawaiite and the basalt plug three kilometres WNW of Bow Hill.

## STRUCTURAL GEOLOGY

### INTRODUCTION

The Parmeener Super-Group is essentially a flat-lying sequence, with beds generally dipping at angles of less than 10°, although locally they may dip more steeply.

Apart from broad, shallow warping and small-scale monoclinal warps probably related to faulting, the Parmeener Super-Group is not folded. Transgressive dolerite sheets up to several hundred metres thick intrude the Parmeener Super-Group and contain dyke-like segments where the sheets rise steeply to higher stratigraphic levels. Thin dolerite dykes are common. Normal faults, and fractures caused by vertical dilation during dolerite intrusion, disrupt the Parmeener Super-Group and some dolerite intrusions. Regional tilting, probably related to uplift of the Central Plateau, is apparent north of Bothwell. By analogy with other areas the intrusion of dolerite is believed to have occurred in the Middle Jurassic (Schmidt and McDougall, 1977). There is no indication that the post-dolerite faulting is younger than the Tertiary deposits in the Oatlands Quadrangle.

### THICKNESS VARIATION OF PARMEENER SUPER-GROUP ROCK UNITS

Accurate measurement of variations in the thickness of the rock units has proved difficult because of younger tilting, faulting, limited outcrop, and the often considerable lateral distance between rock unit boundaries. The thickness of the glaciomarine siltstone (Ps) between the Blackwood Conglomerate Correlate (Pb) and the basal sandstone (Pj) of the Upper Parmeener Super-Group ranges from 36 m at Sandy Toms Rocks [EP144093], to 24 m north of Ram Paddock Hill [EP090058], and to between 20 m and 25 m near Stags Head [EP145185] and near Tunnack. This range is not thought to be caused by erosion prior to Upper Parmeener Super-Group sedimentation, as a characteristic gradation towards a carbonaceous facies is present at the top of the glaciomarine siltstone (Ps) in at least the first three localities.

The basal sandstone unit (Pj) appears to thin towards the east, but this appears to be caused by a 20-30 m reduction in the thickness of the middle sandstone beds and not by erosion of the top siltstone beds of the unit.

## STRUCTURAL TRENDS OF DOLERITE INTRUSIONS AND FAULTS

The trends of dolerite structures and faults have been analysed as follows: fractures, faults, and steep igneous contacts have been considered in one kilometre segments and each dyke segment has been given a weighting of unity irrespective of length. Trend diagrams have been constructed by giving each trend a 5° equal field of influence symmetrical about the measured trend direction. Rose diagrams have been plotted by averaging these results over 5° intervals.

*Short straight dykes (fig. 24a)*

The trends of 38 short straight dykes are surprisingly random, being distributed in a variety of directions but excluding 295°-310°. Only slight clustering occurs about 342°, 002°, and ≅065°.

*Dyke systems (fig. 24b)*

Dyke systems show clearly defined preferred directions; 38% occur between 310°-340°, 20% occur between 345°-005° with a maxima at 355°, and 33% occur between 065°-105°. Only one dyke system was recorded between 010° and 055°.

*Individual dyke segments (fig. 24c)*

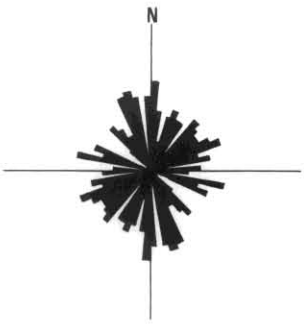
The trends of dyke segments of all dyke systems, plus short straight dykes, fall within two main sectors: 305°-008° (peak at 334°) and 042-118°. This is essentially a 10° broadening of the north-west quadrant maxima for dyke systems and a 35° asymmetric broadening of the east-west trend. In addition to the main peak of 334°, peaks occur at 357°, 315°, 293°, 281°, 040°, and 071°. Pronounced minima occur centred on 025° and 302°.

*Steeply dipping intrusive contacts (fig. 24d, e)*

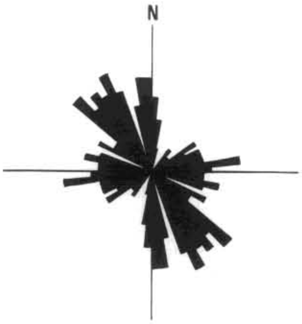
Several trends occur, but the preferred direction lies between 040° and 085° and falls within the lesser of the dyke segment trend sectors. The greater dyke segment trend is not strongly represented by steeply dipping intrusive contacts.

*Dykes in faults or fault-like fractures (fig. 25)*

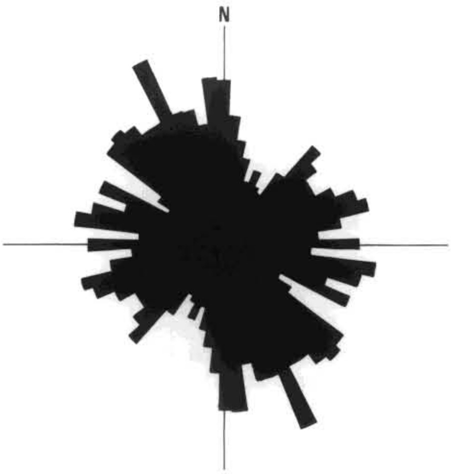
Some dykes occur in fractures separating differing rock types that have undergone tens or hundreds of metres of relative vertical displacement. These fractures may possibly include both pre-dolerite faults and fractures along which movement has occurred because of the dilational effects of underlying dolerite intrusions. Of the dykes for which the trend is accurately known, the main preferred directions are 312°, 334°, and 350°. These directions correspond to the preferred direction of dyke systems in the same quadrant. Both sets of data also show a correspondence of a marked minima between approximately 000° and 055°. With the inclusion of data of probable and possible status (fig. 25*b*), trends between 055° and 070° (the principal trend of steep contacts) become more prominent.



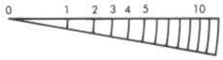

*(a) Trends of 38 short straight dolerite dykes.*




*(b) Average trends of dolerite dyke systems (excluding short straight dykes).*

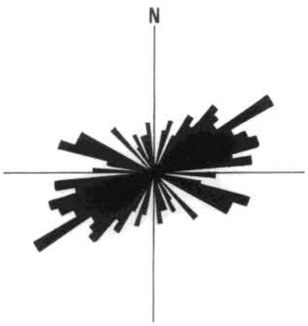



*(c) Trends of dyke segments of dolerite dyke systems and short straight dykes*

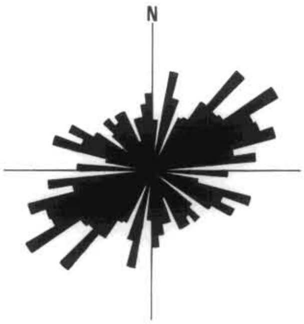



*Scale: Equivalent readings per 5° sector (24a, b, c).*

*Scale: Equivalent 1 km segments per 5° sector (24d, e).*




*(d) Trends of steeply dipping intrusive contacts of major sheets. Trends known accurately.*

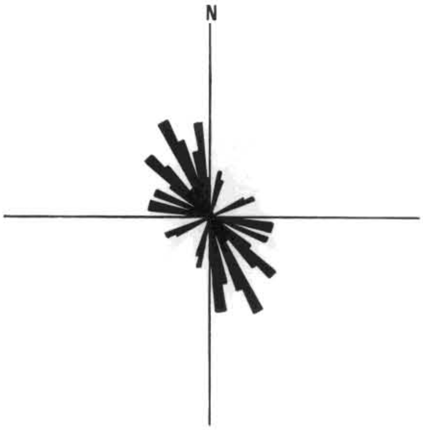



*(e) Trends of steeply dipping dolerite intrusive contacts of major sheets. Includes structures for which trends are known either accurately or only approximately.*

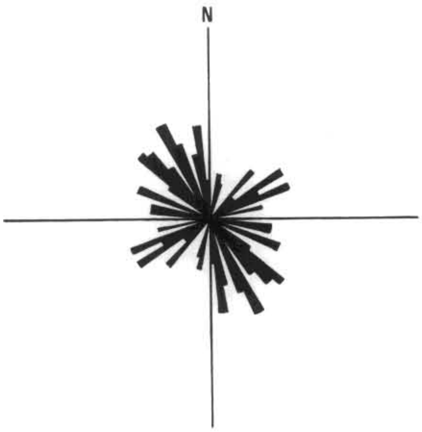
Figure 24.



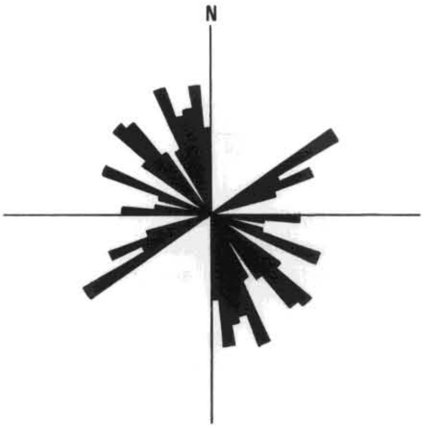
5 cm



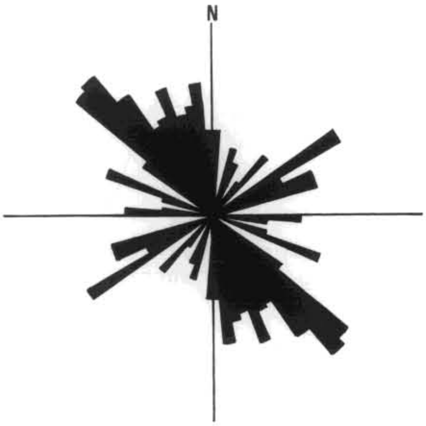

*(a) Trends of dolerite dykes in faults or fault-like fractures. Trends known accurately.*



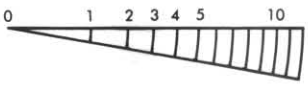

*(b) Trends of dolerite dykes in proved, probable and possible faults or fault-like fractures.*




*(c) Trends of faults and fault-like fractures containing intrusive dolerite. Trends known either accurately or approximately.*




*(d) Trends of proved and probable faults and fault-like fractures containing intrusive dolerite along all or part of structure. Trends known either accurately or approximately.*




*Scale: Equivalent readings per 5° sector (25a, b).*

*Scale: Equivalent 1 km segments per 5° sector (25c, d).*

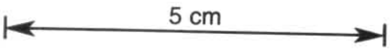
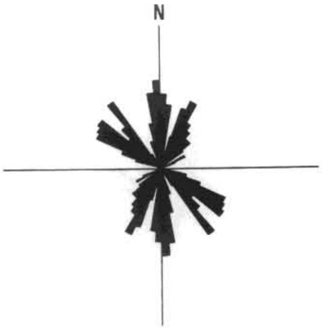
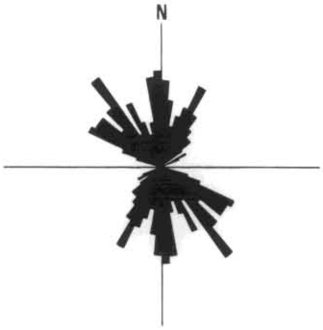


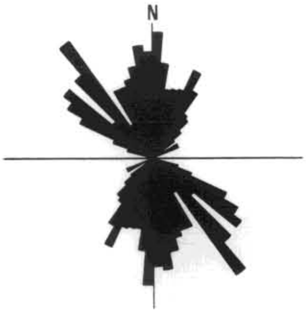

Figure 25.



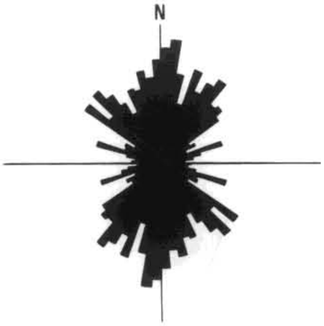

(a) *Trends of faults cutting dolerite. Trends known accurately.*



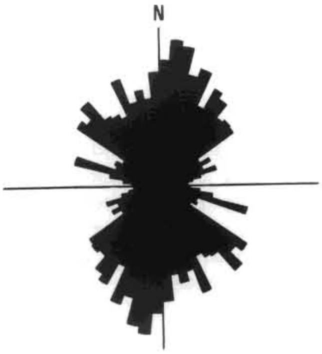

(b) *Trends of faults cutting dolerite. Trends known accurately or approximately.*



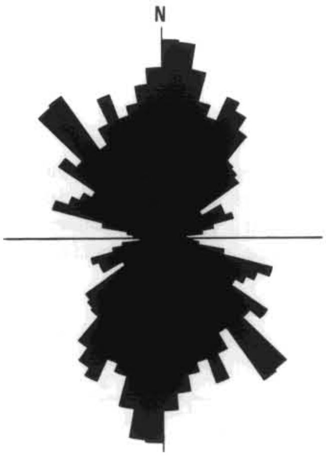

(c) *Trends of proved, probable and possible faults cutting dolerite.*



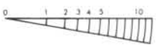

(d) *Trends of faults of unknown relationship to dolerite. Trends known accurately.*




(e) *Trends of faults of unknown relationship to dolerite. Trends known accurately or approximately.*




(f) *Trends of proved and probable faults, excluding faults intruded by dolerite. Trends known accurately or approximately.*




*Scale: Equivalent 1 km segments per 5° sector.*

Figure 26.



5 cm

A similar plot of length-weighted fractures containing dolerite also gives a peak between 055° and 070°.

*Faults cutting dolerite (fig. 26a-c)*

The accurately known faults cutting dolerite cluster about four preferred directions; 302°, 320°, 357°, and 027° (fig. 26*a*). The principal dyke segment trend of 325°-335° and the major trend of steep intrusive contacts are not represented by faults cutting dolerite. The complete absence of faults between 070° and 105° contrasts with the presence of fractures containing dolerite over this sector.

The four preferred directions defined by accurately known trends are retained with the inclusion of faults whose directions are known approximately (fig. 26*b*). In addition, some faults possibly parallel to the 335° principal dyke segment become apparent. Little variation occurs with the further addition of data from probable and possible faults (fig. 26*c*).

*Faults of unknown relationship to dolerite (fig. 26d-f)*

The trend of these faults resembles the general trend distribution of faults cutting dolerite. The principal preferred direction is 357° to 014° (peak 5°). However, many faults occur either side of the principal trend (between 308° and 053°), in either broad sectors or a number of coalescing preferred directions. Subsidiary preferred directions are 308°, 314°-330°, 335°-352°, 020°-028°, 030°-040°, 043°-053°, 288°, and 073° (fig. 26*d*).

With inclusion of data from faults whose trends are known only approximately, a subsidiary peak is developed between 335° and 341° and the principal trend is biased a few degrees to the east (fig. 26*e*). The general distribution remains constant.

When all faults of accurate, approximate, and probable status are considered (fig. 26*f*), excluding only faults or fractures occupied by dolerite, three broad peaks are apparent centred on 003°, 320°, and ≅025°, with lesser peaks at 290° and 338°.

## DISCUSSION OF TRENDS

Some preferred trends are shared by a number of structural elements whilst other preferred trends are restricted to fewer structures. The 028° and 304° trends of faults cutting dolerite are generally insignificant directions, or are directions not represented by structures related to dolerite intrusion. It appears that faults close to 028° and 304° have formed post-dolerite.

Some trends of dolerite structures are not repeated by faults cutting dolerite or are only poorly represented by any fracture not intruded by dolerite. This is particularly so for trends between 055° and 105° (or between 040° to 110° considering only faults cutting dolerite). Dolerite intrusions which do show this trend are shown by steep intrusive dolerite contacts (principal trend), dyke systems and dyke segments, and fault-like fractures with dolerite dykes. The principal direction of dolerite dyke segments is barely represented by faults cutting dolerite for which trends are known accurately, but forms a subsidiary peak when all faults are considered.

The exclusiveness of the 055°-105° directions to dolerite structures

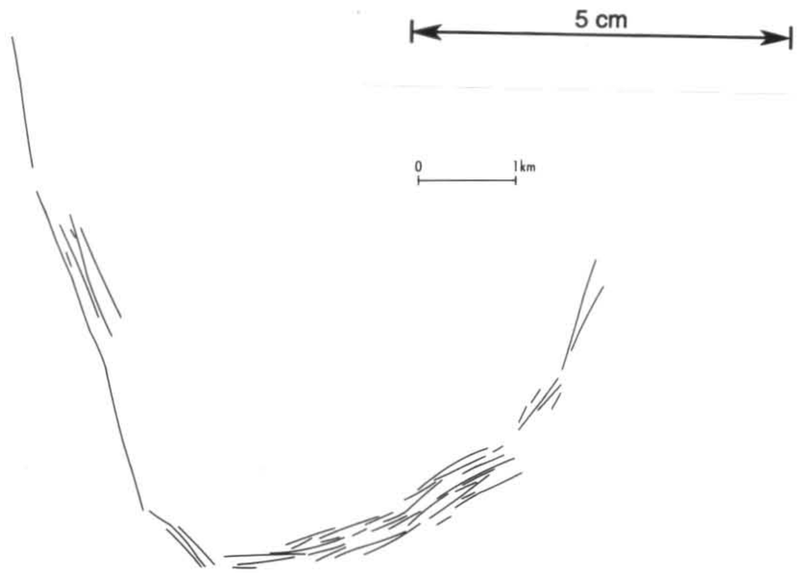



Figure 27. *Photo interpreted linears in dolerite on Flat Top Tier [EN280990] clustered according to trend.*

suggests that either fractures existed with this trend prior to dolerite intrusion, or were generated by the stress field during intrusion, and that a stress field of similar orientation has not since operated in the Oatlands region. This sector of directions also embraces the principal direction of photo interpreted linears in dolerite at Flat Top Tier [EN280990] (fig. 27), but it is not known if the linears are related to external stresses or are caused by internal stresses during cooling of the dolerite magma. The trend of the linears is repeated at Table Mountain in the neighbouring Interlaken Quadrangle, but the trend is not as prominent in stratigraphically lower intrusions. Thus there is a suggestion that the linears of the higher level sheets may be related to the intrusive stress field.

The trend distribution of faults not cutting dolerite at the surface resembles the distribution for faults mapped as dislocating dolerite. The directional concurrence of structures related to both dolerite and faults cutting dolerite suggests possible repetition of fracturing directions, or possibly fracturing of dolerite during subsequent intrusions. An example of a dyke occupying a fault-like fracture that cuts earlier dolerite occurs north of Northumbria Hill [EP229105].

The variety of trends shown by short straight dykes suggests that local focal points of stress, possibly related to the movement of roof rocks above major intrusions, initiated their formation. Abrupt changes in trend and junctions with other dykes suggests existing inhomogeneity strongly influenced the trends of individual segments of larger dykes. That the general directions of the dyke systems parallel the directions of the dyke segments further suggests existing fractures may have largely controlled the direction of some dyke systems. Whether such inhomogeneity was caused prior to the formation of the stress field related to the dolerite intrusion, or occurred at an early stage of the intrusive stress field is not known. The absence of post-dolerite faults trending in the ENE direction and the presence of photo interpreted linears in dolerite in this direction suggest that intrusive forms which have this trend were largely influenced by the intrusive stress field. Ground investigations have indicated that sets of parallel photo linears in dolerite do not appear to be associated with fault displacement, and in some cases coincide with fused contacts between fine-grained dolerite of the sheet upper surface and zones of granophyre.

## EVIDENCE FOR MULTIPLE INTRUSIONS

Leaman (1975*b*) proposed several periods of dolerite injection. Supporting evidence for multiple periods of intrusion is found within the Oatlands Quadrangle, and includes fine-grained dykes with chilled margins intruding coarser grained dolerite (Plates 24, 25) and dykes intruding fractures that have displaced dolerite. Leaman also noted that the presence of more than one major sill in a sequence was indicative of several periods of intrusion. The higher level sheet at Woods Quoin [EP076180] is an example of a second sheet in a sequence.

The classification of faults and fractures into 'pre', 'syn' and 'post' dolerite groups is difficult, as fracturing which occurred during one period of intrusion may both post-date earlier intrusions and pre-date younger intrusions. Radiometric dating of Tasmanian dolerites suggests that they were emplaced during an interval not exceeding 20 million years (Schmidt and McDougall, 1977). Schmidt and McDougall suggest that the uniformity of the major-element chemistry and petrology argues strongly in favour of a single short-lived melting episode, although different periods of intrusion may be sufficiently separated in time to record different magnetic histories.

It is unlikely that the stress field accompanying intrusion should oscillate between intrusive periods to a stress field causing dislocation not accompanied by intrusion. Fracturing occurring during the total span of dolerite intrusion is more likely to be of the type caused by forceful vertical dilation, and such fractures are likely to be occupied by dolerite.

The north-west trending fault passing beneath Mt Mercer [EN236974] does not appear to affect the dolerite nor terminate against it, and appears to pre-date this particular intrusion. A similar situation occurs at Monks Sugarloaf [EP142145], but the evidence for faulting at this location is not as conclusive.

## DESCRIPTION OF SPECIFIC DYKES

There is evidence for the upward extension of dykes into rocks overlying steep risers in intrusive sheets. At Bryans Creek [EP058186] a dolerite sheet rises steeply from an intrusive level within the Cygnet Coal Measures Correlate (Pj) to intrude the quartz arenite sequence (Rp). A dyke apparently extending from the riser continues for four kilometres ENE. The presence of a thin mudstone, siltstone and sandstone association (Rpc) on both sides of the dyke suggests that there was little or no vertical movement across the dolerite. The dyke is believed to mark an extension of a sheet riser at depth, and it is possible that similar dykes elsewhere may be the surface expression of larger hidden structures.

Some dykes vary in trend along short segments of their length, sometimes continuing as short spurs beyond sudden changes of direction. Such dykes are common in the interbedded micaceous sandstone and lutite north-east of Melton Mowbray. Dykes in this area also act as feeders to thin sheets that occur in the Rm horizon.

Several dykes show discontinuous, offset, and some sigmoidal segments.

These dykes appear to crop out towards the limit of their upward extension and probably unite at depth. Other dykes appear to be horns arising from the top of dolerite sheets [EP080146], although in other cases dykes in sedimentary rocks above sheets also intrude the dolerite sheet and must at least post-date the initial crystallisation of the sheet upper contact, if in fact they do not belong to a later period of intrusion.

Coarse-grained leucocratic dykes have only been found internal to dolerite intrusions and appear to be late stage differentiates. These dykes show diffuse or sharp dilational contacts with generally fine-grained to medium-grained dolerite towards the upper contact of the sheet.

The origin of irregular dykes of very fine-grained dolerite with orthopyroxene phenocrysts, intrusive into coarse-grained dolerite of major sheets, is not known. Although usually maintaining a general trend, these dykes are often influenced by prismatic (cooling) joints on the outcrop scale and display splitting, veins, and horizontal segments.

The nature of the dyke at EP047053 is not known, although it appears to merge without sharp contact with the dolerite to the west. This suggests that the dyke may be a feeder to the sheet intruding the quartz arenite west of the dyke, and possibly arises from the dolerite sheet known to be intruding Lower Parmeener Super-Group rocks about seven kilometres to the east. Apparent faulting across the dyke suggests either different degrees of dilation across the dyke due to dolerite sheets, or that earlier movement had occurred.

The dyke north of Sandy Toms Rocks [EP146095] also occupies a fault-like structure. The structure continues with variable strike for several kilometres to the west, and probably towards Spring Hill to the east [EP208049]. It seems unlikely that the dolerite intruding the siltstone (Ps) west of the Jordan River, both north and south of this structure, should belong to separate intrusions. Apparent fault movement across the dyke could be caused by a northward splitting of a dolerite sheet with the dyke feeding a higher level sheet, perhaps that intruding units Ʀs and Ʀg east of the Jordan River. However this is contrary to the argument that more than one major sheet in a sequence is indicative of more than one period of intrusion. Uplift south of the dyke could be the result of a major dolerite feeder centred under this area; alternatively the dyke may be interpreted as post-dating the intrusion of the sheet in unit Ps and giving rise to irregular intrusive forms along strike.

## DOLERITE SHEETS

*Limekiln Spur and possibly related dolerite intrusions*

A dolerite sheet intruding the calcareous sequence (Pl) has been noted in a drill hole at EP125063 and dolerite is exposed at Limekiln Spur [EP110084]. The sheet ascends to the north so that north of Limekiln Spur it passes through the sandstone horizon (Ph) and the lower portion of the glaciomarine siltstone dominated sequence (Ps) to eventually level out above the horizon with fossiliferous beds of sandstone and siltstone (Pe). The sheet is similarly interpreted to rise steeply in a north-easterly direction beneath Munros Hill [EP125085] to intrude between unit Pe and the Blackwood Conglomerate Correlate (Pb). Further outcrops of dolerite intruding between units Pe and Pb, and eventually rising above Pb, occur in the Woodspring area [EP083106] and west of Lower Marshes [EP145115]. These outcrops have been interpreted as being part of the same sheet and separated from the Limekiln Spur area by a cross-cutting dolerite dyke which has intrusive contacts with the quartz arenite sequence of Early Triassic age (Rp).

Along a scarp emanating from Billygoat Hill [EP050130], the sheet rises steeply to intrude the Cygnet Coal Measures Correlate (Pj) north to Bryans Creek [EP051179]. A further steep rise is followed by a levelling out in quartzose sandstone (Rp). The extension of this last rise seems to be indicated by the long dyke emanating from the rise scarp. Mapping in the Interlaken Quadrangle has shown continuity of the sheet beneath Rp from Ben Browns Hill [EP110212] west to Dennistoun Road. Further contacts between the sheet and Rp occur west of the Oatlands Quadrangle. The ascent of the sheet into Rp in a westerly direction can be traced south of Bryans Creek, so that it is probable that the dolerite near Half Moon Tier [EP030160] is part of the same sheet. It is less certain whether dolerite in Rp exposed in the low country around Bothwell is part of the same sheet.

The number of sheets intruding the quartzose sandstone (Rp) south-east of Woods Quoin is not known with certainty, but it is probable that this represents another area where the main sheet intrudes the quartzose sandstone. The sheet in this area has a steep riser east of Lagoon Hill [EP120140], near which post-dolerite faulting has also occurred. East of this riser, the dolerite sheet is not intrusive into Rp, Pj, or the upper part of Ps, and this condition is maintained north to the Exe Rivulet area [EP160197].

Superficial cover has hidden the relationship of the twin ridges of dolerite north of Monks Sugarloaf [EP140140]. These ridges may have fed the thin sheet at Monks Sugarloaf and may be separate from the main sheet. The dolerite at Woods Quoin is part of a thinner sheet, intruding at a higher stratigraphic level, that appears to have extended north-east to Table Mountain [Interlaken Quadrangle] and possibly south-east to Monks Sugarloaf.

Whether the Limekiln Spur dolerite rises to the west or south-west is conjectural, however steep risers of dolerite occur at Ram Paddock Hill [EP090046] and Little Den Hill [EP105035]. The dyke at EP046053 delineates a westerly area consisting of exposures of dolerite intruding quartzose sandstone (Rp), and the dyke may indicate another riser.

The feeder for the Limekiln Spur sheet or body has been located by Ruswandi (1977) who found a significant +50 $\mu m/s^2$ gravity anomaly and a magnetic anomaly [EP104076]. Gravity modelling suggested the feeder was 1000 m across and lay 75-100 m below the surface. Using a magnetic dipole model, Ruswandi considered the depth to the feeder to be 300 m. However he did not consider that a sheet extended from the feeder in the north-east direction, the -20 $\mu m/s^2$ anomaly occurring in this direction possibly being influenced by grabens of quartzose sandstone. The dykes and boss at Ironpot Hill [EP148123] are coincident with a +20 $\mu m/s^2$ gravity anomaly and may overlie a feeder.

*Exe Rivulet sheet*

A steeply rising sheet is dissected by the upper reaches of the Exe Rivulet [EP157198]. The sheet ascends along a linear riser [EP172194] through the siltstone unit (Ps) to intrude quartzose sandstone (Rp) further north. The irregular dyke at Neils Hill [EP134204] may mark an extension of the riser in that direction.

*Apsley sheet and Den Hill area*

Two kilometres north-east of Melton Mowbray the top of a dolerite sheet is exposed where it ascends gradually through interbedded micaceous sandstone and lutite (Rm) and interbedded lithic arenite and lutite (Rsf) in a westerly direction. The sheet is disrupted by a graben structure at Apsley where a downfaulted sequence of lithic arenite, lutite, and coal measures (Rg) contains irregular dolerite intrusions. West of the graben, the apparent base of probably the same sheet is exposed intruding the feldspathic sequence (Rsf), quartz arenite and lutite (Rsq), and quartz arenite and lutite with carbonaceous beds (Rsq'). Large coarse-grained dolerite boulders, sometimes mixed with sandstone fragments, have been interpreted as either talus or slightly displaced blocks from towards the base of the sheet.

Fine-grained dolerite at Gaol Hill [EP091008] and Den Hill [EP069011] suggests the top of the sheet may be exposed, although these two localities are possibly separated from each other by a post-dolerite fault extending along the mapped linear south of Knights Marsh [EP092035].

The gravity survey results of Ruswandi (1977) are consistent with feeders in the Moorlands area, and indicate probable feeders both north-west and south-east of Den Hill summit and south-east and south-west of Black Tier [near EN055965 and EN093945]. From this latter locality dolerite rises north through units Ps and Pj into Rp and possibly Rm in the upper reaches of Mosquito Creek [EN091980]. It is not clear whether features such as Mother Lords Hill [EN108965], Beddingdown Hill [EN103983], and Black Tier are intrusive bosses or fault-bounded blocks. Butters (1970) recorded a positive gravity anomaly at Beddingdown Hill.

The north-west and north-east margins of the Den Hill area are marked by steep risers where the dolerite ascends through units Ps, Pj, and Rp. Blocks of the calcareous beds unit (Pl) have been found adjacent to the north-west dolerite margin and are assumed to be detached xenoliths. A small dyke [EP075054] may arise from an extension of the steep riser forming Ram Paddock Hill [EP088044]. No evidence for an extension of the 351° trending dyke between Ps and Rp could be found in the escarpment of the riser at EP048041, nor could conclusive evidence be found for post-dolerite faulting along the linear margin between dolerite and lithic sandstone talus further south.

The topographical position of very fine-grained dolerite [EP050030] and baked quartz sandstone at EP050028 is suggestive of the base of a sheet. However the outcrop of lithic arkose with volcanic grains (Rg) on the southern flank of Pig Farm Hill [EP050018] could similarly be interpreted as lying below the dolerite sheet, or could be separated from the sheet by a possible extension of the fault at EP030033.

The western foothills of Rough Hills [EP010020] consist of dolerite rising to the east through quartzose sandstone (Rp). Large rafted angular blocks of Pj, Ps, and Pl lithologies occur at the upper contact of the sheet. A similar occurrence of rafted fossiliferous Permian xenoliths has been reported eleven kilometres further west by Stevenson (1973). A south-westerly ascending portion of the sheet is exposed on the north-eastern face of Rough Hills. Faulting may repeat this ascending portion on the northern side of Home Run Hill [EP030025]. The escarpment on the southern portion of Rough Hills may be the edge of a thin sheet capping an Rsq and Rg sequence.

Whether the dolerite bodies at Langdon Hill [EN010980] and Wetheron Tier [EN030960] are discrete intrusions is not certain. However positive gravity anomalies at Wetheron Tier and possibly at Langdon Hill may indicate separate feeders in these areas. The intrusion at Langdon Hill has steep contacts on the north-west and north-east flanks of the hill. The latter contact is shown by exhumed fine-grained dolerite surfaces. The south-east margin is associated with unit TRsq, whilst the foothills of Wetheron Tier and Sag Hill [EN045970] show contacts with unit TRg.

*Boomer Hill intrusion*

A sheet rises irregularly through quartzose sandstone (TRp) in a northerly direction towards Boomer Hill [EP220190], which appears to be a large boss. The sheet extends north-east to Rockton Sugarloaf [EP245220] and east to be cut by a fault. The dolerite in the Flynns Flat area [EP195218] may be part of the same sheet, although contacts with TRg and the lithic arenite, quartz arenite and lutite unit (TRs) are suggestive of either a second sheet or of Jurassic displacement of sedimentary rock units.

The boss-like protrudence of Northumbria Hill [EP220090] may rise from the same sheet, possibly fed from a feeder south-west of Northumbria Hill where a number of dykes are present.

*Lower Marshes sheet*

A thin (<100 m) sheet intrudes near the TRs-TRg boundary south of Lower Marshes [EP162114] and may be fed by the dyke north of Sandy Toms Rocks [EP150094]. The outlier at EP174118 may be part of this sheet. The sheet appears to extend behind the Lower Marshes Church [EP173112] and possibly along the eastern flanks of Rose Hill [EP193078]. The two north-south trending ridges of Rose Hill may be faulted portions of the sheet or superimposed dykes.

*Spring Hill dolerite*

This intrusion appears to be dyke-like, with evidence of multiple intrusion [EP214047] consisting of irregular chilled dykes in coarse-grained dolerite, dykes in joint planes, and large scale (>50 m wide) intrusions with chilled margins against coarse-grained dolerite. Sheet-like bodies occur in close association [for example EP198062, EP213026, and EN220997]. The structure may be continuous with the Lower Marshes sheet.

*Mount Mercer*

West of Mount Mercer a steeply dipping intrusive contact between dolerite and quartzose sandstone (TRp) is exposed [EN222965]. This dolerite may level out to form the sheet-like body intruding units TRs and TRg at Mt Mercer and further south.

A sheet rises steeply in a north-westerly direction in unit TRp at Green Timbers [EN240991]. The dolerite merges with the Spring Hill dolerite in the west and is fault-bounded to the east. Although sheet-like, the detailed structure is not known. This intrusion may extend to join with Northumbria Hill.

*Big Flinty sheet*

The broad plateau surrounding Big Flinty [EP270210] consists of a sheet intruding units Ʀg and Ʀs. The sheet is more irregular near the limit of its western outcrop, which is marked by the major fault west of Pertherton Creek [EP244200]. Mapping in the Interlaken Quadrangle has shown that the dolerite at Little Flinty [EN283223] is a thinner sheet intruding higher in the lithic arkose with volcanic grains (Ʀg) sequence. The major sheet seems to continue without break east to the Midland Highway [EP335210] and possibly to beyond the railway line near York Plains [EP865222]. Baked sedimentary rock skins and dolerite contacts suggest the sheet descends into older units near Oatlands.

*Mt Pleasant sheet*

A thin dolerite sheet in lithic arkose with volcanic grains (Ʀg) caps Mt Pleasant [EP403216] and the hill to the south. This is the stratigraphically highest sheet in the Oatlands Quadrangle.

*Mt Anstey area*

Several thin, westerly-dipping sills intrude unit Ʀg at Mt Anstey [EP248136]. Some of these sills are as thin as one metre. Leithwalk Hills [EP258145] is similar in structure, consisting of a thin dolerite sheet intruded in Ʀg and dipping west at about 10°. The structure of Pages Tier [EP250110] is not known; it and other dolerite bodies of similar trend in this area may resemble Mt Anstey in structure and perhaps represent the same thin sheet repeated by faulting.

*Flat Top Tier - Pikes Hill*

The dolerite appears to be sheet-like at Flat Top Tier [EN280990], but the structure is not known in detail. In the south the sheet may ascend from the west where it is associated with unit Ʀg [EN266977]. This association continues east to EN317946. It is not known whether this sheet was connected to the Bisdee Tier [EP235015] dolerite. Broad dykes exposed around Lake Tiberias may be feeders to the sheet. Morphology suggests the base of the sheet may be exposed on the northern and eastern flanks of Pikes Hill [EP285075].

*Parattah*

Scattered areas of dolerite crop out near Parattah [for example EP345110]. Drill hole intersections and baking of Triassic rocks suggest a sheet underlies this area.

*Mt Seymour - Gullivers Hills*

The number of dolerite sheets in this area is not known. Subsequent investigations at EP390175 have located an upfaulted area in which the upper surface of a sheet intruding unit Ʀs is exposed.

*Tunnack*

The calcareous beds unit (Pl) at EN395993 has been baked, although located over one kilometre from known dolerite outcrops, and may indicate subsurface occurrences of dolerite. Intrusive contacts occur with units Pl and Ps south-east of Tunnack. Uplift of Permian horizons in this area may be due to a major feeder. The uplift generally diminishes away from the main outcrop of dolerite.

## REGIONAL STRUCTURE

The generalised geology of the Oatlands Quadrangle is shown in Figure 28. Two major lineaments cross the quadrangle in a north-south direction, each resulting in a nett east-side-down displacement.

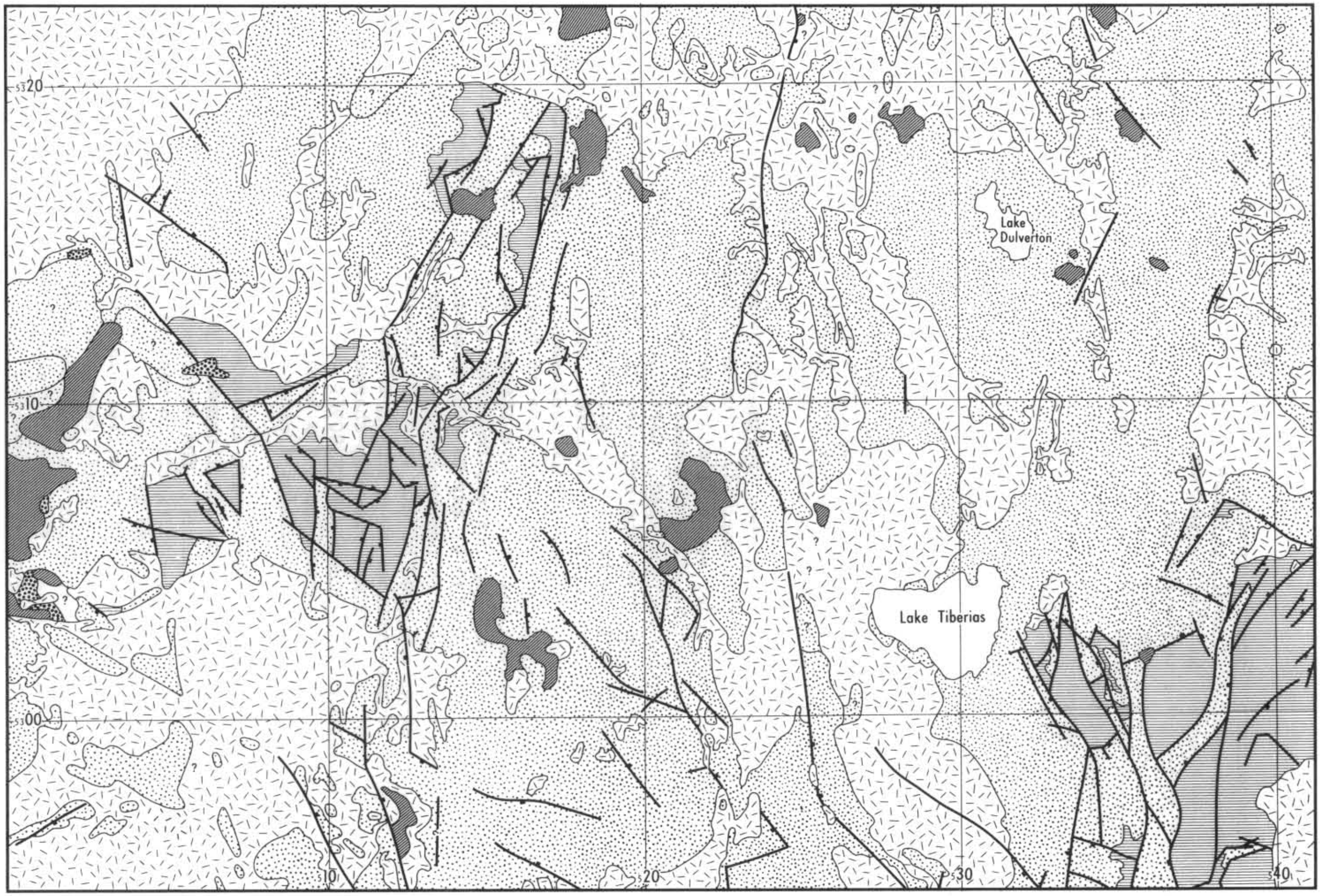
The western lineament consists of a family of faults with associated grabens and is approximately coincident with the valley of the Jordan River from Kempton [Brighton Quadrangle] to Lower Marshes [EP160114]. Dips of up to 20° towards the east and south-east occur along the eastern margin of the lineament from north of Apsley [EP130025] to Lower Marshes. The lineament continues north to near Bow Hill [EP175190] and possibly to the quadrangle boundary west of Flynns Flat [EP190220]. Uplift of rocks west of the lineament is enhanced in the area of the major dolerite feeder near Limekiln Spur [EP104076].

Although local dip variations occur, the general dip north of the Limekiln Spur complex is between the south-west or south-east, and appears to be due to post-dolerite tilting.

The eastern lineament is accompanied along almost the entire length [from about EN282946 to EP250224] on its eastern side by down-faulted lithic arkose with volcanic grains (Ꞧg) intruded by dolerite. The comparatively downthrown strata extends along the northern margin of the quadrangle to the York Plains [EP363197] area.

The northern section between the two north-south lineaments is structurally simple. The Boomer Hill dolerite intrudes strata dipping towards the south. Further south, the dip swings towards the south-west, and what appears to be the axis of a shallow synclinal warp is crossed near the Lower Marshes-Jericho road. Continuing south, uplifted rocks are encountered as the Sandy Toms Rocks-Spring Hill Tier structure is crossed, but for a few kilometres south of this structure dips are still to the south-west, although disrupted by faulting. South of Little White Hill [EP150035] fault-bounded blocks dip in south-west, west, and north-west directions. This is in contrast to a zone of downthrown rocks along the western flank of Spring Hill Tier where steeper dips (up to 50°) are towards the east. Rapid dip changes recorded in cuttings on the old Midland Highway [near EP214030] may be due to monoclinal to slightly anticlinal folding as exposed in nearby cuttings on the realigned highway. A new cutting shows a change of dip from 30° towards the ENE in the northern part of the cutting, to a dip of 8° towards the SSE in the southern part of the cutting. The dip changes over a distance of about 30 m. A monoclinal warp occurs at EN190959 where the dip and strike change markedly over a distance of a few hundred metres in an area in which continuity of strata precludes faulting.

East of the eastern north-south lineament in the Jericho-Mt Anstey area the strata dip WSW towards the lineament, producing NNW trending hogback ridges capped by dolerite. The structure of the region around Lake Dulverton [EP320150] is difficult to resolve because of difficulties in recognising distinct Triassic lithotypes. Pronounced uplift, probably associated with the intrusion of dolerite, has occurred in the Tunnack area [EN395990]. The degree of uplift decreases away from the main area of dolerite outcrop, around which the faulting tends to curve from a N-S trend to a north-east trend. This area is also characterised by several narrow grabens and the intrusion of dolerite into faults or other fracture zones.

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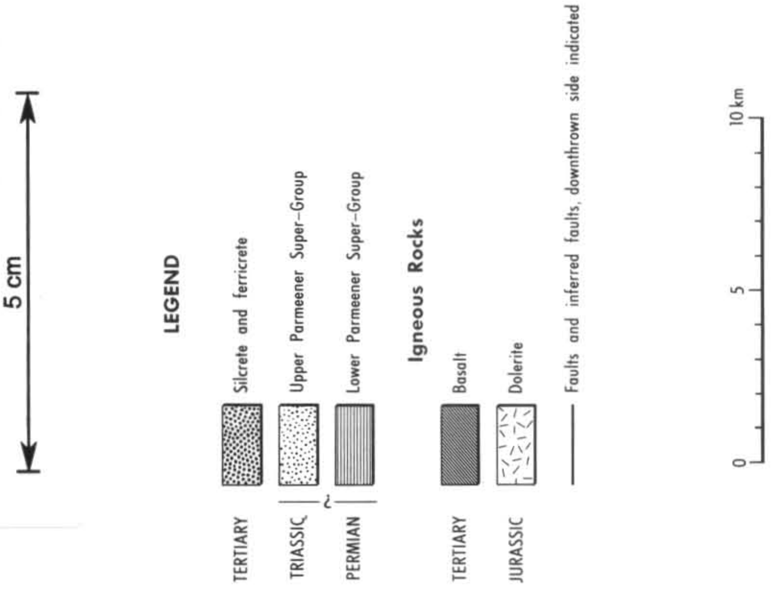


*Figure 28. Generalised geological map, Oatlands Quadrangle.*

The continuity of dolerite from Spring Hill Tier to Sandy Toms Rocks and possibly to Robert Hill [EP045080] is suggestive of a single Jurassic structure extending between these localities, but this cannot be shown conclusively.

The alignment of linear features, including the dolerite-talus boundaries west of Black Tier [EN069970] and Den Hill [EP053015] and the dykes at EP045060, EP042099, and EP033170, suggest a major structure. The fault at EP037150, although displacing dolerite, is bordered by strongly baked sedimentary rocks possibly altered by fluids of Jurassic age, and may be considered as part of this lineament. There is insufficient data to decide whether the linears west of Den Hill and Black Tier are faults or intrusion margins. The alignment of these linears suggests the existence of a pre-dolerite fracture along which variable vertical displacement has occurred.

Other families of faults of approximate parallel trend cross the quadrangle, for example the north-west trending faults between Mt Mercer [EN235964] and Half Moon Tier [EP030160]. Other possible examples include the faults and linears passing close to Melton Mowbray [EN148973] and Home Run Hill [EP035020] and the faults, dykes, linears, and hogback ridges from three kilometres west of Tunnack to Leithwalk Hill [EP250150].

## ECONOMIC GEOLOGY

### COAL

A very thin (30 mm) coal seam occurs in the Cygnet Coal Measures Correlate (Pj) and thin (100-600 mm) coal seams and carbonised wood occur in the upper parts of the lithic arenite, quartz arenite, and lutite sequence (Rs). Seams of potential economic significance occur in the volcanic lithic arenite, lutite, and coal measure sequence of Late Triassic age (Rg). There is no surface outcrop of rocks correlateable with the Mersey Coal Measures in the Oatlands Quadrangle.

*Table 4. COMPARATIVE DETAILS OF SOME COAL SEAMS, OATLANDS QUADRANGLE*

| | Coal Mine Hill south | | | Coal Mine Hill north | | Mt Pleasant saddle | Tin Dish Rivulet |
|---|---|---|---|---|---|---|---|
| | Lower seam | | Upper seam | Lower seam | Upper seam | | |
| Thickness (m) | 0.917-1.07 | | 1.22 | 0.46 | 0.30 | 1.43 with two 76 mm clay bands | at least 0.38 |
| Roof | Sandstone | | Shale and clay | Shale and sandstone | Shale, clay and sand-stone | Sandstone | |
| Floor | Soft clay | | Shale and clay | | Shale | Shale and sandstone | |
| Dip | NE at 2° | | | | | S at 8° | |
| *Analysis* (%) | (1) | (2) | (3) | | | (4) | |
| Moisture @ 100°C | 1.80 | 1.19 | 1.70 | | | 8.4* | |
| Volatiles | 13.28 | 13.55 | 15.80 | | | 21.30 | |
| Fixed carbon | 57.32 | 60.74 | 56.80 | | | 48.82 | |
| Ash | 27.60 | 24.52 | 25.70 | | | 21.48 | |
| Sulphur | 0.46 | 0.48 | - | | | 0.43 | |
| Specific energy (MJ/kg) | | | | | | 19.46 | |
| Fusion point of ash | | | | | | 1200°C | |

Analyses 1-3 from Hills *et al.* (1922), analysis 4 from Blake (1936*b*).

* moisture at 105°C.

Coal has been mined from seams in Rg at the York Plains Coal Mine [EP361179] and from a seam in rocks correlated with the quartz arenite, lutite, and carbonaceous bed sequence (Rsq') at the Jerusalem workings immediately south of the Oatlands Quadrangle on the east bank of Coalmine Creek [EN294945].

Perhaps the first record of coal from the Oatlands Quadrangle is the description by Strzelecki (1845) of a section containing coal exposed during the digging of a well in rocks of unit Rs at the Guard House [EP212023] at Spring Hill. Gould (1869) recognised the rocks of the coal measure sequence and drew attention to extensive areas having coal potential north and north-west of Lake Tiberias. Gould also noted coal outcrops in the Jordan River, probably at Jericho, at Fourteen Tree Plain (which is in the vicinity of Park Farm [EP262088]), and in and west of the Tin Dish Rivulet at Coal Mine Hill [EP360180]. Gould gave an account of investigations for coal including drilling results for an area along Coalmine Creek. A portion of this area lies within the Oatlands Quadrangle. The "2 foot seam" worked at the Jerusalem Coal Mine was considered by Gould to have been intersected at 37' (11.3 m) depth in a bore drilled near the confluence of Coalmine Creek and a tributary sometimes known as Flat Top Rivulet [EN293949]. A thin coal seam associated with quartz arenite currently crops out in the east bank of Coalmine Creek south of the first bend in the rivulet downstream from the railway bridge. A further seam occurs slightly further downstream, but upstream from the old coal workings and a dolerite intrusion. The section containing this seam was described by Gould as follows:

| | |
|---|---|
| Greyish and yellow sandstone with fine dark streaks | 4'8" (1.42 m) |
| Carbonaceous shale | 2" (51 mm) |
| Coal | 9" (228 mm) |
| Band | 1" (25 mm) |
| Coal | 1'3" (381 mm) |
| Band | 1" (25 mm) |
| Coal | 1'0" (305 mm) |
| Fire clay with plants | |
| Dips west 8 inches in one yard (about 12°) | |

A coal seam in Flat Top Rivulet (Milligan, 1849; Gould, 1869) occurs in the coal measures of the volcanic lithic arenite, lutite, and coal measures sequence (Rg). Coal also occurs in a railway cutting west of Coalmine Creek (Hills *et al.*, 1922).

Johnston (1888) mentioned coal workings at Coal Mine Hill where a "four foot anthracite" seam was being mined. There was a second seam about 17 m lower. More details of the lower seam of about 980 mm thickness were given by Nye (*in* Hills *et al.*, 1922). Nye recorded a production of 9489 tons of coal from 1902 to 1919. Another coal outcrop listed by Nye and exposed in a cutting on the York Plains Road near the Mount Pleasant saddle was subsequently exposed in an adit. Blake (1936*b*) noted that this seam was 1.54 m thick and contained two 80 mm clay bands. Possible extensions of the seams worked on the southern side of Coal Mine Hill were noted by Blake (1936*a*) on the northern side of Coal Mine Hill where 18.4 m of strata separated an upper 305 mm thick seam from a lower seam 460 mm thick. The information shown in Table 4 is extracted from the reports of Johnston (1888), Hills *et al.* (1922), and Blake (1936*a*, *b*).

*Table 5. SUMMARY OF COAL INTERSECTIONS, YORK PLAINS AREA (from Glenie et al., 1981)*

| Depth (m) | Interval thickness (m) Coal | Mudstone | Moisture (%) | Ash (%) | Volatile matter (%) | Fixed carbon (%) | Relative density |
|---|---|---|---|---|---|---|---|
| | | HOLE 0-01 [EP385200] | | | | | |
| 5.85- 6.88 | 1.03 | | 3.6 | 34.6 | 8.9 | 52.9 | 1.58 |
| 36.42-37.02 | 0.60 | | 3.3 | 25.3 | 11.8 | 59.6 | 1.47 |
| | | HOLE 0-02 [EP400212] | | | | | |
| 7.70- 7.94 | 0.24 | | Inferior coal | | | | |
| 7.94- 8.01 | | 0.07 | | | | | |
| 8.01- 8.70 | 0.69 | | 3.5 | 29.3 | 13.7 | 53.5 | 1.50 |
| 7.70-8.70 composite thickness 1.00 | | | 4.0 | 37.3 | 13.2 | 45.5 | |
| 31.07-31.49 | 0.42 | | 2.4 | 24.7 | 14.4 | 58.5 | 1.52 |
| 31.49-31.60 | | 0.11 | | | | | |
| 31.60-31.76 | 0.16 | | 3.3 | 52.2 | 9.2 | 35.3 | 1.75 |
| 31.07-31.76 composite thickness 0.69 | | | 3.9 | 44.3 | 11.5 | 40.3 | |
| 32.98-33.31 | 0.33 | | 2.3 | 20.2 | 12.2 | 65.3 | 1.48 |
| 33.31-33.34 | | 0.03 | | | | | |
| 33.34-33.45 | 0.11 | | 4.9 | 48.4 | 10.0 | 36.7 | 1.75 |
| 33.45-33.62 | | 0.17 | | | | | |
| 33.62-34.20 | 0.58 | | 2.4 | 26.8 | 13.6 | 57.2 | 1.53 |
| 34.20-34.35 | | 0.15 | | | | | |
| 34.35-34.57 | 0.22 | | 3.0 | 25.4 | 13.9 | 57.7 | 1.52 |
| 34.57-34.68 | | 0.11 | | | | | |
| 34.68-35.18 | 0.50 | | 1.9 | 32.0 | 12.0 | 54.1 | 1.55 |
| 35.18-35.26 | | 0.08 | | | | | |
| 35.26-35.51 | 0.25 | | 3.1 | 28.5 | 11.6 | 56.8 | 1.49 |
| 35.51-35.60 | | 0.09 | | | | | |
| 35.60-36.30 | 0.70 | | 2.4 | 23.2 | 13.1 | 61.3 | 1.47 |
| 36.30-36.33 | | 0.03 | | | | | |
| 36.33-36.62 | | 0.29 | | | | | |
| 36.62-36.86 | | 0.24 | | | | | |
| 36.86-37.37 | 0.51 | | 3.3 | 28.5 | 12.1 | 56.1 | 1.51 |
| Total thickness | 3.20 | 1.19 | | | | | |
| 32.98-37.37 composite thickness 3.39 | | | 4.3 | 44.5 | 10.6 | 40.6 | |

*Table 5. (continued)*

| Depth (m) | Interval thickness (m) | | Moisture | Ash | Volatile matter | Fixed carbon | Relative density |
|---|---|---|---|---|---|---|---|
| | Coal | Mudstone | (%) | (%) | (%) | (%) | |
| | | HOLE 0-03A [EP392206] | | | | | |
| 37.84-37.96 | 0.12 | | 8.9 | 56.1 | 8.7 | 21.3 | 1.80 |
| 37.96-38.14 | | 0.18 | | | | | |
| 38.14-38.35 | 0.21 | | 3.8 | 33.3 | 14.4 | 48.5 | 1.60 |
| 38.35-38.48 | | 0.13 | | | | | |
| 38.48-38.85 | 0.37 | | 3.9 | 34.5 | 13.0 | 48.6 | 1.56 |
| 38.85-39.03 | 0.18 core loss, probably coal | | | | | | |
| 39.03-39.11 | | 0.08 | | | | | |
| 39.11-39.34 | 0.23 | | 2.2 | 20.0 | 13.5 | 64.3 | 1.46 |
| 39.34-39.52 | | 0.18 | | | | | |
| 39.52-39.72 | 0.20 | | 3.1 | 24.9 | 13.2 | 58.8 | 1.49 |
| 39.72-39.86 | | 0.14 | | | | | |
| 39.86-40.47 | 0.61 | | 2.3 | 19.3 | 14.8 | 63.6 | 1.45 |
| Total thickness | 1.74 | 0.71 | | | | | |
| | | HOLE 0-03B [EP361181] | | | | | |
| 34.35-34.87 | | 0.52 | | | | | |
| 34.87-36.00 | 1.13 | | 2.3 | 21.4 | 14.6 | 61.7 | 1.48 |
| 34.35-36.00 | composite thickness 1.65 | | 2.3 | 22.3 | 14.3 | 61.1 | |
| | | HOLE 0-06 [EP401224] | | | | | |
| 27.35-30.35 | 3.00 | Core loss with 30% coal recover | | | | | |

Recent exploration for coal in the York Plains area has included the drilling of five diamond drill holes for Capricorn Mining Limited on E.L. 28/79. The drilling results are presented by Glenie *et al.* (1981) and the more significant coal intersections are summarised in Table 5. The bore holes, each about 50 m deep, intercepted seams of various thickness commonly interbedded with mudstone in composite sequences. The Upper Parmeener Super-Group rocks near York Plains were not differentiated on the Oatlands 1:50 000 map (Forsyth *et al.*, 1976) beyond what was possible from a cursory inspection. Based on the current information, it is therefore not possible to ascertain which parts of Rg have been sampled by Capricorn Mining. Certainly more faults are present in the area than indicated on the 1:50 000 map. For example a fault-bounded block of Rsq in Rg has recently been observed in an area depicted as Rg? by Forsyth *et al.* (1976). Unit Rg is more extensive than shown on the Oatlands map and occurs in some areas depicted as Rg? and Ru.

A Capricorn Mining drillhole at Jericho [Hole 0-05; EP236073] was collared below Rg and contains no coal in a lutite dominated sequence. The Rg strata near Jericho remains untested.

Surface outcrops of coal in Ꞧg or immediately underlying Ꞧg have been noted in three other areas.

(1) A thin (<1.0 m) coal seam dipping north-west is exposed in a creek north-west of Sag Hill at EN039974.

(2) Drill holes at Spring Hill intersected 100 mm thick coal seams immediately below unit Ꞧg. Nearby, the major road cutting south of the Spring Hill crest exposes similar coal seams up to 800 mm thick. The seams dip north-east at about 30° towards the dolerite ridge above.

(3) Dull coal with a few bright bands is exposed in a cutting on the Midland Highway Jericho bypass [near EP263080].

Because of the thinness of the seams, steep dip, and proximity to dolerite, exposures at Sag Hill and Spring Hill have no economic significance in their own right, but serve to indicate that coal seams are of widespread distribution. The coal near Jericho appears to have a high ash content, but no analysis is available, nor is the continuity of the seam known.

Underground water boring has left a legacy of drillers' logs referring to coaly matter. An analysis of one such bed has shown it to be carbonaceous shale, however some true coal may have been intersected. Some occurrences are listed below.

| *AMG reference* | *Depth (m)* | *Drillers log* | *File reference** |
|---|---|---|---|
| about EP284202 | 10.7-13.7 | 3.0 m coal | 67 |
| EN227978 | 2.8- 4.6 | 1.8 m black shale with coal-like matter | 166 |
| EN261988 | 11.3-13.7 | 2.4 m coaly matter | Leaman, 1971, p. 94; hole CO9 |
| about EP232084 | 8.5-10.3 | 1.8 m coaly matter | 79 |
| about EP235085 | 7.6-12.2 | 4.6 m coaly matter | 80 |
| about EP243092 | 8.5- 9.1 | 0.6 m coaly matter | 81 |
| about EP240100 | 10.7-11.3 | 0.6 m coaly matter | 83 |
| about EP247060 | 27.4-28.9 | 1.5 m coal | 156 |
| D. Munnings, York Plains | 2.4- 4.5 | 2.1 m coaly matter | Interlaken 71 |

* File reference figures refer to underground water record cards held by the Department of Mines. Number is reference for Oatlands Quadrangle (unless otherwise noted).

Exploration to date has not comprehensively examined the coal potential of a thick or complete sequence of unit Ꞧg, nor has the mapping of the eastern portion of the quadrangle resulted in a stratigraphic subdivision of the Upper Parmeener Super-Group in that area. The distribution and structure of Ꞧg is not known accurately in the main areas with coal potential.

The symbols Ꞧq, Ꞧf, and Ꞧb used on the Oatlands map in areas of undifferentiated Upper Parmeener Super-Group rocks (Ꞧu) can be used as a rough guide to rock distribution. The symbols indicate rock types at isolated localities: Ꞧq indicates quartz sandstone; Ꞧf indicates feldspathic sandstone, arkose, and lithic sandstone; and Ꞧb indicates mudstone. These probably indicate the following mapped units:

Rq alone is probably the quartz arenite sequence (Rp)
Rq, Rb together is probably the interbedded micaceous sandstone and lutite unit (Rm) or quartz arenite and lutite (Rsq)
Rq, Rf, Rb together is probably the quartz arenite, lithic arenite, and lutite sequence (Rs)
Rf alone is probably either the lithic arenite, lutite, and coal measures sequence (Rg), the lithic arenite and lutite sequence (Rsf), or the Cygnet Coal Measures correlate (Pj)

It is likely that most areas containing thick sequences of unit Rg, or the beds immediately underlying Rg, contain coal seams. Shallow exploratory drilling may find open-cut workable seams of economic significance, but thorough exploration would perhaps best proceed by overcoming the shortcomings in the mapping and knowledge of coal seam distribution in the entire Rg sequence.

The only major economic working of coal in the quadrangle has been in the York Plains area. Johnston (1888) recorded working at Coal Mine Hill, while some coal had been extracted at least as early as 1883. The mine was initially worked as Lord's Colliery, but was renamed the York Plains Coal Mine (or Gregg's Colliery) early this century. Recorded production for the years 1898 to 1947 was 32 369 tonnes, production ceasing during September 1947.

## BUILDING STONE

Quartz sandstone, particularly of Rp lithology, has been quarried and used extensively for building purposes in the Oatlands area. Twelvetrees (1902) noted that building stone from Oatlands was used in the construction of buildings at Launceston. Lithic arenite from unit Rg was used in the construction of the bridge over the Jordan River on the pre-1982 Midland Highway at Jericho. Ornamental stone has been quarried at EP041065. This quarry is cut in thinly-bedded planar beds with primary current lineations and some low angle cross-bedded sandstone of the type more common in the upper parts of unit Rp.

## ROAD MAKING MATERIALS

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

Fresh dolerite of fine to coarse grain size yields material suitable for crushing when a uniform clean aggregate is required. Cooling joints near and at right angles to intrusive margins often form a platy structure in the dolerite and may assist in quarrying operations. Examples of quarries in this type of material occur on the old Midland Highway north of Lovely Banks [EP193012], north of Jericho [EP248087], and near Lemon Hill [EP283132].

Dolerite tending to a granophyric composition, where sufficiently weathered to be easily crushable but not clayey, forms a material often used to top-surface gravel roads. The rock quarried often exfoliates from around boulder-sized kernels of fresher dolerite. The largest quarry in this type of rock is at Billygoat Hill on the Dennistoun Road [EP051131].

Well fractured and slightly weathered margins of major intrusions or smaller dykes and sills yield rock which may require little or no crushing to produce coarse gravel. For example the top margin of a dolerite sheet with roof pendants and xenoliths has been quarried six kilometres south of Bothwell on Abyssinia Road [EP009020]. A major, steeply dipping sheet margin has been quarried near the Lake Highway seven kilometres east of Bothwell [EP070056], a thin sheet has been quarried 1.5 km east of Lovely Banks on Lovely Banks Road [EN196999], and large dykes have been quarried at Rotherwood [EP138157] and two kilometres west of Baden [EP363022].

Numerous small quarries occur along thin (2-10 m thick) dolerite dykes. The metamorphosed host rocks are also often used in such quarries. More extensive metamorphism is found in the host rocks overlying major dolerite sheets. The most intensive metamorphism yields quartzite from the quartz arenite, and flinty hornfels from the lutite. Hornfels and other thermally altered rocks and dolerite have been quarried in the hills west of the York Plains Road-Midland Highway junction. Weathering of quartzite and less altered sandstone in some areas yields siliceous gravel, but such deposits usually occur as discontinuous veneers. Thermally metamorphosed rocks has been indicated with an overprint on the map.

Dry hillsides in hard fissile siltstone of the dominantly glaciomarine sequence (Ps) have thin veneers of loose or partially consolidated flaky gravel. These deposits may thicken locally, particularly on scarps [for example EP135088] and have been used in the construction of gravel roads. Several shallow pits, in which the near-surface beds of unit Ps and the surficial gravels have been stripped, occur about five kilometres east of Bothwell. Gravel composed of chips of Cygnet Coal Measures correlate (Pj) siltstone has been worked at EP056175.

Pebble conglomerate, granule conglomerate, and very coarse sandstone of the Blackwood Conglomerate correlate (Pb) and lag deposits developed from Pb are only likely to be of economic significance where erosion has exposed the unit over large areas and where land use can accommodate stripping. Although the conglomerate reaches five metres in thickness, this figure is a maximum and erosion usually results in thinner outcrops. Rocks of unit Pb have been worked, mostly in the Tunnack area. Because of their lenticular nature, conglomerate beds in unit Pj are generally less significant than Pb.

Basalt agglomerate has been quarried beside the Lake Highway about thirteen kilometres east of Bothwell [EP112036].

The distribution of road building materials in the Oatlands Municipality was noted by Threader (1968*a*). A register of quarry materials for all quadrangles is maintained by the Economic Geology section of the Department of Mines.

## SAND

Although sandy deposits are widespread, few clean sand deposits are known. Sand occurs beside the Lake Highway near the Rest Area three kilometres east of Bothwell [EP035068]. Clean loose sand has been noted in talus deposits, creek banks, and in hollows and valleys in sandstone terrain, and in some aeolian deposits. No attempt to estimate the extent or thickness of these deposits has been made during regional mapping.

## CLAY

Clay suitable for use as core material at specific rock-fill dam sites on the Coal River, Dulverton Rivulet, and Jordan River has been discussed by MacLeod (1962*a*, *b*) and Moore (1968*a*, *b*). Clay has been dug locally on a very small scale for home industry pottery. It is likely that suitable material for brick making could be found in the mudstone dominated portions of the Upper Parmeener Super-Group. Lutite in unit Rs near EP211025 contains mostly illite with some montmorillonite (based on X-ray diffraction traces; W.L. Matthews, pers. comm.).

## LIMESTONE

Very impure limestone occurs in the calcareous sequence (Pl) of the Lower Parmeener Super-Group. This has been quarried at Limekiln Spur, but a grab sample analysis reported by Hughes (1957) indicated a $CaCO_3$ content of only 24%.

## SILICA STONE

Small areas of greybilly have been mapped on the plains near Bothwell, based on definite outcrops and floaters of greybilly. Such deposits are likely to be irregular and seldom more than one metre thick, and may not be continuous between outcrops. The outcrops are marginal to basalt flows. Further occurrences may be hidden beneath basalt and surficial deposits.

## METALLIFEROUS DEPOSITS

Local residents claim that alluvial tin was worked in a tributary of the Exe Rivulet and that several bags were won before operations ceased. No record of cassiterite production from this area has been found. The tributary drains Jurassic dolerite and Parmeener Super-Group terrain. The alleged tin occurrence occurs close to Tertiary basalt containing ultramafic xenoliths several centimetres diameter [EP149189].

## UNDERGROUND WATER RESOURCES

An early assessment of underground water potential of parts of the quadrangle was made by Nye (1921, 1922). A more recent assessment of the Coal River basin was made by Leaman (1971). An underground water investigation of the entire quadrangle is currently being carried out by the Engineering Geology section of the Department of Mines.

Since 1947 approximately 200 underground water bores have been drilled within the Oatlands Quadrangle. The Department of Mines maintains a register of drilling results including drillers logs of lithologies, water yield and quality, depth to water, and locality information. Private contractors drillers logs have been provided to the Department of Mines subsequent to the Underground Water Act, 1966. In some cases this basic information has been upgraded by visits of Departmental geologists to bore sites to provide precise locality details, operating water yields, data on rock types encountered, and in some cases chemical analyses of water. With improving technology the drilling time has been reduced by a factor of ten. Consequently the time available to drillers to make lithological logs has also decreased. Recent logs are considerably less detailed than those of the 1940s and 1950s.

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## APPENDIX 1

### Revisions to 1:50 000 map sheet

#### MIDLAND HIGHWAY

Since publication of the Oatlands 1:50 000 map in 1976 the realignment of the Midland Highway has provided some new rock exposures, necessitating minor revisions to the map. Those affecting rock distribution are listed below, in order of occurrence north from Melton Mowbray.

(1) Thin dolerite sill intruding sandstone at EN165997, western side of highway.

(2) Very thin dolerite dyke. Near EP173002, north and south cuttings.

(3) Fault between the muddy alluvial plain facies (Rm) and interbedded quartz-rich lithic arenite and lutite (Rsf). EP188011, east cutting. This is an extension of the mapped fault.

(4) Extension of Rsf in cuttings east of EP188011. The northern boundary fault of Rsf is not exposed because of thick Quaternary deposits.

(5) Dolerite dyke near EP210020, west cutting (probably an extension of dolerite dyke cutting old highway).

(6) Irregular dolerite dyke at EP212022, east and west major cuttings. Probably a down-faulted extension of the major east-west dyke.

(7) Anticlinal structure in Rsf. EP213032, east and west cuttings.

(8) Small sub-horizontal thrust faults displacing coal seam. Quaternary deposits. EP215040, major cutting eastern side.

(9) Additional minor exposures of Ru beneath Quaternary talus with basalt clasts (Qtb), north of Spring Hill pass, western cuttings.

(10) Steep contact between dolerite and Triassic roof pendant near EP231070.

(11) Clean sand deposit (now obscured) near EP233072.

(12) Interbedded quartz-rich lithic arenite and lutite (Rsf) south-west side of new bridge over Jordan River.

(13) Volcanic lithic arenite (Rg) with coal seam, intruded by dolerite dykes, overlain by dolerite cobble beds. Cuttings near EP260079 (previously shown as dolerite).

(14) Stonor Road junction to EP278116. Foundations of underpass and road cuttings in Rsf. Basalt (amygdaloidal) dykes cut across highway south of access road to 'Lemon Springs'. A fault runs sub-parallel to highway on eastern side, cutting acutely across highway north of basalt dykes. Dip steepens near fault. Quartz sandstone east of road appears to be cut off by north-trending fault close to highway.

## YORK PLAINS AREA

An uplifted fault block of quartz arenite and lutite (Ƭsq), probably intruded by dolerite at shallow depth and associated with some surface outcrops of dolerite, has been located in an area depicted as Ƭg? on the map [EP390175]. Volcanic lithic arenite (Ƭg) crops out south-west and north-east of this block. Dolerite at EP392182 is part of a north-east trending dyke. The volcanic lithic arenite extends for 2.8 km along the northern margin of the map from the north-east corner. It is intruded by dolerite [EP412223 and EP405222]. Dolerite was also intersected in a Capricorn Mining drill hole at 46 m depth [EP399221]. Triassic rocks (probably Ƭs) occur above dolerite on the old railway [EP362218]. Interbedded quartz arenite and lutite with carbonaceous beds (Ƭsq') north of Coal Mine Hill at EP355195 extends south-east along the south-west bounding fault for about one kilometre. An area depicted as basalt below the 550 m contour on Vincents Hill [EP345220] includes outcrops of dolerite and Tertiary ferricrete. Volcanic lithic arenite? (Ƭg?) west of Vincents Hill includes definite lithic arenite beds.

## OATLANDS AREA

The summit of Barwicks Hill [EP281192] is dolerite, not basalt. No basalt occurs on the northern flank of Barwicks Hill and dolerite extends south-west into the creek. Dolerite intruding quartz sandstone to the south and overlain by basalt to the north occurs at EP278186. The summit of Fernleigh Hill [EP266189] is basalt not dolerite. A fault probably extends along the linear marked by the eastern flank of Fernleigh Hill to run east of Big Flinty. Lithic arenite occurs east of the assumed fault at EP277216 and dolerite to the west. Middle or Late Triassic plants occur in siltstone exposed in a waterhole [EP281213]. It is possible that the entire valley area here is floored in Triassic rocks overlain by Quaternary talus and alluvium with dolerite clasts. The northern, western and eastern slopes at least of Little Flinty [between EP280223 and EP286223] are composed of lithic arenite, with dolerite only above the 580 m contour. The north-south linear 0.7 km east of Little Flinty also probably marks a fault, as coarse-grained dolerite occurs west of the linear and lithic arenite occurs from 0-200 m east of the linear near the map margin. The ENE trending linear is a dolerite dyke where it intersects the last mentioned lithic arenite outcrop at EP292223. Rare thin skins of hornfels sometimes cap the dolerite between Little Flinty and the Midland Highway.

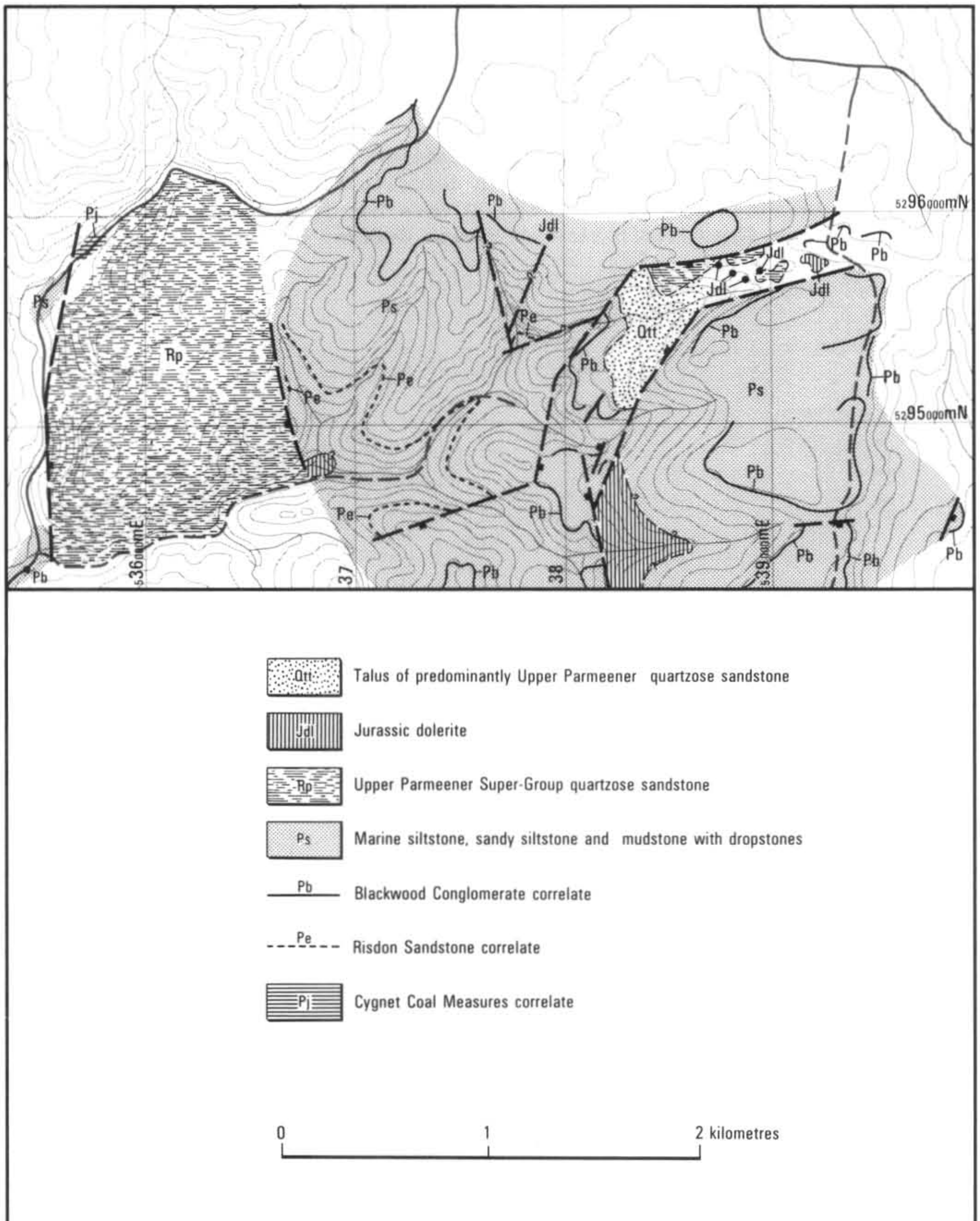
The lithic arenite exposed west of Petherton Creek at EP253200 extends north to include all the undifferentiated Upper Parmeener Super-Group rocks exposed west of the creek. The major north-trending fault east of Petherton Creek continues its trend to pass between the dolerite and basalt of Rockton Sugarloaf [EP250220] and extends into the Interlaken Quadrangle.

## SOUTH OF TUNNACK

New outcrops of units Pe, Pb and Ƭp, and of dolerite have been located. Remapping of a portion of this area has redefined the distribution of Pb and altered the fault pattern (fig. 29).

## MUD WALLS ROAD (JERICHO)

Unmapped Tertiary basalt occurs beside the Mud Walls Road [EP258060]. The basalt may overlie conglomerate exposed in a nearby road cutting. The conglomerate includes clasts of dolerite, Upper Parmeener sedimentary rocks, basalt and silicified wood. Similar conglomerate containing predominantly dolerite and basalt overlies basalt in a road cutting a few hundred metres further north.




**REVISED MAPPING OF PART OF THE SOUTH- EAST CORNER OF THE OATLANDS QUADRANGLE**

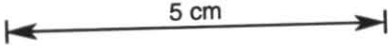
Figure 29.

## APPENDIX 2

### Faulting based on topographical position of dolerite intrusions

It is possible to derive a distribution of faults from the topographic position of dolerite intrusions, based on the assumption that the apparent displacement of the intrusion is not due to abrupt transgression. Mapping of the Oatlands area of the quadrangle was undertaken by B.F. Abtmaier, and he deduced a fault pattern based rarely on fault exposure, but on topographic variation of dolerite outcrops and occasionally on lithological change.

Because of the unpredictable variability of dolerite intrusions, the method of deducing structure based on dolerite altitude is regarded by the writer as unreliable, and these faults were not included in the Oatlands 1:50 000 map. The distribution of faults derived by Abtmaier is given in Figure 30.



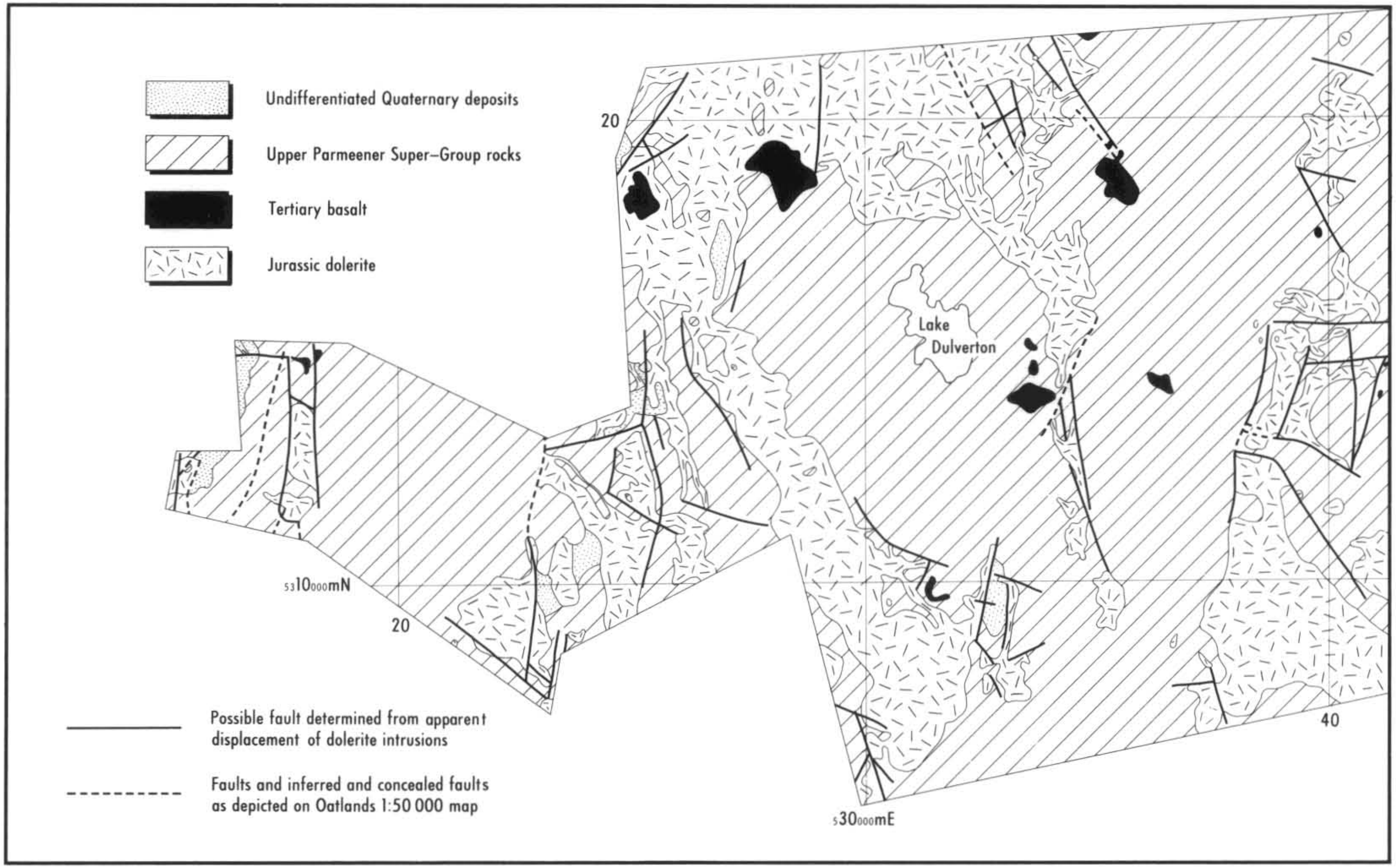




Figure 30. *Fault pattern determined from apparent displacement of dolerite intrusions, Oatlands area.*

## APPENDIX 3

## Triassic macroflora in the Oatlands Quadrangle

### OLD MIDLAND HIGHWAY - SPRING HILL [EP21550360]

The fossils at this location are preserved in fine-grained buff coloured lithic quartzose sandstone exposed in a low cutting on the old Midland Highway. The horizon probably occurs in a transitional zone between interbedded quartz arenite and lutite with carbonaceous beds (Rsq') and interbedded quartz-rich lithic arenite and lutite with carbonaceous beds (Rsf). The leaves consist solely of once-forked specimens of *Xylopteris, Dicroidium* and *Johnstonia* and show clear pinnule outlines, but venation is only preserved on a few specimens. Species of *Dicroidium* show some variation and some may intergrade. The following species occur:

*Xylopteris elongata* var. *rigida* (Dun) Stipanicii and Bonetti, 1957.
Venation is clear on some specimens.

*Dicroidium* sp. cf. *D. natalense* (Frenguelli) Retallack, 1977.
Forms range from specimens close to *X. elongata* in pinnule shape to distinctly bipinnafid specimens with more than one vein in each lobe.

*Dicroidium prolongatum* (Menendez) Retallack, 1977.
Venation is not visible.

*Dicroidium lancifolium* var. *lineatum* (Tenison-Woods) Retallack, 1977.
Venation is not visible.

*Dicroidium odontopteroides* var. *odontopteroides* (Morris) Gothan, 1912.
Venation obscure. Some species are close to *D. lancifolium* var. *lancifolium* (Morris) Gothan, 1912.

*Dicroidium odontopteroides* (Morris) Gothan var. *moltenense* Retallack, 1977. Venation obscure.

*Dicroidium odontopteroides* var. *X.*
Venation obscure to clear. Uniperinate with constricted basal pinnae. Resembles *D. odontopteroides* var. *remotum* (Szajnocha) Retallack, 1977, but pinnae are more widely spaced.

*?Johnstonia* sp. cf. *J. stelzneriana* var. *stelzneriana* (Geinitz) Frenguelli, 1943. Some specimens are clearly unipinnafid but the majority are deeply incised and probably are unipinnate.

### REDSIDE [EP218010]

Fossil leaves are preserved in grey silty mudstone below the top quartz sandstone bench. Venation is preserved except on possible *Dictyophyllum* specimens which underlie the main fossiliferous bed. The horizon is within Rsq'.

*?Dictyophyllum* sp.
Numerous cylindrical moulds 1 mm or less lie along bedding plains and also cut obliquely through the bedding and are accompanied by iron stained zones which occasionally have sharply defined edges resembling *Dictyophyllum davidii* Walkom, 1917.

*Sphenobaiera ugotheriensis* Holmes, 1982.

*Phoenicopsis elongatus* (Morris) Seward, 1903.

*Dicroidium zuberi* var. *zuberi* (Szajnocha) Archangelsky, 1968.

*Dicroidium odontopteroides* var. *odontopteroides* (Morris) Gothan, 1912.

*Johnstonia stelzneriana* (Geinitz) Frenguelli var. *serrata* Retallack, 1977.

*Johnstonia stelzneriana* var. *stelzneriana* (Geinitz) Frenguelli, 1943.

MELTON MOWBRAY [EN133985]

Fossils are preserved in light grey siltstone underlying quartz sandstone of Rsq'. The outcrop is a cutting on the Lake Highway.

*Cladophlebis* sp.

*Phoenicopsis elongatus*

*Xylopteris elongata* var. *rigida* (Dun) Stipanicii and Bonetti, 1957.

*Dicroidium odontopteroides* var. *obtusifolium* Johnston, 1886.

*Dicroidium odontopteroides* var. *odontopteroides* (Morris) Gothan, 1912.

*Dicroidium odontopteroides* var. *moltenense* Retallack, 1957.

*?Lepidopteris.*

QUARRY 1.6 km WEST OF YORK PLAINS

A collection from this locality held in the Department of Mines may have been collected by P.B. Nye about 1921. The fossils are preserved in medium-grained quartz sandstone, probably Rsq'. The specimens range from the more elongate pinnule forms of *Dicroidium odontopteroides* var. *odontopteroides* (Morris) Gothan, 1912 to *Dicroidium odontopteroides* (Morris) Gothan var. *moltenense* Retallack, 1977.

MIDLAND HIGHWAY - SPRING HILL [EP213023]

Well preserved leaves occur in olive-grey sandy mudstone exposed above the bench on the eastern side of a large road cutting on the Midland Highway.

*Sphenobaiera tenuifolia* (Johnston) Jain and Delevoryas, 1967.

*Dicroidium odontopteroides* (Morris) Gothan var. *moltenense* Retallack, 1977.

*Dicroidium odontopteroides* var. *obtusifolium* Johnston, 1886.

*Dicroidium odontopteroides* (Morris) Gothan, 1912 var. *Y*. The specimen is incomplete but possesses large constricted basal pinnae and slightly constricted pinnae above the fork.

*Johnstonia coriacea* var. *coriacea* (Johnston) Walkom, 1925.

*Johnstonia stelzneriana* (Geinitz) Frenguelli var. *serrata* Retallack, 1977.

*Philophorosperma* sp.

sphenopsid nodal diaphragm.

LONDON INN - SPRING HILL [EP212023]

Strzelecki (1845) noted *Pecopteris australis* and *Zeugophyllites* occurred in shale overlying coal in a well section at the London Inn.

Johnston (1888) lists the following occurring in blackish carbonaceous shale.

*Thinnfeldia obtusifolia* (R.M. Johnston)

*Thinnfeldia media* (Tenison-Woods)

*Sphenopteris elongata* (Carr)

*Trichomaniides ettenghauseni* (R.M. Johnston)

*Taeniopteris tasmanica* (R.M. Johnston)

*Rhacophyllum coriaceum* (R.M. Johnston)

*Sphenozamites(?) feistmantellii*

The following species were collected from dark grey carbonaceous micaceous shale underlying quartz sandstone immediately south of the well section.

*Dicroidium odontopteroides* var. *odontopteroides* (Morris) Gothan, 1912.

*Dicroidium odontopteroides* var. *obtusifolium* Johnston, 1886

*Dicroidium odontopteroides* var. *moltenense* Retallack, 1977.

*D.* sp. cf. *D. odontopteroides* var. *argenteum* Retallack, 1977.
The specimen is too incomplete for confident identification.

*Johnstonia stelznerian* var. *serrata* Retallack, 1977.

*Johnstonia coriacea* var. *coriacea* (Johnston) Walkom, 1925.

*?Taeniopteris* sp.

*Strzeleckia gangamopteroides* Johnston, 1895.

APSLEY [EP121038]

The fossils occur as a diffuse white colouration on grey mudstone interbedded with quartz sandstone exposed above farm road. The horizon is in unit Rsq', and contains *Dicroidium* spp.

LOVELY BANKS [EP185088]

The fossils occur in dark grey micaceous muddy siltstone exposed in the northern gutter of the access road to 'Lovely Banks' where the road leaves the Midland Highway. The horizon occurs in unit Rs and probably near the base of the interbedded quartz arenite and lutite unit (Rsq'), providing no faults occur in the valley of Serpentine Creek to the east.

*Dicroidium odontopteroides* (Morris) Gothan, 1912.

A single specimen of *Dicroidium odontopteroides* was found in quartz sandstone of Ꝛs near EP187190.

ST PETERS PASS [EP337210]

Fossils occur in grey claystone exposed in low road cuttings on the Midland Highway. Horizon is in Ꝛsq'.

*Phoenicopsis elongatus*

*Sphenopsid stems*

SPRING HILL [EP215035]

Fossils are well preserved in olive claystone. The horizon is immediately above or towards the top of Ꝛsq'.

*Phoenicopsis elongatus*

Stems, leaves and nodal diaphragms of sphenopsids

Wood

SPRING HILL [EP214040]

Fossils occur in siltstone and claystone at several horizons in the large Midland Highway road cutting. The horizons all lie in the lutite dominated sequence with quartz-rich lithic sandstone between Ꝛsq' and the volcanic lithic arenite (Ꝛg). Some horizons are dominated by sphenopsids.

Horizon about 6 m below main coal seam.

*Phoenicopsis elongatus*

*Cladophlebis australis*

*?Taeniopteris* sp.

This occurrence is dominated by *Phoenicopsis elongatus*.

A similar occurrence on the bench near the top of the cutting dips in the opposite direction and is probably faulted. *P. elongatus* was also recorded from drill holes in this sequence.

6.5 km SOUTH-EAST OF YORK PLAINS

A collection kept at the Department of Mines was probably collected by P.B. Nye about 1921. The fossils occur in brick red (baked?) fine siltstone. The horizon is probably low in Ꝛg or in Ꝛs.

*Cladophlebis australis*

*?Taeniopteris* sp.

*Pseudoectenis* sp.
The species resembles *P. eathiensis* (Richards) Seward, 1911.

MOUNT PLEASANT [EP401222]

Horizon is in cream fine-grained siltstone in unit Ꞧg exposed in a small gravel pit.

*?Cladophlebis*

*?Linguifolium*

*?Taeniopteris*

*Dicroidium odontopteroides* (Morris) Gothan, 1912.

ABYSSINIA CREEK [EN039974]

Horizon is in hard silicified thin siltstone in unit Ꞧg exposed in a creek. Bipinnifid to bipinnate *Dicroidium* and *Xylopteris* specimens are most common.

*Xylopteris elongata* var. *rigida* (Dun) Stipanicic and Bonetti, 1957.

*Xylopteris spinifolia* (Tenison-Woods) Frenguelli, 1943.

*Dicroidium prolungatum* (Menendez) Retallack, 1977.

*Dicroidium natalense* (Frenguelli) Retallack, 1977.

*Dicroidium* sp. *A*.
This species has sparse clear venation with basally constricted pinnules which resemble those of *D. dubium* var. *dubium* (Feistmantel) Gothan, 1912 on the outer side of the rachis and pinnules which resemble *D. incisum* between the rachis fork.

*Dicroidium* sp. *B*.
This species has clear uncrowded veins and some basally constricted pinnules intermediate between *D. dubium* var. *dubium* and *D. dubium* var. *australe* (Jacob and Jacob) Retallack, 1977.

*D*. sp. *C*. aff. *D. dubium* var. *dubium*.
The pinnules are basally constricted.

*D*. sp. *D*. aff. *D. dubium* var. *tasmaniense* (Anderson and Anderson) Retallack, 1977. The pinnules are slightly basally constricted.

*D*. sp. *E*. aff. *D. townrovii* Retallack, 1977.
This species is bipinnate or deeply incised bipinnifid with pinnae well separated. There is a gap of 40 mm from the fork to the first pinnae on the inner edge of the rachis and pinnae on the outer edge are about 20 mm apart.

*Ginkgoites* sp.

# APPENDIX 4

## Lithological logs of bore holes and measured sections

The logs of fully-cored diamond-drill holes and measured sections which are stratigraphically significant or enhance the lithological description of the various mapped rock units of the Oatlands Quadrangle are included in this appendix, together with a generalised stratigraphic location diagram (fig. 31).

### FORMAT OF LOGS

Commonly occurring lithologies or groups of lithologies have been listed below with an allocated numerical index number and rock description. The logs are presented as a series of depth intervals and the corresponding numerical index. This format has been chosen as it provides a convenient input for computer-generated graphic logs.

### DESCRIPTION OF LITHOLOGICAL GROUPS

| *Lithological group* | *Description* |
|---|---|
| 1 | Medium grey, less commonly light grey mudstone or silty mudstone. |
| 2 | Medium grey, rarely light grey or olive mudstone with fine to coarse siltstone laminae. Rippled siltstone laminae are rare. |
| 3 | Grey or olive-grey siltstone or muddy siltstone. |
| 4 | Thick or thin subordinate sandstone laminae in grey lutite. Some starved ripples or rippled, thick laminae may be present. |
| 5 | From 40-80% sandstone laminae and very thin sandstone beds in grey lutite. Sandstone commonly ripple laminated, sometimes flaser bedded. Common soft sediment deformation. |
| 6 | Interbedded and interlaminated grey or olive-grey mudstone with thin dark grey beds approximately at one metre spacing. |
| 7 | Medium, occasionally thinly or thickly interbedded mudstone and siltstone or mudstone with siltstone laminae. Generally light to light-medium grey, rarely medium grey in colour. |
| 8 | Grey lutite with sandstone laminae and very thin beds, interbedded with mudstone and siltstone or mudstone with siltstone laminae. Sandstone beds form <7% of interval. |
| 9 | From 25-50% very thinly to thickly bedded fine-grained or very fine-grained sandstone interbedded with lutite with sandstone laminations and lutite without sandstone laminations. Commonly medium grey in colour. |
| 10 | Dark grey (rarely black) to medium dark grey mudstone, muddy siltstone or interlaminated mudstone and siltstone. |

Appendix 4 (continued).

| *Lithological group* | *Description* |
|---|---|
| 11 | Similar to category 10 but with sandstone laminae 5-20% (rarely 40%). |
| 12 | Fine to medium-grained lithic sandstone, rarely with very fine-grained or coarse-grained lithic sandstone. Common tendency to become finer grained near top of intervals. Mud pellets sometimes present. |
| 13 | Medium-coarse to fine-grained crossbedded lithic sandstone. One-third of intervals show a degree of upward grain size reduction but only rarely is there a reduction in depositional structures to ripple lamination. |
| 14 | Ripple laminated fine-grained lithic sandstone. |
| 15 | Planar laminated or thin to medium planar bedded fine and/or medium-grained lithic sandstone. Rippled laminated sandstone present in some intervals. |
| 16 | Lithic siltstone or very fine-grained sandstone intervals generally with ripple lamination near the base and planar lamination near top. Buff coloured when weathered. Intervals thicker than one metre tend to contain large (>0.5 m) carbonate concretions. Thin light grey mudstone beds or laminae occasionally present. |
| 17 | Interlaminated to thinly interbedded coarse lithic siltstone and fine-grained siltstone, muddy siltstone or mudstone. The weathered coarse siltstone laminae range from buff to medium grey-buff in colour whilst the finer grained laminae are darker in colour. Carbonate concretions may be present. |
| 18 | Transitional zones consisting of thinly interbedded buff weathering lithic siltstone or very fine-grained lithic sandstone and medium grey mudstone or mudstone with silt laminae at one end of the zone. Mudstone forms 25% of the rock in beds 25 mm thick. The mudstone proportion rises to 60% at the other end of the zone where the mudstone beds are 25 to 50 mm thick. |
| 19 | Transitional fining upward bed, passing up from medium-grained through fine-grained siltstone to mudstone, generally with a corresponding upward darkening of colour. When weathered, typically buff, grey-buff or medium grey at the base and dark grey at the top. Fossil leaves sometimes present. Overlies types 16, 17 or 18. |
| 20 | Medium to thickly interbedded (270-500 mm) types 16 and 17 and lesser lithic sandstone. |
| 21 | Very thinly to thickly (<0.62 m) interbedded lithic sandstone and lutite, generally mudstone. Some medium bedded lithic sandstone always present. |

Appendix 4 (continued)

| *Lithological group* | *Description* |
|---|---|
| 22 | Consists of single or repetitive intervals 2.52-5.0 m thick which commence with a sharp based lithic sandstone and pass up into lutite. Three thinner intervals (1.2-1.35 m) have been included which may represent eroded examples of the fuller sequence. The basal sandstone is 0.7 m to 1.5 m thick (one exception 0.35 m) and is massive, planar or wavy bedded, generally is fine to medium-grained and commonly contains mud pellets. Rarely the basal sand grain-size may reach medium to coarse-grained or not exceed fine-grained, but it never shows large scale (>100 mm) crossbedding. The basal sandstone fines upward and is rapidly or gradually replaced by lutite, frequently by an increase in the frequency of lutite laminae until eventually sandstone and siltstone laminae are subordinate to finer lutite. Some cycles consistently fine upwards, others only generally fine upwards and some coarsen towards the top as overlying sandstone is approached. The lutite may contain very fine to fine-grained sandstone beds <40 mm and rarely up to 100 mm thick, which may be rippled, but generally the lutite consists of light grey to light-medium grey interlaminated to thinly interbedded mudstone and siltstone with occasional fine-grained sandstone laminae. Less commonly medium or dark grey fissile mudstone, leaf fossils, bioturbation or soft sediment deformation may be present. |
| 23 | Single or repetitive thin (0.27-2.2 m, commonly 0.4-1.75 m) fining upward cycles. Most cycles commence with fine to medium-grained lithic sandstone 0.1-0.7 m, commonly 0.2-0.5 m thick and grade up through interlaminated (rarely interbedded) siltstone and fine-grained sandstone, massive or laminated siltstone to generally interlaminated siltstone, muddy siltstone or mudstone. Occasionally cycles may pass up into claystone. Most cycles are laminated, the laminae are clearly defined to diffuse. Lutite exceeds arenite and is generally light grey to medium grey in colour. In sequences composed of such cycles similar cycles occur commencing with basal interlaminated sandstone and siltstone and have been included in this category. Coarser, medium to coarse-grained sandstone and coarse-grained sandstone less frequently forms the base of some cycles. Such basal sandstone tends to be thin (<0.2 m) and rarely contains mud pellets. |
| 24 | Similar cycles to type 23 but with finer grained base and dark, very carbonaceous top. Cycles 0.7-1.75 m (rarely 2.0 m) thick, basal bed 0.1-0.67 m thick consists of coarse siltstone to fine-grained sandstone, rarely fine to medium-grained sandstone which in some cases is laminated or ripple laminated. Cycle passes up through finer grained rocks, siltstone or laminated or interbedded mudstone and siltstone to dark grey carbonaceous mudstone or rarely coal in high stratigraphic horizons. |

Appendix 4 (continued)

| *Lithological group* | *Description* |
|---|---|
| 25 | Fining upward sequences 0.46-4.5 m thick in which basal arenaceous portion (40-400 mm thick) occurs as very thin sandstone beds (<40 mm) or laminae or is generally only a minor (<7%) component of the sequence compared to lutite. Because of the fine grain size of the arenite it has not always been possible in hand specimens to distinguish sequences with quartzose arenite from the more common lithic arenite. The sequence bases contain very fine-grained to fine-grained sandstone which is occasionally rippled, or less commonly coarse siltstone. The middle portion of the sequences may contain some arenaceous laminae but the top portion normally consists of light grey to medium grey mudstone or mudstone with silty laminae. |
| 26 | Similar to type 25 but medium-dark grey to black upper part is always present. |
| 27 | Somewhat artificial category similar to type 25, except that no gradual transition separates the arenaceous base from the generally mudstone top. Sequences are thin (0.32-1.1 m) with 6-33% arenaceous base. Lutite tops are medium-dark grey to black in colour in DDH SH5 but generally lighter coloured elsewhere. |
| 28-31 | Intervals of white fine to medium-grain quartz sandstone with partings, laminae, thin beds or mud pellets of dark grey carbonaceous lutite. Some sandstone grey due to dispersed carbonaceous grains or plant fragments. Intervals commonly fine upward and pass gradationally into overlying rocks. The following bedding styles are indicated:<br>28 cross-bedded<br>29 rippled fine-grained sandstone<br>30 thinly planar bedded or planar laminated, rarely with ripple lamination<br>31 massive or unresolvable structure. |
| 32 | Very thinly to thinly-interbedded quartz sandstone and medium-dark to black lutite rich beds. Sandstone beds commonly form about 30% of the interval but range from 5% to 50%. Ripple lamination present in some sandstone beds. Rarely medium-bedded sandstone may be present. |
| 33 | Similar to 32 but >50% sandstone, commonly about 70% sandstone. Sandstone beds 100-250 mm thick present in all intervals. |
| 34 | Quartz sandstone generally fine to medium-coarse grained, less commonly with very fine-grained or coarse-grained intervals. Lamination sometimes accentuated by micaceous and graphitic partings or light to medium grey-green weathering siltstone. Structure unresolvable.<br>35 crossbedded, beds 80-350 mm (rarely 600 mm) thick<br>36 ripple laminated |

Appendix 4 (continued)

| *Lithological group* | *Description* |
|---|---|
| | 37 Thinly bedded dominantly planar-laminated<br>38 Massive |
| 39 | Multiple and occasionally single cross-bedded quartz sandstone cycles which in a general way fine upward. Individual cycles are generally two to four metres thick but range from one to five metres thick. Cycles commence with cross-bedded fine to medium-grained sandstone in sets 0.08 m to 0.60 m (rarely one metre) thick. Mud pellets are sometimes present. Ripple laminated, planar-laminated or small scale (<100 mm) dune cross-bedded beds are usually present near the tops of cycles. Tops of cycles consist of fine or very fine-grained sandstone or occasionally very thin sandstone beds in lutite or interlaminated siltstone and mudstone. Included are similar cycles below 51 m in DDH BOTHWELL 2 which are medium to very coarse-grained at the base and fine to medium-grained to medium-grained at the top. |
| 40 | Interbeds 0.25-0.50 m (rarely 0.75 m) thick of ripple laminated, planar-laminated, low angle cross-bedded and massive generally fine-grained sandstone. Fine to medium-grained and medium-grained sandstone is less common. Common thin zones or partings with siltstone laminae. Intervals <0.25 m thick consist of fine-grained quartzose sandstone. |
| 41 | Similar to type 40 but with numerous lutite laminae in sandstone and thin lutite rich zones between some sandstone beds. |
| 42 | Thin intervals of subordinate (15-25%) thin to medium (40-260 mm) beds of fine to very fine-grained sandstone in lutite. All intervals contain some sandstone beds >120 mm thick. Sandstone is generally ripple-laminated, less frequently planar-laminated or rarely cross-bedded. Some sandstone beds fine upward into overlying lutite. Most commonly the interbedded lutite consists of interlaminated siltstone and mudstone or interlaminated fine or very fine-grained sandstone, siltstone and mudstone. Very thin (<40 mm) beds of sandstone may occasionally be present. Massive mudstone or siltstone is less common. The lutite-rich intervals are normally micaceous and light-medium grey in colour but medium grey or rarer darker coloured lutite is present in some intervals. Two characteristic lutite-rich lithologies form a subordinate portion of some intervals. These lithologies are lustreous, micaceous medium to dark grey lutite and light grey-blue (or green) lutite which rapidly weathers to orange-brown colours. Intervals consisting of a major proporation of these lithologies have been treated separately. |
| 43 | Intervals of characteristic micaceous lustreous medium to dark grey lutite-rich rocks interbedded with 5-25% (rarely 40%) sandstone beds 50-350 mm thick. Generally the lutite-rich rock is interlaminated muddy siltstone, |

Appendix 4 (continued)

| *Lithological group* | *Description* |
| --- | --- |
| | siltstone and sandstone and may include very thin sandstone beds, although some lutite-rich rocks consist solely of muddy siltstone or less commonly may include interlaminated muddy siltstone and siltstone. Commonly sandstone/lutite laminae appear crenulate due to load deformation or mud drapes over ripples. Depicted intervals <200 mm thick contain no sandstone beds. |
| 44 | Intervals containing predominately light grey to light-blue-grey or light green-grey lutite and 0-10% (rarely 30%) sandstone in beds generally <120 mm thick. Sandstone beds may be ripple laminated and occasionally fine upwards into overlying lutite. The unweathered lutite colour is characteristic and upon weathering changes to orange or green hues. Also characteristic is the common occurrence of dewatering structures. Lutite consists of beds or interlaminations of muddy siltstone and mudstone. Sand laminae occur in some beds. Lamination is well defined to obscure and sometimes totally obliterated to form a clotted texture with pods of sand. |
| 45 | Intervals containing about 50% very fine-grained and fine-grained sandstone beds 150-500 mm (average 300 mm) thick. Sandstone beds may grade up or down or pass abruptly into light grey to medium grey micaceous lutite-rich zones which usually include laminae of sandstone or less frequently thin (<50 mm) sandstone beds. Such laminae and thin beds are often also ripple laminated. Some lutite-rich zones or portions of zones consist solely of siltstone, muddy siltstone or interlaminated siltstone and mudstone. Dark grey mudstone rarely occurs. |
| 46 | Intervals containing 15-30% very fine-grained and fine-grained sandstone in beds <100 mm thick. Sandstone beds are sometimes ripple laminated and tend to form parts of fining upward cycles 0.15-1.0 m thick. Lutite portion of intervals commonly is micaceous medium grey silty mudstone usually with sandstone laminae. Dark grey mudstone is generally rare but may be common in particular intervals. |
| 47 | Usually solitary fining upward sequences commencing with a basal quartzose sandy horizon 150-500 mm thick which forms 12-20% of the sequence. One exceptional sequence has a basal sandy horizon 1.05 m thick which forms 25% of the sequence. In the coarsest examples the basal sandstone consists of fine-grained sandstone, but generally some siltstone or very fine-grained sandstone or even mudstone is present. Occasionally the sandstone is ripple laminated. In some sequences there is a short transition into an overlying lutite-rich zone consisting of mudstone or muddy siltstone or similar rocks with sand laminae. In other sequences the upward transition is more gradual and very thin sandstone beds may be present in the transitional interval. The lutite tends to be light grey or rarely light medium grey in colour with common blue or green-grey portions which rapidly weather orange or green. |

| *Lithological group* | *Description* |
|---|---|
| | Some water escape structures may be present. Thin fining upward sequences in DDH JERICHO 2 have been interpreted as remnants of eroded cycles. |
| 48 | Fining up intervals about 1.0-1.5 m thick with basal quartzose sandstone 0.36-0.55 m thick forming 30-50% of the sequence. The basal sandstone is fine or medium-grained and may fine up to very fine-grained sandstone. Cross-bedding with mud pellets or ripple lamination may be present. Grades up through lutite with laminae or very thin beds of sandstone which may be rippled into medium or dark grey mudstone or muddy siltstone which may be laminated. |
| 49 | Bituminous coal. |
| 50 | Dolerite. |
| 51 | Interbedded cross-bedded quartzose sandstone (>60%) and lutite-rich beds. |
| 52 | Very thinly to thinly interbedded medium-dark to black lutite-rich beds and lithic sandstone beds. |
| 53 | Poorly sorted muddy sandy siltstone, silty fine-grained sandstone and mudstone generally medium to thickly interbedded with granules and lonestones. Usually bioturbated and hydroplasticly deformed. |

MEASURED SURFACE SECTION 1

*Location:* Midland Highway, Spring Hill [EP214038 to EP215041]

| *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* |
|---|---|---|---|---|---|
| 0 - 6.31 | 7 | 18.01-18.13 | 10 | 32.62-33.17 | 19 |
| 6.31- 6.41 | 10 | 18.13-19.53 | 1 | 33.17-35.43 | 17 |
| 6.41- 7.17 | 49 | 19.53-19.63 | 17 | 35.43-36.37 | 19 |
| 7.17- 8.25 | 18 | 19.63-20.18 | 1 | 36.37-38.08 | 16 |
| 8.25-10.73 | 20 | 20.18-20.40 | 49 | 38.08-39.73 | 21 |
| 10.73-11.47 | 18 | 20.40-21.59 | 2 | 39.73-40.28 | 1 |
| 11.47-11.59 | 49 | 21.59-23.21 | 20 | 40.28-41.14 | 30 |
| 11.59-12.64 | 18 | 23.21-24.26 | 10 | 41.14-41.61 | 9 |
| 12.64-13.42 | 10 | 24.26-25.72 | 7 | 41.61-41.85 | 19 |
| 13.42-13.76 | 13 | 25.72-27.15 | 13 | 41.85-43.56 | 18 |
| 13.76-14.71 | 10 | 27.15-27.30 | 49 | 43.56-44.39 | 10 |
| 14.71-14.81 | 16 | 27.30-27.93 | 1 | 44.39-44.67 | 29 |
| 14.81-15.48 | 10 | 27.93-28.44 | 19 | 44.67-45.53 | 10 |
| 15.48-15.95 | 16 | 28.44-29.08 | 16 | 45.53-46.71 | 32 |
| 15.95-16.29 | 1 | 29.08-30.42 | 17 | 46.71-47.26 | no exposure |
| 16.29-17.65 | 16 | 30.42-30.61 | 10 | 47.26-48.65 | 32 |
| 17.65-18.01 | 1 | 30.61-32.62 | 16 | 48.65-52.87 | 6 |

*Notes:* Most mudstone layers are medium grey or olive-medium grey (*e.g.* 17.65-20.18 m) in colour. Darker coloured mudstone is indicated - that below 44.67 m slight brown hue. Sandstone notably lenticular 9.64-10.10 m and 44.39-44.67 m. Several horizons with fossil leaves between 7.17 m and 13.76 m.

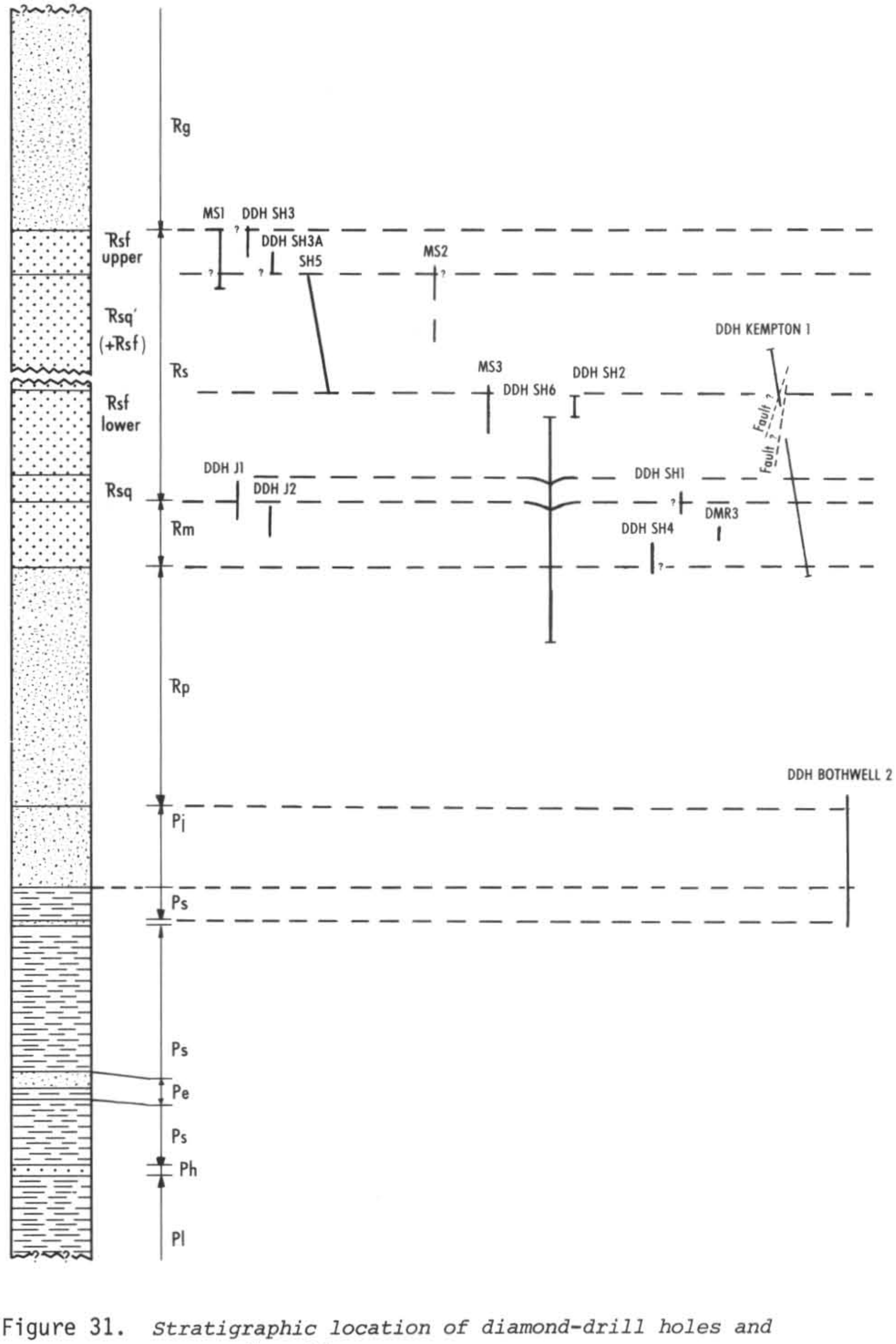



Figure 31. *Stratigraphic location of diamond-drill holes and measured sections.*



5 cm

Appendix 4 (continued)

## MEASURED SURFACE SECTION 2

*Location:* Midland Highway, Spring Hill [EP214033]

| *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* |
|---|---|---|---|---|---|
| 0 - 6.0 | 1 | 14.4 -14.7 | 31 | 49.49-49.78 | 10 |
| 6.0 - 6.5 | 3 | 14.7 -16.7 | 29 | 49.78-50.26 | 31 |
| 6.5 - 7.75 | 1 | 16.7 -24.0 | 28 | 50.26-52.35 | 10 |
| 7.75- 9.2 | poorly exposed | 24.0 -25.8 | 10 | 52.35-55.22 | 6 |
| | | 25.8 -37.46 | not exposed | 55.22-56.08 | 10 |
| 9.2 -10.2 | 12 | 37.46-41.47 | 9? poorly exposed | 56.08-59.23 | 28 |
| 10.2 -10.4 | not exposed | | | 59.23-61.38 | 6 |
| 10.4 -12.7 | 28 | 41.47-43.48 | 10 | 61.38-61.80 | 30 |
| 12.7 -14.0 | 31 | 43.48-49.49 | 28 | | |
| 14.0 -14.4 | 28 | | | | |

*Notes:* *Phoenicopsis elongatus* and sphenopsid plant fossils occur in the top interval and *Dicroidium* sp. occurs in the interval 6.5-7.75 m. Large (>0.5 m) lithic sandstone carbonate concretions occur near 4.5 m and 9.0 m. Smaller concretions occur in the bed at 6.0-6.5 m. An erosional scour or fault occurs at 43.48 m and a fault occurs above the fining-up sandstone horizon at 56.08 m. The sandstone bed at 49.78-50.26 m is notably lenticular.

## MEASURED SURFACE SECTION 3

*Location:* Midland Highway, Spring Hill [EP213032]

| *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* |
|---|---|---|---|---|---|
| 0 - 7.49 | 10 | 14.13-18.05 | 17 | 34.20-38.51 | 22 |
| 7.49- 9.49 | 13 | 18.05-21.59 | 6 | 38.51-42.14 | 7 |
| 9.49-11.61 | 16 | 21.59-23.59 | 13 | 42.14-42.32 | 12 |
| 11.61-11.90 | 13 | 23.59-25.59 | 16 | 42.32-42.94 | 7 |
| 11.90-12.43 | 5 | 25.59-28.61 | 22 | 42.94-43.00 | 10 |
| 12.43-12.88 | 12 | 28.61-31.20 | 26 | 43.00-43.44 | 3 |
| 12.88-14.13 | 16 | 31.20-34.20 | 13 | | |

*Notes:* The sandstone from 7.49-9.49 m is quartz rich and fines upward, but layers with quartz granules are found throughout. Quartz includes white, stained pink and pink varieties and reaches 10 mm size at the base. The base of the interval 14.13-18.05 m fines up from a 180 mm medium-grained sandstone bed with mud pellets. A medium bed of very hard sandstone has been included at the top of the interval. All type 16 siltstone intervals (9.49-11.61 m, 12.88-14.13 m, and 23.59-25.59 m) include finer grained rocks near the interval tops. *Dicroidium odontopteroides* and sphenopsids occur near 42.00 m.

Appendix 4 (continued)

DDH KEMPTON 1

*Location:* EN174951
*Collar height:* 245.3 m
*Average bedding intersection angle:* 73°

| *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* |
|---|---|---|---|---|---|
| 0 -21.00 | NR | 74.70- 75.90 | 23 | 111.60.111.75 | 43 |
| 21.00-23.90 | 10 | 75.90- 76.20 | 41 | 111.75-113.50 | 36 |
| 23.90-27.45 | 30 | 76.20- 78.10 | 2 | 113.50-115.90 | 38 |
| 27.45-28.40 | 1 | 78.10- 79.45 | 23 | 115.90-120.30 | 47 |
| 28.40-29.00 | 4 | 79.45- 80.95 | 22 | 120.30-121.20 | 4 |
| 29.00-30.00 | 1 | 80.95- 82.30 | 23 | 121.20-121.85 | 36 |
| 30.00-32.00 | NR | 82.30- 85.45 | 12 | 121.85-122.70 | 43 |
| 32.00-32.18 | 1 | 85.45- 89.60 | 47 | 122.70-124.15 | 40 |
| 32.18-32.33 | 4 | 89.60- 89.90 | 1 | 124.15-127.20 | 33 |
| 32.33-32.60 | 32 | 89.90- 91.33 | 24 | 127.20-132.05 | 42 |
| 32.60-34.05 | 29 | 91.33- 91.90 | 42 | 132.05-133.42 | 48 |
| 34.05-34.35 | 1 | 91.90- 92.60 | 36 | 133.42-134.70 | 46 |
| 34.35-35.20 | 4 | 92.60- 93.80 | NR | 134.70-135.25 | NR |
| 35.20-35.55 | 1 | 93.80- 94.00 | 36 | 135.25-139.45 | 43 |
| 35.55-36.50 | 4 | 94.00- 94.30 | 34 | 139.45-141.00 | 3 |
| 36.50-37.00 | NR | 94.30- 94.65 | NR | 141.00-143.85 | 46 |
| 37.00-37.30 | 4 | 94.65- 95.10 | 10 | 143.85-144.25 | 36 |
| 37.30-38.30 | 5 | 95.10- 95.90 | 34 | 144.25-147.42 | 46 |
| 38.30-39.82 | 12 | 95.90- 96.70 | 36 | 147.42-147.83 | 40 |
| 39.82-41.60 | 31 | 96.70- 98.60 | 35 | 147.83-149.62 | 46 |
| 41.60-43.00 | 28 | 98.60- 99.60 | 25 | 149.62-150.95 | 40 |
| 43.00-43.50 | 10 | 99.60-100.45 | 2 | 150.95-152.20 | 50 |
| 43.50-48.00 | NR | 100.45-102.30 | 23 | 152.20-154.92 | 47 |
| 48.00-50.25 | 11 | 102.30-106.80 | 22 | 154.92-167.20 | 50 |
| 50.25 | Fault | 106.80-107.95 | 9 | 167.20-167.83 | 43 |
| 50.25-51.00 | 12 | 107.95-109.08 | 8 | 167.83-169.90 | 46 |
| 51.00-66.90 | 22 | 109.08-109.30 | 10 | 169.90-175.47 | 45 |
| 66.90-67.70 | 23 | 109.30-109.50 | 34 | 175.47-179.08 | 39 |
| 67.70-69.30 | 25 | 109.50-109.70 | 10 | 179.08-180.93 | 36 |
| 69.30-69.90 | 24 | 109.70-109.80 | 11 | 180.93-186.20 | 40 |
| 69.90-71.88 | 23 | 109.80-110.25 | 36 | 186.20-192.05 | 50 |
| 71.88-73.20 | 25 | 110.25-110.50 | 5 | 192.05-194.80 | 34 |
| 73.20-74.70 | 26 | 110.50-111.60 | 36 | 194.80-250.00 | 50 |

NR = interval not recovered

*Notes:* Burrows or other bioturbation or probable bioturbation occurs in some beds between 98.60-102.30 m, and 109 m, at less than four metre intervals between 131.95-148.00 m and between 146.50-148.00 m. Other bioturbation may be present but concealed by soft sediment deformation. Vitreous black grains (possibly coal) were derived from above the cored interval (*i.e.* above 21.00 m). Coalified plant material occurs at 26.50 m, 50.25 m, 54.55 m and 73.20 m. Sphenopsid stems occur at 69.30 m and other plant fragments at 132.10 m, 145.80 m, and 167.50 m and between 34.35-35.20 m. The interval 29.00-34.05 m with core loss resembles a fining-up cycle 22 but has a basal lithic and feldspar-rich quartz sandstone. The interval 35.20-43.00 m fines upward with a gradual increase in lithic sand content. The interval 89.90-91.32 m has a very quartz-rich lithic sandstone at the base.

Between 106.8-109.8 m the lutite is intermediate in character between that of type 10 and type 43. The interval 127.20-121.85 m is a sequence of quartzose sandstone interbedded with subordinate type 43 lutite. Below 124.30 m the sandstone is medium to thickly bedded and crossbedded. Above 124.30 m the sandstone is ripple-laminated, initially thickly bedded, but thinly bedded at the top. The interval 144.25 m to 139.45 m, possibly to 138.80 m, may be considered to form a single fining-upward sequence. The dolerite intrusive contacts make the following angles with bedding;

| | | | |
|---|---|---|---|
| 150.95 m | 45° | 167.20 m | 0° |
| 152.20 m | >45° | 186.20 m | ∿0° |
| 154.92 m | 0° | | |

DDH DMR MIDLAND HIGHWAY 3

*Location:* Midland Highway, north-east of Melton Mowbray [approximately EP173003]

| *Depth (m)* | *Lithological group* |
|---|---|
| 0.8 - 1.40 | 3 |
| 1.40- 1.55 | 40 |
| 1.55- 2.40 | 3 |
| 2.40- 4.00 | 38 |
| 4.00- 5.57 | 9 |
| 5.57- 8.25 | 39 |
| 8.25-12.30 | 7 |

*Notes:* The interval 0.8-4.00 m is a gradually fining-upward sequence in which the erosive sandstone fines from fine-grained to very fine-grained. The interval 8.25-12.30 m consists of thickly interbedded mudstone, muddy siltstone and siltstone. Mudstone is generally medium or dark grey coloured, but below 10.18 m some mudstone has green blotches and grey-purple colours.

DDH JERICHO 1

*Location:* EP212087

| *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* |
|---|---|---|---|
| 0.81- 2.46 | 21 | 12.84-15.91 | 35 |
| 2.46- 3.20 | 4 | 15.91-18.60 | 44 |
| 3.20- 4.42 | 50 | 18.60-20.70 | 46 |
| 4.42- 6.85 | 46 | 20.70-21.08 | 36 |
| 6.85- 7.80 | 40 | 21.08-22.20 | 46 |
| 7.80- 8.68 | 1 | 22.20-23.25 | 36 |
| 8.68- 9.60 | 34 | 23.25-24.60 | 44 |
| 9.60-10.10 | 1 | 24.60-25.54 | 1 |
| 10.10-11.82 | 35 | 25.54-26.20 | 4 |
| 11.82-12.84 | 1 | 26.20-29.29 | 39 |

*Notes:* Burrows occur between 2.46-2.90 m, 21.80-22.0 m and 25.76-26.20 m. Sphenopsids occur between 25.54-25.76 m. The interval from 4.42-6.85 m consists of medium-dark grey coloured silty mudstone with lithic sandstone. Between 8.68 m and 15.81 m the sandstone is quartzose, medium to very coarse-grained with many layers of white and pink quartz granules. Characteristic type 43 lutite occurs in the interval 25.44-26.20 m.

Appendix 4 (continued)

DDH JERICHO 2

*Location:* EP210083

| *Depth (m)* | *Lithological group* |
|---|---|
| 5.80- 8.36 | 4 |
| 8.36- 8.40 | 40 |
| 8.40- 9.60 | 4 |
| 9.60-11.83 | 5 |
| 11.83-12.95 | 36 |
| 12.95-17.05 | 47 |
| 17.05-20.00 | 41 |
| 20.00-20.40 | 36 |
| 20.40-26.27 | 44 |
| 26.27-27.03 | 36 |
| 27.03-28.49 | 44 |

*Notes:* Light purple-pink coloured lutite laminae occur 18.30-18.40 m with further minor pink lutite between 24.40-28.49 m. The interval 5.80-12.95 m is interpreted as a single fining-up sequence.

DDH SPRING HILL 1

*Location:* EP197009

| *Depth (m)* | *Lithological group* |
|---|---|
| 0.40- 1.30 | 1 |
| 1.30- 2.50 | 34 |
| 2.50- 2.73 | 2 |
| 2.73- 3.25 | 35 |
| 3.25- 3.40 | 2 |
| 3.40- 3.60 | NR |
| 3.60- 4.00 | 35 |
| 4.00- 5.42 | 39 |
| 5.42- 6.40 | 7 |
| 6.40- 8.20 | 39 |
| 8.20- 9.75 | 7 |
| 9.75-10.10 | 2 |
| 10.10-11.15 | 48 |
| 11.15-11.72 | 41 |
| 11.72-12.75 | 48 |
| 12.75-13.90 | 44 |
| 13.90-15.80 | 4 |
| 15.80-18.48 | 5 |

*Notes:* Burrows occur at 2.60 m, 10.10-10.50 m and 16.35-18.48 m, and other possible bioturbation at 12.10-12.20 m. The lutite below 13.90 m is medium-dark grey coloured and slightly micaceous. Portions of this lutite partly or closely resemble the lutite of type 43. The lutite at 14.50 m partly resembles type 10 lutite and contains some poorly preserved silvery plant fragments.

Appendix 4 (continued)

DDH SPRING HILL 2

*Location:* EP212025

| *Depth (m)* | *Lithological group* |
|---|---|
| 2.65- 4.85 | 12 |
| 4.85- 5.00 | 1 |
| 5.00- 6.00 | 12 |
| 6.00- 8.10 | 7 |
| 8.10- 8.25 | 15 |
| 8.25-12.70 | 7 |
| 12.70-13.08 | 10 |
| 13.08-13.80 | 7 |
| 13.80-16.32 | 22 |
| 16.32-16.73 | 23 |
| 16.73-18.10 | 4 |
| 18.10-19.29 | 2 |

*Notes:* Some mudstone weathers to olive colours. Burrows occur at 13.80 m. Lutite horizons with plant remains are common above 15 m. *Cladophlebis* sp. and sphenopsids are present and also probably *Phoenicopsis elongatus*. Other leaves resemble *Xylopteris* and *Ginkgoites*. White and black mudstone occur in close association 12.70-13.45 m.

DDH SPRING HILL 3

*Location:* EP215042

| *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* |
|---|---|---|---|---|---|
| 2.52- 2.58 | 12 | 10.65-12.80 | 17 | 20.75-20.93 | 49 |
| 2.58- 3.20 | 1 | 12.80-13.20 | 10 | 20.93-21.70 | 10 |
| 3.20- 3.40 | 10 | 13.20-13.40 | 16 | 21.70-22.40 | 15 |
| 3.40- 4.40 | 1 | 13.40-16.00 | 26 | 22.40-22.93 | 11 |
| 4.40- 5.00 | 21 | 16.00-16.58 | 52 | 22.93-24.08 | 24 |
| 5.00- 6.18 | 12 | 16.58-17.33 | 16 | 24.08-24.95 | 25 |
| 6.18- 6.90 | 27 | 17.33-18.60 | 20 | 24.95-26.20 | 15 |
| 6.90- 8.40 | 2 | 18.60-19.10 | 52 | 26.20-26.40 | 52 |
| 8.40- 8.68 | 10 | 19.10-19.40 | 16 | 26.40-26.80 | 10 |
| 8.68- 9.60 | 16 | 19.40-20.15 | 23 | 26.80-27.35 | 52 |
| 9.60-10.65 | 27 | 20.15-20.75 | 10 | 27.35-28.34 | 7 |

*Notes:* Mudstone is generally medium grey in colour with a tendency to olive-grey tones in the upper half of the hole. Between 20.15-23.56 m (including some occurrences in type 15) the mudstone is medium-dark, dark or black in colour. Burrows were recorded in type 52 at 16.15 m and 27.8-27.35 m. Plant remains occur at 27.35-28.00 m and with coaly matter from 2.58-4.20 m.

Appendix 4 (continued)

## DDH SPRING HILL 3A

*Location:* EP214038

| *Depth (m)* | *Lithological group* |
|---|---|
| 3.0- 3.73 | 23 |
| 3.73- 4.12 | 16 |
| 4.12- 4.95 | 1 |
| 4.95- 5.45 | 21 |
| 5.45- 9.92 | 25 |
| 9.92-11.46 | 13 |
| 11.46-12.08 | 4 |
| 12.08-13.08 | 25 |
| 13.08-14.40 | 6 |
| 14.40-15.00 | 5 |
| 15.00-18.40 | 22 |
| 18.40-19.20 | 7 |
| 19.20-23.55 | 13 |
| 23.55-24 | 7 |

*Notes:* Disrupted fabric which may be caused by bioturbation occurs at 4.12-4.95 m, 6.70-7.18 m and 15.00-15.50 m. Grey mudstone at 5.7 m contains numerous sphenopsids. The interval 18.40-19.20 m continues a fining-up trend commenced in the underlying sandstone. This interval contains a layer with small (1 mm) white spheres. Several silty mudstone layers may be weathered lithic siltstone. All type 4 layers consist of light grey siltstone with laminae of lithic sandstone. Towards the bottom of the hole the lithic sandstone may be more quartzose than normal.

## DDH SPRING HILL 4

*Location:* EP207012

| *Depth (m)* | *Lithological group* |
|---|---|
| 0.08- 0.55 | 2 |
| 0.55- 0.80 | 40 |
| 0.80- 2.07 | 5 |
| 2.07- 3.40 | 47 |
| 3.40- 4.40 | 5 |
| 4.40- 5.45 | 39 |
| 5.45- 7.50 | 9 |
| 7.50- 8.95 | NR |
| 8.95- 9.20 | 4 |
| 9.20-11.60 | 2 |
| 11.60-11.90 | 35 |
| 11.90-12.45 | 41 |
| 12.45-13.23 | 44 |
| 13.23-14.35 | 36 |
| 14.35-15.10 | 4 |
| 15.10-15.35 | 2 |
| 15.35-16.34 | 51 |
| 16.34-19.32 | 40 |
| 19.32-21.02 | 38 |
| 21.02-25.00 | 39 |
| 25.00-25.23 | 3? |

*Notes:* Pink lutite is present on some horizons in the interval 6.10-7.45 m and pink very fine-grained sandstone is present in the interval 12.45-13.23 m. The interval 13.23-15.35 m is like a reversely graded cycle type 48.

Appendix 4 (continued)

DDH SPRING HILL 5

*Location:* EP2143003879
*Inclination:* 16°
*Bedding intersection angle:* 80°

| *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* |
|---|---|---|---|---|---|
| 0 - 3.18 | NR | 41.64-42.08 | 31 | 75.63-76.30 | 31 |
| 3.18- 4.17 | 24 | 42.08-42.90 | 36 | 76.30-77.18 | 11 |
| 4.17- 6.17 | 25 | 42.90-43.27 | 5 | 77.18-77.90 | 2 |
| 6.17- 7.05 | NR | 43.27-43.68 | 11 | 77.90-78.08 | 5 |
| 7.05- 7.62 | 24 | 43.68-44.40 | 4 | 78.08-78.54 | 26 |
| 7.62- 8.23 | 11 | 44.40-46.49 | 11 | 78.54-79.09 | 3 |
| 8.23- 8.31 | 15? | 46.49-47.44 | 32 | 79.09-79.51 | NR |
| 8.31- 8.90 | 29 | 47.44-48.88 | 9 | 79.51-79.69 | 10 |
| 8.90-10.43 | 28 | 48.88-48.95 | 49 | 79.69-80.75 | 9 or 8 |
| 10.43-12.96 | 22 | 48.95-49.86 | 6 | 80.75-81.00 | 10 |
| 12.96-13.28 | 25 | 49.86-50.82 | 24 | 81.00-82.13 | 9 |
| 13.28-15.66 | 12 | 50.82-51.26 | 5 | 82.13-85.05 | 29 |
| 15.66-19.22 | 22 | 51.26-51.80 | 2 | 85.05-86.23 | 8 |
| 19.22-19.82 | 5 | 51.80-52.28 | 1 | 86.23-86.49 | 31 |
| 19.82-20.61 | 2 | 52.28-52.85 | 10 | 86.49-86.58 | 5 |
| 20.61-22.03 | 26 | 52.85-53.16 | 11 | 86.58-87.39 | 33 |
| 22.03-23.24 | 5 | 53.16-53.42 | 10 | 87.39-88.43 | 32 |
| 23.24-24.50 | 26 | 53.42-54.88 | 32 | 88.43-88.80 | 9 |
| 24.50-25.70 | 26 | 54.88-55.74 | 33 | 88.80-89.04 | 10 |
| 25.70-25.97 | 5 | 55.74-56.60 | 29 | 89.04-91.17 | 9 |
| 25.97-26.40 | 2 | 56.60-57.91 | 26 | 91.17-92.29 | 27 |
| 26.40-28.65 | 12 | 57.91-61.44 | 29 | 92.29-95.45 | 25 |
| 28.65-29.77 | 10 | 61.44-61.79 | 28 | 95.45-95.80 | 7 |
| 29.77-30.59 | 32 | 61.79-61.93 | 5 | 95.80-98.41 | 31 |
| 30.59-32.72 | 33 | 61.93-62.78 | 27 | 98.41-101.50 | 28 |
| 32.72-34.00 | 29 | 62.78-64.10 | 25 | 101.50-102.45 | 31 |
| 34.00-36.58 | 31 | 64.10-66.36 | 9 | 102.45-103.92 | 1 |
| 36.58-38.86 | NR | 66.36-67.18 | 27 | 103.92-105.10 | 50 |
| 38.86-38.07 | 31 | 67.18-68.41 | 9 | 105.10-105.45 | NR |
| 38.07-38.62 | 10 | 68.41-69.90 | 29 | 105.45-160.86 | 50 |
| 38.62-39.22 | 32 | 69.90-70.56 | 28 | | |
| 39.22-39.43 | 11 | 70.56-71.50 | 32 | | |
| 39.43-41.43 | 5 | 71.50-75.41 | 31 | | |
| 41.43-41.64 | 10 | 75.41-75.63 | 4 | | |

*Notes:* The thicker quartz sandstone units generally form or are part of upward-fining units, *e.g.* the intervals 7.62-10.43 m, 28.65-38.07 m. There is no uniform reduction of grain size in the lithic sandstone portion of the interval from 13.28-15.66 m, however the upper lutite-rich portion of the interval does fine upwards. Coarsening-upward intervals occur between 19.22-20.61 m, 41.43-41.64 m and 50.82-52.28 m. Medium-dark to black mudstone is slightly more common than indicated:-

7.05-7.62 m lutite medium-dark grey in colour throughout
15.66-19.22 m top metre is medium-dark grey in colour, coalified wood present in lutite and basal sandstone

47.44-48.88 m contains dark grey lutite
10.69-12.96 m lutite includes buff, medium grey to dark grey coloured types with coalified wood present.

The sandstone at 41.64-42.08 m contains numerous mud pellets and approximately 50% quartz. The sandstone at 42.08-42.90 m contains approximately 60% quartz. Further thin laminae of coal or coalified wood occur between 17.20 m and 29.50 m, 44.79-44.93 m, 50.26-52.59 m and 66.36-72.0 m. Bioturbation occurs between 11.20-11.50 m, 19.45-19.63 m, at 26.40 m, near 54 m and in several beds between 80.32 m and 90.09 m. The following fossil leaves were observed:

*Dicroidium* sp. and *Johnstonia?* sp. at 7.8 m, *Dicroidium* sp. & *Phoenicopsis?* sp. at 10.45 m, and *Dicroidium* sp. at 95.45-95.71 m.

A faulted dolerite contact occurs at 104.92 m. Above the fault the sandstone interval from 101.56-102.38 m has a disrupted fabric and is underlain by brecciated mudstone. Dolerite breccia with clasts from one to seventy millimetres diameter occurs from 103.92 m to 104.82 m. This is underlain by intervals with coarser dolerite breccia and massive dolerite. At 108.28-108.65 m the dolerite is brecciated, but the fragments have undergone little displacement.

DDH SPRING HILL 6

*Location:* EP2123802665

| *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* |
|---|---|---|---|---|---|
| 0 -17.93 | NR | 49.45-50.32 | 12 | 89.59- 90.16 | 34 |
| 17.93-18.03 | 14 | 50.32-58.30 | 13 | 90.16- 92.08 | 44 |
| 18.03-19.05 | 2 | 58.30-58.37 | 1 | 92.08- 92.80 | 43 |
| 19.05-20.72 | 12 | 58.37-60.52 | 13 | 92.80- 95.42 | 39 |
| 20.72-21.82 | 13 | 60.52-60.87 | 3 | 95.42- 96.99 | 47 |
| 21.82-22.35 | NR | 60.87-62.85 | 4 | 96.99- 99.77 | 9 |
| 22.35-23.39 | 13 | 62.85-63.05 | 5 | 99.77-100.40 | 43 |
| 23.39-24.74 | 22 | 63.05-63.69 | 4 | 100.40-101.33 | 36 |
| 24.74-25.78 | 1 | 63.69-66.22 | 8 | 101.33-101.67 | 35 |
| 25.78-26.05 | 5 | 66.22-67.85 | 15 | 101.67-102.03 | 36 |
| 26.05-28.14 | 8 | 67.85-69.61 | 13 | 102.03-102.09 | 1 |
| 28.14-28.46 | 16 | 69.61-70.82 | 40 | 102.09-103.94 | 36 |
| 28.46-29.72 | 13 | 70.82-71.72 | 25 | 103.94-104.73 | 44 |
| 29.72-30.90 | 23 | 71.72-72.42 | 48 | 104.73-105.42 | 42 |
| 30.90-31.97 | 9 | 72.42-73.13 | 35 | 105.42-106.44 | 47 |
| 31.97-33.42 | 23 | 73.13-73.25 | 4 | 106.44-107.25 | 44 |
| 33.42-34.89 | 8 | 73.25-73.52 | 35 | 107.25-112.19 | 43 |
| 34.89-35.94 | 24 | 73.52-73.77 | 7 | 112.19-113.05 | 36 |
| 35.94-37.65 | 23 | 73.77-74.70 | 25 | 113.05-113.26 | 4 |
| 37.65-38.42 | 6 | 74.70-75.90 | 33 | 113.26-114.60 | 36 |
| 38.42-40.13 | 13 | 75.90-77.70 | 25 | 114.60-117.45 | 44 |
| 40.13-42.45 | 21 | 77.70-78.42 | 8 | 117.45-118.13 | 45 |
| 42.45-46.55 | 22 | 78.42-81.60 | 11 | 118.13-120.75 | 44 |
| 46.55-47.41 | 5 | 81.60-85.78 | 8 | 120.75-122.03 | 42 |
| 47.41-48.55 | 23 | 85.78-86.05 | 9 | 122.03-123.59 | 43 |
| 48.55-49.45 | 21 | 86.05-89.59 | 44 | 123.59-125.01 | 44 |

Appendix 4 (continued)

| *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* |
|---|---|---|---|---|---|
| 125.01-126.43 | 43 | 143.10-144.55 | 36 | 186.38-194.75 | 39 |
| 126.43-128.63 | 42 | 144.55-147.65 | 42 | 194.75-195.75 | 35 |
| 128.63-129.53 | 36 | 147.65-148.31 | 36 | 195.75-202.65 | 39 |
| 129.53-130.97 | 42 | 148.31-150.69 | 42 | 202.65-207.00 | 38 |
| 130.97-131.27 | 34 | 150.69-169.97 | 39 | 207.00-208.24 | 35 |
| 131.27-134.05 | NR | 169.97-174.85 | 38 | 208.24-209.75 | 50 |
| 134.05-138.96 | 39 | 174.85-176.78 | 4 | 209.75-212.41 | 35 |
| 138.96-140.26 | 42 | 176.78-178.00 | 35 | 212.41-214.80 | 38 |
| 140.26-141.10 | 36 | 178.00-183.53 | 39 | 214.80-219.10 | 50 |
| 141.10-142.37 | 42 | 183.53-186.38 | 38 | 219.10-221.10 | 35 |
| 142.37-143.10 | 34 | | | | |

*Notes:* Rocks with slight purple hues occur in the lower quartzose part of the sequence in type 44 at 87.40-87.57 m, 88.77-88.89 m and 91.13-91.15 m. In the upper (lithic) part of the sequence, slight purple hues are found in basically green-grey coloured lutite associated with bioturbated or probable bioturbated intervals at 18-19 m, 25.06-25.62 m, 33.42-34.22 m (some burrows down to 34.89 m) 35.46-35.77 m and 37.12-37.65 m. Traces of coalified plant remains and probable fossil roots occur in the top (18-19 m) interval and probable roots immediately below the interval at 35.93-36.29 m. Further grey-green lutite occurs in layers between 29.80-31.58 m and 61.66-61.78 m. Discrete burrows and possible fossil roots occur between 76.20-76.90 m and narrow tubes (possibly roots) between 45.37 m and 45.74 m. Elsewhere, isolated burrows, bioturbated beds or probable bioturbated beds occur above 140 m at less than 6 m intervals except between 49.45-58.30 m, 65.05-76.20 m, and 81.23-95.42 m. Coalified plant material occurs down to 66.40 m with other plant remains at 82.40 m and 144.67-145.14 m. Coalified wood may occur with mud pellets in sandstone *e.g.* 20.16-20.21 m, 23.22-23.34 m and 66.22-66.40 m and other coalified remains or leaf fossils in lutite *e.g.* 32.05 m, 62.0-62.20 m, 63.60 m, 64.75-65.05 m including medium-dark grey lutite at 32.05 m. *Dicroidium* sp. cf. *D. dubium* var. *australe* (Jacob and Jacob) Retallack, 1977, occurs at 65.69 m. The interval 36.41-37.65 m coarsens upward. Silicified quartz sandstone occurs at 70.21-70.30 m overlying 100 mm siltstone, and 131.25 m. Interval 78.42-86.05 m: the lutite is medium-dark grey and in places approaches type 43 lutite, but is finer grained with finer mica and some silvery-grey plant remains. The quartz sandstone beds are <400 mm thick and ripple-laminated except for mud-pellet conglomerate between 84.21-84.42 m and a thicker sandstone at 85.0-85.78 m which forms part of a fining-upward cycle up to 84.70 m, with small scale cross-bedding and mud pellets at the base overlain by ripple lamination and then medium grey lutite. The interval 130.00-130.39 m approximates type 43 lutite. Intervals 206.82-206.88 m and 215.57-215.80 m have been interpreted as large mudstone clasts. Intervals 176.78-186 m, 192-221.10 m: the sandstone averages medium-grain size but ranges between medium-coarse and fine-medium grain. The dolerite contact at 208.24 m is concordant, that at 209.75 m is irregular but may be concordant. Contacts at 214.80 m and 219.10 m are both inclined at approximately 45°.

Appendix 4 (continued)

DDH BOTHWELL 2

*Location:* EP0892705412

| *Depth (m)* | *Lithological group* | *Depth (m)* | *Lithological group* |
|---|---|---|---|
| 6.25- 7.10 | 38 | 35.25- 35.70 | 4 |
| 7.10- 9.00 | 34 | 35.70- 36.30 | 2 |
| 9.00-11.45 | 35 | 36.30- 37.20 | 2 |
| 11.45-14.50 | 44 | 37.20- 39.50 | 40 |
| 14.50-15.00 | 36 | 39.50- 41.25 | 36 |
| 15.00-16.20 | 44 | 41.25- 42.40 | 9 |
| 16.20-17.60 | 9 | 42.40- 50.80 | 36 |
| 17.60-18.30 | 41 | 50.80- 70.85 | 39 |
| 18.30-19.25 | 36 | 70.85- 77.65 | 38 |
| 19.25-20.10 | 5 | 77.65- 80.30 | 40 |
| 20.10-20.75 | 35 | 80.30- 80.60 | 4 |
| 20.75-22.00 | 9 | 80.60- 81.35 | 40 |
| 22.00-23.10 | 40 | 81.35- 83.30 | 9 |
| 23.10-24.20 | 47 | 83.30- 86.70 | 34 |
| 24.20-26.15 | 40 | 86.70- 88.75 | 36 |
| 26.15-31.85 | 39 | 88.75- 91.70 | 3 |
| 31.85-33.50 | 42 | 91.70-114.70 | 53 |
| 33.50-34.15 | 36 | 114.70-118.90 | see Notes |
| 34.15-35.25 | 8 | 118.90-124.0 | 53 |

*Notes:* The interval 114.70-118.90 m consists mostly of coarse-grained massive sandstone with granules. Pebble layers occur below 118.10 m and granules to large pebbles in a grey silty matrix occur at 114.70-115.20 m. Above 88.75 m the sandstone is lithic-feldspathic quartz sandstone. Above 11.45 m the sandstone is more quartzose. Irregular red-purple colouration develops on weathering near 14.0 m. The interval 16.20-17.60 m contains considerable "homogenised" light grey sandy siltstone, similarly the top of interval 20.75-22.00 m. A strongly bioturbated bed occurs at 18.00-18.20 m, bioturbation is very rare below this level to 89.20 m. The top 900 mm of the fining cycle 23.10-24.20 m is mudstone with fine silt laminae. A fining-up cycle from rippled sandstone to mudstone occurs 31.85-32.40 m. Lutite horizons at 23-37 m are medium grey in colour, 80.30-83.30 m lutite is dark grey. Type 40, 77.65-80.30 m is atypical in that it contains mostly medium-grained sandstone. Layers with granules occur between 52.6-77.65 m; at 52.60 m, 68.95-69.00 m, 69.10-69.25 m, 70.05-70.85 m, 77.40-77.65 m. Layers with pebbles occur between 69.10-86.70 m; at 69.10-69.25 m, 70.85 m, 77.40-77.65 m, 79.70 m, 86.35-86.50 m, 86.60-86.70 m. The granule and pebble occurrences normally occur at the base of fining-up sandstone cycles. The two lowest pebble beds may be separated by either a bed or clast of laminated fine-grained sandstone. Garnet occurs 6.25-9.50 m, 38.10-88.20 m and is particularly common from 51.00-79.00 m. Foraminifera tubes occur from 88.75-121.0 m. They are rare below 110 m and common to very common at 100 m, 92 m and 89 m.

# APPENDIX 5

## Reputed kimberlite occurrences : Oatlands area

*A.V. Brown*

Ferguson (1980), Ferguson and Sheraton (1979) and Stracke *et al.* (1979) refer to recently discovered kimberlite rock occurrences at Oatlands. Field work in the Oatlands Quadrangle has failed to confirm the presence of kimberlite or related rock types.

The reported occurrences originated from Stracke *et al.* (1979) on the basis of stream sediment samples containing chrome diopside and garnet concentrates. A chemical analysis of a chrome diopside concentrate from the 'Oatlands occurrence' was published by Ferguson and Sheraton (1979). The garnets were classified as kimberlitic on the basis of optical properties (pers. comm., Acting Director Bureau of Mineral Resources 6 September 1978).

Two occurrences were listed as kimberlitic. One was noted as a body of unknown shape and size [EP281182] and the other as an inferred body near Lemont [EP492139 and EP482166; Swanston Quadrangle] (pers. comm., Director B.M.R., 1 August 1978). At both localities present day streams run through Triassic sandstone and Jurassic dolerite capped by Tertiary alkali olivine basalt suite rocks.

The Triassic sandstone contains numerous heavy mineral bands with abundant garnet, and the basaltic rocks contain significant areas of high spinel lherzolite xenolith concentrations which contain chrome diopside.

The reported composition of the chrome diopside concentrate given in Ferguson and Sheraton (1979) for the Oatlands area falls within the range of chrome diopside compositions from lherzolite xenoliths from Tasmanian alkali basaltic rocks. Well rounded, presumably second cycle garnets from the Triassic sandstone, have been analysed by electron microprobe (Table 4). The pyrope content of these garnets suggests an eclogitic source.

There is no confirmatory evidence of kimberlitic rocks occurring in the Oatlands area and therefore their presence cannot be accepted.

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