PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA, VOLUME 91

A TYPE SECTION OF THE PERMIAN SYSTEM IN THE HOBART AREA, TASMANIA

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(With 9 Text Figures)

ABSTRACT

An unbroken succession of Permian sediments about 1430 feet thick on the northern flanks of Mt. Nassau, about 10 miles north-west of Hobart, Tasmania, shows the following succession of formations from the base upwards: Bundella Mudstone; Faulkner Group including the Geiss Conglomerate, Rathbones Sandstone and Siltstone, Byers Sandstone, Jarvis Siltstone, Parramore Sandstone and Siltstone, Altamont Conglomerate and Fergusson Siltstone; Rayner Sandstone; Cascades Group including the Nassau Siltstone, Berriedale Limestone and Grange Mudstone; " Woodbridge Glacial Formation "; Risdon Sandstone and finally the Ferntree Mudstone. These range in age from Lower Artinskian to Kungurian. These formations, except the " Woodbridge Glacial Formation ", are defined. The Faulkner Group consists of two cyclothems, recording two brief emergences, one soon after the other, in a time of general submergence. The Grange Mudstone and Berriedale Limestone are at least partly facies variants of one another. A notable feature is the presence of erratics, except in the two non-marine formations in the Faulkner Group, and this is perhaps related to the poor sorting, and mineralogical immaturity of the sediments and the angularity of most of the grains in all rocks. All of these features are considered as the result of glacio-marine deposition. The source area included granitic, sedimentary and regionally metamorphosed rocks.

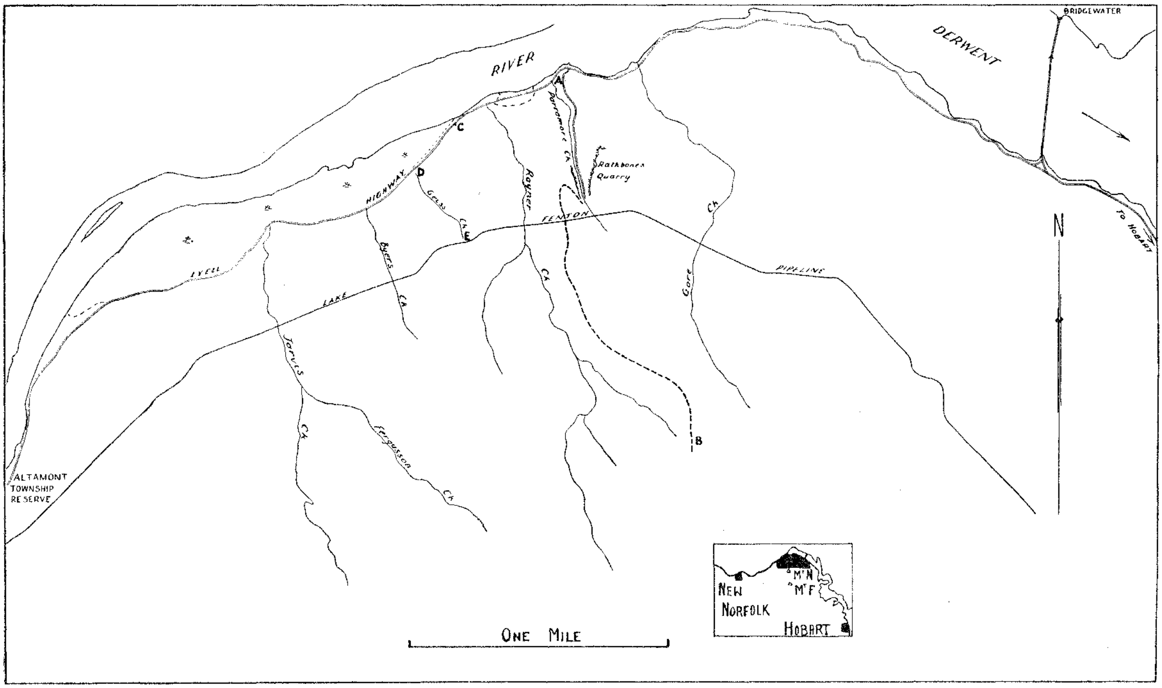


Fig. 1

N.B.—On the advice of the Nomenclature Board of Tasmania, the names of Parramore Creek and Rayner Creek should be transposed.

INTRODUCTION

Mapping of the Hobart district indicated that the Permian succession suggested by Lewis (1946) was inadequate for close mapping so that when a section was discovered which is not complicated by faulting, it was studied in some detail for use as a standard of reference. The type section lies between road level of the Lyell Highway from Rayner Creek to Geiss Creek and the base of the Knocklofty Sandstone and Shale (Triassic) on Mt. Nassau. It is all included on air photo Hobart, Run 1, No. 9744, of the Department of Lands and Surveys, Tasmania, and is shown on the map, text figure 1.

The section was initially taken from point A (see map) along Rayner Creek for a couple of hundred yards, then up the east bank across the present access road to the western quarry to the former access road to the eastern quarry and along and up this road to that quarry. From this quarry the section crosses Rayner Creek and goes up and along an old timber track which skirts the southern edge of the western quarry and goes on up the spur over the Lake Fenton Pipeline to the foot of the last slope up to Mt. Nassau at point B. All thicknesses in this section were measured by means of an Abney level as the beds have a very low dip. Attention should be drawn here to the more detailed sections of the Berriedale Limestone measured in the quarries on the eastern and western sides of Rayner Creek by Brill and published as section 4 of fig. 1 of Brill (1956). These sections were measured on the quarry faces with a tape and are thus rather more accurate than the general section. The authors' attention was directed by Mr. H. A. Bartlett to fossiliferous mudstones on the Lyell Highway at point C on the map. On investigation these proved to be well exposed and below the lowest beds in Rayner Creek. A section was therefore measured up from the gutter on the western side of the Lyell Highway just west of Parramore Creek at the eastern end of the road cutting and westwards along the cuttings to Geiss Creek and then up to Geiss Creek to the top of the well-exposed portion of the succession. The Bundella Mudstone in the road cuttings and in the lower part of Geiss Creek was measured with a steel tape but the creek section and road section are not connected by good exposures. They were joined by measuring up from the top exposures in the road cutting to the base of the Geiss Conglomerate, tracing this conglomerate around the hill slope and into the creek where the beds immediately below the Geiss Conglomerate are exposed and were measured. This leaves a gap in the section due to inadequate exposures. The beds in Geiss Creek from the upper part of the Bundella Mudstone into the Fergusson Siltstone are well exposed and were measured with a steel tape but the section above that was measured up the western hill slope to the Rayner Sandstone, back into the bed of Geiss Creek and along the creek bed with an Abney Level until good exposures of the Nassau Siltstone were reached when the tape was used again for a few feet and then the Abney Level was used to complete the section to point E. Co-ordinates quoted refer to the state grid on the 8-mile map (Lands Dept., Hobart).

The authors wish to acknowledge discussions with Professor K. G. Brill, Visiting Fulbright Professor at the University of Tasmania, and Professor S. W. Carey concerning stratigraphic methods and nomenclature. We are indebted to Mr. H. A. Bartlett for drawing our attention to the exposures of the Bundella Mudstone on the Lyell Highway. Finally we would like to acknowledge the assistance of Mr. A. H. Spry in checking mineralogical determinations in some cases.

HISTORY OF STRATIGRAPHIC NOMENCLATURE IN THE PERMIAN SYSTEM IN THE HOBART AREA

Darwin (1844) and Strzelecki (1845) were perhaps two of the earliest authors to deal with Permian rocks from the Hobart area. Later Jukes (1847) and Selwyn (1855) added further observations. The first author to deal at length with the Hobart Permian was Harrison in 1865 who noted that the colonists referred to the "Mountain Limestone" (now Berriedale Limestone) and this name was used, albeit informally, by Wintle (1865). In 1866 Gould formally proposed the first formational name for a Permian rock in this area when he suggested that the prominent spiriferous limestones around Hobart should be called the Mount Wellington Limestone to distinguish it from the Gordon Limestone of Ordovician age. There is little doubt that the limestone named thus by Gould is the limestone formation called Berriedale Limestone by Voisey (1938) and subsequent workers. Although it is clear that Gould's name has priority the later name will be used in order to avoid further confusion. The next major contribution was that of Johnston (1888) who described several sections in the area but used terms such as Lower Marine Series, Lower Coal Measures and Upper Marine Series to suggest correlations with New South Wales and names such as *Spirifer* Zone, *Fenestella* Zone and *Pachydomus* Zone to characterize the beds by their dominant fossil. However, he had earlier (1886) given formal names to some of these beds such as those at Porter Hill, the Porter Hill Beds, and the beds at the 3-mile post on the Channel Highway as the Lower Sandy Bay Beds. However, his usage of these names was not consistent and Porter Hill Beds was used in a different sense by him in 1888. The approximate usage of Johnston's terms will be considered under the appropriate formation heading. Johnston also seems to have laid the foundation of an error which has led all workers astray. He correlated the limestone at the shoreline at Lower Sandy Bay, i.e., Porter Hill, with the limestone at Cascades and Bridgewater (i.e., Mt. Nassau), which is now considered on stratigraphical, lithological and palaeontological grounds to be a distinct and higher formation, the Berriedale Limestone. By so doing he caused later workers to assume that the Grange Mudstone was above the Berriedale Limestone and separated from it by several hundred feet of sediment instead of equivalent to it as will be suggested later in this paper. This latter assumption confused Voisey (1938), Lewis (1946) and Banks (1952) and all workers in Tasmania and elsewhere who tried to make faunal correlations. It also led to the idea of very great similarity in the faunas on all horizons and blinded workers to the differences between the faunas from different horizons.

The first worker to consistently use stratigraphic names for Permian formations in this area was Voisey (1938) who proposed formation names later used also by Lewis (1946). These names were in some cases not very clearly defined and the beds below the supposed Berriedale Limestone were covered only by a wide term "Snug Stage", synonymy of which will be considered later.

Establishment of good sections below the Berriedale Limestone has indicated a number of formations previously included as Snug Stage or ignored. These new formations are defined here and formal definitions suggested for those terms used earlier. When dealing with each formation whether new or old, apparent synonymys will be listed and the nomenclature discussed.

STRATIGRAPHY

In the detailed section on the eastern flanks of Mt. Nassau there are at least 15 formations and by considering sections elsewhere in the district at least two more can be recognised below the lowest one at Mt. Nassau. The type section will be discussed in detail and then short notes on other sections will provide comparisons with the type.

Bundella Mudstone

The Bundella Mudstone is that formation consisting dominantly of siltstone with subordinate sandstone bands which is exposed in road cuttings on the Lyell Highway between Parramore Creek and Geiss Creek and in the lower part of Geiss Creek. It is overlain by the Geiss Conglomerate and its base is hidden by alluvium. It is at least 140 feet thick and contains *Eurydesma cordatum, Keeneia platyschismoides, Stenopora johnstoni* and *S. tasmaniensis*. It is Permian and probably Lower Artinskian in age. The name is derived from Bundella Railway Station on the northern bank of the Derwent River, near which this formation was first recognised. The co-ordinates of the centre of the type area are 504·8 E-736·8 N.

Synonymy

Bundella Mudstone
  Banks, Hale and Yaxley, 1955, pp. 219, 227.
  Banks in Hill, 1955.

Porter Hill Beds
  Johnston 1888, pp. 105 *et seq.*, very approximately only.

"Porters Hill" Siltstone
  Banks, Hale and Yaxley, 1955.

Snug Stage
  Lewis, 1946, p. 26 *et. seq.*, very approximately only, if at all.

Lithology

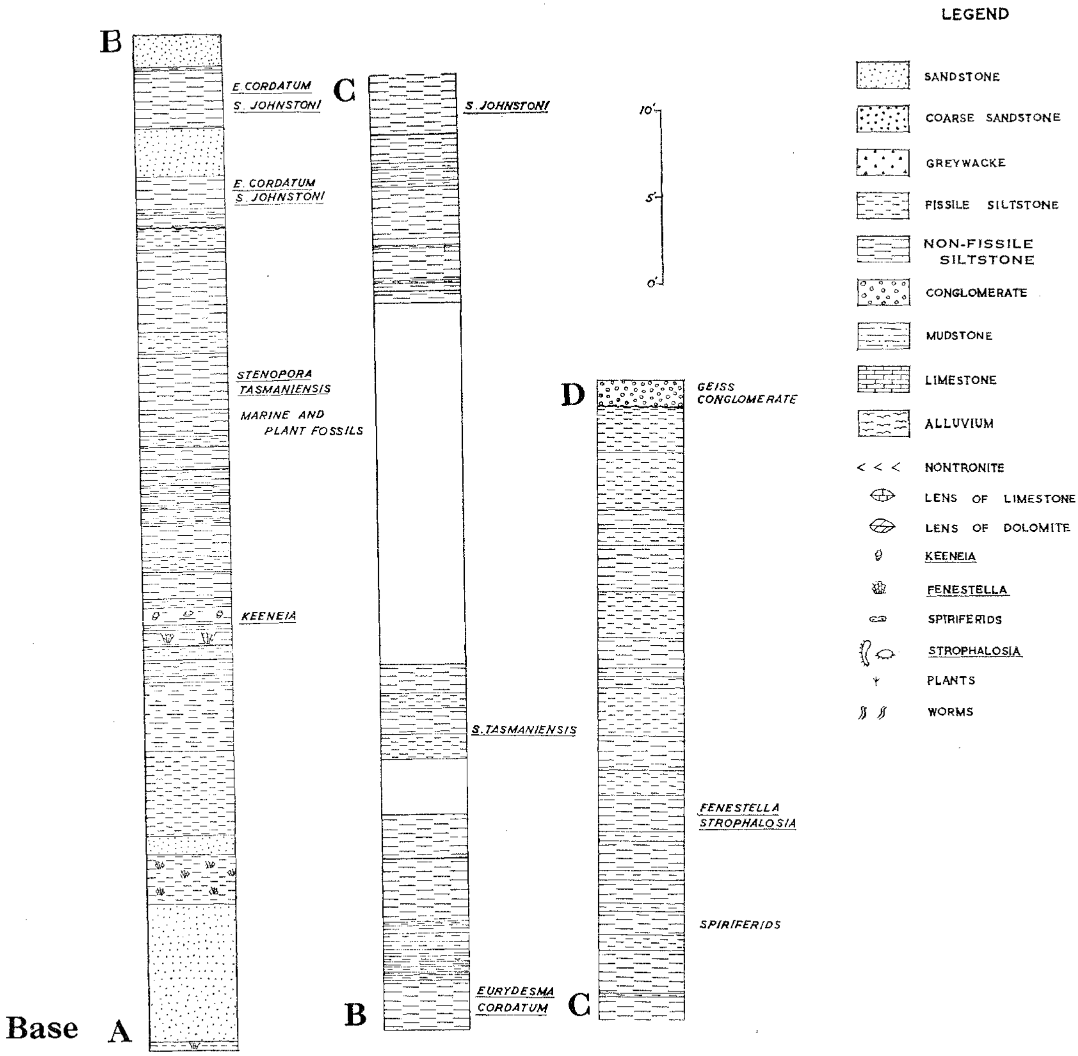
For the most part this formation is a regular alternation of fissile and non-fissile siltstone which in the lower parts of the formation as exposed in the type section is richly fossiliferous. Near the base there at at least four beds of sandstone which weathers into small, somewhat cuboidal blocks. Most of the beds contain erratics, one of which is an irregular block of quartzite three feet across but most of the erratics are less than eight inches in diameter. The erratics are frequently facetted and a few are also striated. There are many rock types represented by the erratics. The succession in the type section along the road cuttings and in the lower parts of Geiss Creek is shown in text figure 2.

Thin sections were cut of the representative rock types in the Bundella Mudstone. The non-fissile siltstone consists of 30-40 per cent of rock fragments which include quartzite, schist, phyllite and granite, 20-30 per cent of quartz some of which shows undulose extinction and some of which appears to have reacted with the matrix, 20 per cent of fine grained groundmass, 5-10 per cent of feldspar including orthoclase, microcline and plagioclase both fresh and altered to sericite, 5-10 per cent of mica mostly muscovite which appears to be squeezed around the other grains, and a few grains of zircon, apatite and tourmaline. The grains are dominantly in the silt grade but particles from clay grade to sand grade (1·5 mm.) are present. On the whole sorting is poor but there are a few finer bands. However, no mechanical analyses have been done. Particles of all grades are sub-angular to angular and equidimensional to bladed. There is no preferred orientation visible. The fissile siltstone is essentially the same as the non-fissile but shows better sorting, bedding is apparent and there is some orientation of the micas. In addition it is somewhat finer-grained, the dominant size in the sand grade being about 0·2 mm. whereas that in the non-fissile is 0·25-0·3 mm. Iron staining occurs in both types and in the fissile type is parallel to the finer beds but in the coarser beds is at an angle to the bedding.

The colour of the rock when weathered is buff but they tend to be yellowish-grey or light olive-grey when fresh.

A thin section of an unfossiliferous siltstone from the top of the Bundella Mudstone showed that it consists mainly of quartz and mica of coarse silt grade in a fine silt to clay grade matrix. The grains are dominantly angular and are equant to bladed. The micas show distinct parallel orientation which is reflected also by lines of haematite. In addition to quartz and muscovite the rock contains rare grains of plagioclase, some blue tourmaline, green biotite and some chlorite. Rock fragments include some of quartz muscovite schist and some of the quartz in the rock shows undulose extinction indicating possible derivation from a metamorphic source.

The sandstones are olive in colour. They consist of about 30 per cent of quartz, 5-10 per cent of feldspar, both orthoclase and plagioclase, 10-15 per cent of mica, mainly muscovite but with some biotite and 40-50 per cent of groundmass and rock fragments with minor amounts of zircon, apatite and garnet. The rock fragments are mainly of metamorphic rocks rich in mica. Many of the quartz grains have inclusions of garnet, apatite and zircon. Sorting is good with most of the grains in the sand grade (0·06 to 0·1 mm.). No bedding is apparent in the thin sections nor is there any apparent orientation of the micas, which are of



SECTION OF THE BUNDELLA MUDSTONE MT. NASSAU SECTION

FIG. 2

the same grain size as the other minerals in the sections. The grains are equidimensional to bladed and sub-rounded to sub-angular.

A thin section of a conglomeratic siltstone close to the top of the formation showed that the rock is composed dominantly of rock fragments, with up to 15 per cent of quartz, 5-10 per cent of muscovite, 5 per cent of feldspar, mainly plagioclase with some orthoclase, and 5-10 per cent of groundmass. Heavy minerals present include zircon, garnet and calcite. The quartz is usually bladed and the muscovite twisted around the other grains. Particles in the groundmass range in size from clay grade to near the top of the silt grade (0·04 mm.) although there were a few longer, very thin almost acicular fragments composed of a number of grains of quartz forming a mosaic. In some places these very long grains show a preferred orientation but in most parts there is no preference. Grains other than the acicular grains are bladed to equidimensional and angular to sub-rounded. A few flakes of green biotite are present in addition to the more abundant muscovite. The rock could probably best be described as a poorly sorted conglomeratic siltstone.

One of the most noticeable features of this formation in the field is the alternation of fissile and non-fissile beds. Near the base the non-fissile bands are consistently rather thicker than the fissile bed above them, but towards the top the position is reversed. It seems from preliminary examination that the fissility could be a function of the better sorting and the orientation of the micas.

Both of these differences suggest that current or wave action was stronger during the deposition of the fissile beds than during the formation of the non-fissile beds. The alternation in the intensity of current and wave action could be a function of changes in sea-level, involving changes in depth and/or distance from shore, or of climate affecting the velocity and volume of water entering the sea in rivers, or of climate affecting the intensity of glaciation and altering the mode of transport and distance of transport of the sediment, or of several of these factors and perhaps others operating together. Tectonic activity in the source or depositional area could also cause changes in the intensity of current action but it is difficult, but by no means impossible, to account for the remarkably regular alternation on such a small scale under a tectonic hypothesis. As far as can be judged on information at present available the beds are of almost constant thickness over distances of half a mile along the dip and a quarter of a mile along the strike. They show no or very little cross-bedding which is in accord with the general lack of sorting but they also show no obvious graded bedding. Contacts between adjacent beds are normally gradational. Thus there is little if any evidence of the action of turbidity currents and slump structures were not seen either in the field or in thin section. From the information available in this one section it would seem unwise to choose one cause rather than another for the alternation but as regional work is done and three dimensional evidence becomes available the cause should be revealed.

The sandstone beds apparently represent even better conditions of sorting than either of the siltstones and it is noteworthy that they seem to lack erratics. They possibly represent times of fall in sea-level producing shallowing of the water and increase in current action and at the same time a reduction in the density of icebergs in the vicinity relative to other times or else the current action is strong enough to separate the sand from the coarser grades, e.g., erratics.

Palaeontology

Fossils are abundant in both the fissile and non-fissile beds but seem to be rare in the sandstone. The fissility is not controlled by abundance and type of fossils except near the base where fenestellid fronds parallel the bedding and increase fissility. Many phyla are represented but braciopods and bryozoa are the most abundant. The brachiopods are predominantly spiriferids but some *Strophalosia* spp. are also present. Significant bryozoa are *Stenopora johnstoni* and *S. tasmaniensis* which are commonest in, if not restricted to the lower part of the Permian sequence of Tasmania. Fenestellids including *Fenestella* spp., *Polypora* spp. and *Protoretepora* are common. The pelecypod *Eurydesma cordatum* is present on several horizons and other pelecypods are present but not common. Gasteropods are also common, the main forms being species of *Mourlonia* but *Platyschisma ocula* and a *Straparollus* are also present. An important gasteropod which occurs in the lower part of the formation is *Keeneia platyschismoides* which is significant for correlation. Ostracodes are present and abundant on some horizons. Near the top of the formation fossils become very rare and the rock could easily be mistaken for the Ferntree Mudstone, a feature noted by Lewis (1946, p. 30).

Correlation

The abundance of *Stenopora johnstoni*, *S. tasmaniensis* with the presence of *Eurydesma cordatum* and *Keeneia platyschismoides* as well as the lithology suggests that the Bundella Mudstone is equivalent to the beds along the foreshore at Sandy Bay just above the blue-grey limestone with *Calcitornella* which has been correlated by Banks (1957 *b*) with the Darlington Limestone. These beds are what Johnston referred to in 1888 as the Porter Hill Beds but beds referred to by this name seem to go higher into the sequence than the Bundella Mudstone and the name has been used by later workers for the beds in the top of Johnston's (1888) Porter Hill Beds which are almost certainly not equivalent to the Bundella Mudstone. The Bundella Mudstone was first recognised on the northern side of the Derwent River on the slopes of Mt. Dromedary above Bundella Station. Recently in this area I. McDougall discovered a richly fossiliferous limestone, in which *Eurydesma cordatum* was a prominent fossil on some horizons, just below the Bundella Mudstone. This is correlated with the Darlington Limestone and on the flanks of Mt. Dromedary occurs about 140 feet below the base of the Faulkner Group so that it might be expected to occur just below the lowest outcrop in the Mt. Nassau section. In the Collinsvale and Glen Lusk Road sections a *Eurydesma*-rich limestone with *Calcitornella* is overlain by richly fossiliferous mudstones which would therefore be equivalent to the Bundella Mudstone. At Snug the section is not clear but the base of it exposed in cuttings on the Channel Highway just north of the bridge over the Snug Falls River is an alternation of fissile and non-fissile siltstone with some limestone bands and the siltstones are very rich in *Eurydesma cordatum*. These are probably correlates of the Bundella Mudstone but more detailed stratigraphic work is necessary to establish this. They underlie a fossiliferous erratic-rich conglomerate which is probably the equivalent of the Geiss Conglomerate and this is succeeded by the mottled-brown mudstone and sandstone of the Snug Stage of Lewis (1946) in its type area. It will be shown later that on present stratigraphic knowledge the best correlation of the Snug Stage is with the Faulkner Group. In the Collinsvale Road section the Darlington Limestone is underlain by a considerable thickness of dark-grey pyritic siltstone which is probably equivalent in a general way to the beds below the Darlington Limestone on Woody Island, especially the Woody Island Siltstone. It appears then that these beds in the lower part of the section on the Collinsvale Road are the lowest exposed in the Hobart area although the section below the Huon Road section should be investigated in this connection. On Woody Island the Darlington Limestone is overlain by about 40 are the lowest exposed in the Hobart area. On Woody Island the Darlington Limestone is overlain by about 40 feet of richly fossiliferous alternating fissile and non-fissile siltstone which contains, among other fossils, *Keeneia platyschismoides*. These beds are correlated on lithological and palaeontological grounds with the Bundella Mudstone (Banks, Hale and Yaxley, 1955). On the northern end of Maria Island the Darlington Limestone is much thicker than in the Hobart area and may be partially equivalent in time to the Bundella Mudstone. It is overlain by sandstones and siltstones which could also be equivalent to the Bundella Mudstone but they are lithologically rather different. The Bundella Mudstone would appear on stratigraphic evidence to be equivalent to the richly fossiliferous siltstones above the Darlington Limestone in the Deloraine area, i.e., to the top part of the Golden Valley Limestone and Shale of Wells (1957).

The presence of *Stenopora johnstoni, S. tasmaniensis, Eurydesma cordatum* and *Keeneia platyschismoides* suggests correlation with part of the Dalwood Group of New South Wales. The fact that it overlies a limestone with *Calcitornella* suggests correlation with part of the Rutherford Formation (in New South Wales) which includes and overlies a foraminiferal limestone with the same fossils.

Conditions of Deposition

The Bundella Mudstone is a marine formation for the most part and even in the top part of the formation where fossils are rare it is still marine although the relative absence of fossils suggests that the conditions of life deteriorated during the latter part of the time during which the Bundella Mudstone was being deposited. Possibly the water became brackish at this time although there are other possibilities. The fossils, especially the pelecypods gasteropods, spiriferids and *Stenopora johnstoni* all suggest shallow water deposition, but currents and waves apparently did not affect the bottom very greatly. Judging from the erratics in the siltstone icebergs were common in the sea in which the Bundella Mudstone was being deposited. Alternations in the intensity of current and wave action occurred. The land surface supplying the sediment included schists and quartzites of several types and some granite masses. The metamorphic rocks correspond best to the Precambrian rocks of Tasmania but no diagnostic types have been noticed.

Faulkner Group

The Faulkner Group is here defined as all those formations lying between the Bundella Mudstone below and the Rayner Sandstone above and consists in this, the type area, of seven formations as listed below from the base upwards: Geiss Conglomerate, Rathbones Sandstone and Siltstone, Byers Sandstone, Jarvis Siltstone, Parramore Sandstone and Shale, Altamont Conglomerate and Fergusson Siltstone. The type area for all of these formations is along Geiss Creek.

The rocks in the succession in Geiss Creek pose a problem in stratigraphical nomenclature. Some of the formations listed above are very thin and can only be traced for short distances on the ground away from the creek and some have been recognised with certainty only in the creek bed itself. Several of them are not strictly formations in the sense that they are mappable units, because they are not mappable except on a very large scale. Each formation is however, composed of a single rock type or alternation of rock types. The group on the other hand is composed of a variety of rock types but is the mapping unit for work on air photo scale (20 chains to the inch). To regard the group as a formation and each individual formation as a member is perhaps the obvious thing to do but it ignores the diversity of rock types, subgreywacke conglomerates, subgreywackes siltstone, siliceous sandstones and siliceous siltstones and makes it impossible to express this diversity adequately without considerable circumlocution. It is impossible to find a lithological term to adequately describe the rocks in such a formation. Although several of the formations are only 18 inches thick, and are not mappable units in the usual sense of the words and thus perhaps do not warrant separate status, similar rocks occur in similar stratigraphic positions in other parts of the State and to express correlations concisely it is necessary to name them. Finally all the formations in this group are parts of two cyclothems and are thus genetically connected so that the term group is permissible for such a collection in the terms of the recent definition of the word in the revised code of stratigraphic nomenclature for Australia (Raggatt, 1956).

Geiss Conglomerate

The Geiss Conglomerate is that formation of subgreywacke conglomerate 18 inches thick which occurs in the lower part of Geiss Creek (co-ordinates 504·7 E-736·6 N) and on the hill slopes to the east. It is underlain by the Bundella Mudstone and overlain by the Rathbones Sandstone and Siltstone. It is Permian, probably lower Artinskian, in age.

Although this formation is so thin it can be traced for about half a mile around the hill slope between Geiss Creek and Parramore Creek and can be identified again in Rayner Creek, it has an uneven base on the underlying fissile siltstone of the Bundella Mudstone where the contact is exposed in Geiss Creek. It is olive-brown in colour (5 Y 5/4) and in the field is apparently a poorly-sorted conglomerate containing angular to rounded rock fragments up to cobble size in a groundmass of angular to sub-rounded grains of quartz, feldspar and mica. It has no internal bedding planes and is not fissile. The rock fragments which in Geiss Creek are up to three inches in longest dimension and in Rayner Creek are up to eight inches long, are of quartz, quartzite, granite, schist, phyllite, slate and feldspar porphyry and are commonly facetted. In the Rayner Creek occurrence the top of the bed contains plant stems and a few *Gangamopteris* leaves.

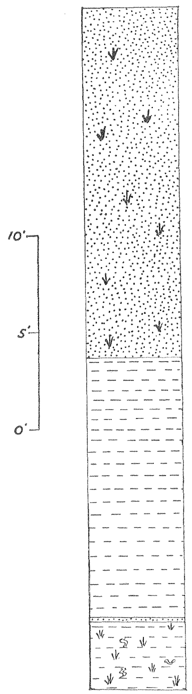
A thin section showed that the rock consists of rock fragments at least up to pebble size in a very poorly sorted groundmass of sand, silt and clay grade. Mineral fragments include much quartz, both fresh and weathered microcline, plagioclase, muscovite and a little biotite. The groundmass is composed of quartz, muscovite, much chlorite and carbonaceous material. The mineral fragments in all grades were angular to almost cuspate. The rock fragments include sheared quartzite, micaceous quartzite, muscovite schist, and muscovite chlorite schist. Other rock fragments are now mainly ferruginous material. There is no bedding or any other type of orientation of the fragments. The rock is a sub-greywacke conglomerate.

The Geiss Conglomerate was apparently deposited in an environment of little or no current or wave action and under conditions of little water or wind transport from its source. The only fossils known in it are plants so that the *a priori* assumption is that it was deposited on land but a marine origin under conditions where marine life was inhibited is not impossible. Until more is known of its areal distribution and variations in thickness and lithology it is premature to assign it to any specific environment.

Rathbones Sandstone and Siltstone

The Rathbones Sandstone and Siltstone is that formation of quartz rich sandstone and fissile siltstone overlying the Geiss Conglomerate and underlying the Byers Sandstone in the bed of Geiss Creek. It is 35 feet thick. Fossils include worm casts and plant fragments. It is Permian, probably Lower Artinskian, in age. It is named for Rathbones Lime Kilns on the eastern side of Rayner Creek (505·8 E-737·3 N) in the bed of which the formation was first recognized.

In Geiss Creek this formation consists of four units, the succession being illustrated as text figure 3.



SECTION OF RATHBONES SILTSTONE AND SANDSTONE
MT NASSAU SECTION
FIG. 3
(for legend see fig. 2)

The basal unit is a well-sorted, light olive-grey carbonaceous siltstone with thin bedding and containing some worm casts. It is followed by a yellowish-grey quartz sandstone with feldspar visible in hand specimen. The next unit is a dark-grey, very thinly bedded fissile siltstone which is noticeably micaceous and contains lenses of cross-bedded sandstone. The final unit is a yellowish-grey, pale-red or medium-grey sandstone composed dominantly of quartz but with quite a lot of feldspar and golden mica. It is essentially an alternation of thin-bedded fissile beds and thick-bedded non-fissile beds. Sets of cross bedding up to three feet thick were noticed in the field and ripple marks and mud pellets are common.

A thin section of the fissile, thin-bedded siltstone shows that it contains quartz, both muscovite and biotite, and some rock fragments in a groundmass of clay, chloritic material and mica. The content of feldspar is very low. Zircon and tourmaline are present in minor quantities. The grains are not even in grain size and are angular except for the zircon in the finer bands which is rounded. Cross bedding is visible in the thin section.

A sandstone from the top unit was sectioned and the section showed that it is composed mostly of quartz (70%) and mica (25%) with the rest made up of zircon, tourmaline and garnet grains with some opaque iron minerals. There is very little groundmass and very few rock fragments most of them quarzitic. No feldspar is visible. Both muscovite and biotite are present with the former more abundant than the latter. It is well-sorted with the grain size about ·05-·1 mm. The grains are equidimensional and with the exception of the zircon lack rounding and are remarkably angular. There is some suturing of the quartz grains producing a mosaic texture. The micas are well oriented.

The overall lithology of this formation is very reminiscent of that of the lower part of the Triassic of Tasmania, i.e., the Knocklofty Sandstone and Shale and when first found in the lower part of Rayner Creek the question of a fault dropping the Triassic into the Permian sequence was seriously entertained but the exposures in both creek beds are such that there is no doubt of the Permian age of the formation. The similarity of this formation to the Triassic is heightened in the vicinity of Rayner Creek by the occurrence of slump structures in the sandstone and the occurrence of graphite flakes on the bedding planes. Current ripples with currents coming from a generally southerly direction are present in a cliff section on the western side of Rayner Creek.

The only fossils found were some plant fragments and the worm casts in the basal unit in the Geiss Creek section.

This formation is very different from the underlying formations in several important respects. Rock fragments are much less common, sorting is very much better and cross bedding, ripple marking and slump structures occur. Mica is much more abundant and better oriented than in the siltstones of the Bundella Mudstone. Also significant is the occurrence of pellets of mudstone in the higher sandstones. Apparently current action was much stronger during the deposition of this formation than the earlier ones and icebergs not present in the depositional area. The mud pellets suggest very shallow water and the plant fossils and carbonaceous material suggest a terrestrial origin although the worm casts are more difficult to interpret. Similar types of worm casts are present in the Ferntree Mudstone which is generally considered to be marine, or at least estuarine. However, the occurrences of worm casts elsewhere in the Permian in Tasmania need further study before their significance is finally appreciated. It is possible that the lower part of the formation is marine and the upper part lacustrine or paludine in origin. The angularity of almost all the grains in the rocks of this formation is somewhat anomalous but is consistent with brief reworking of earlier Permian rocks with the sorting of the various grades by streams or in lakes or swamps and short transport to the depositional site. The mica could well also have been concentrated from earlier Permian sediments in the same way as the quartz while the feldspars from the older sediments were either physically or chemically removed. The presence of such a high proportion of heavy minerals in the top unit also supports some reworking hypothesis. Variations in competence of the transporting medium are reflected in the presence of both siltstone and sandstone.

This formation has not been recognized with any certainty anywhere else in the Hobart area but similar beds occur in the same relationship to beds correlated with the Bundella Mudstone on Maria Island and in the Cressy-Deloraine area where they form part of the Liffey Sandstone of Wells (1957). No direct palaeontological evidence for this correlation is available.

Byers Sandstone

The Byers Sandstone is that formation of sub-greywacke sandstone exposed in Geiss Creek between the Rathbones Sandstone and Siltstone below and the Jarvis Siltstone above. It is only two inches thick. It is Permian, probably Lower Artinskian, in age. It is named after Byers Creek, whch has the co-ordinates 506·3 E-737·5 N.

In the field this rock appears to be a poorly sorted, medium to coarse-grained sandstone with pebbles of porphyry, quartz and quartzite in a groundmass of angular to sub-angular grains of quartz, feldspar and mica. It is dusky yellow in colour. A thin section revealed that it contains 40 per cent of quartz, 30 per cent of rock fragments, 15 per cent of mica, 10 per cent feldspar and 5 per cent of groundmass with minor quantities of zircon, tourmaline, apatite, garnet and epidote. The groundmass is chloritic and micaceous with some haematitic cement. The feldspar includes plagioclase and both muscovite and green biotite are present.

Examination of the thin section reveals that the rock is better sorted than it appears to be in the field. Many grains from 0·125-0·25 mm. in size occur in a groundmass of fine silt to clay grade. The grains and the groundmass are in about equal proportion. The grains are angular, even cuspate, to sub-angular and equidimensional to somewhat bladed. There is distinct parallelism of the bladed grains in some parts of the section but in others their orientation is apparently random. Some of the mica flakes have been moulded around the other grains in a complex fashion.

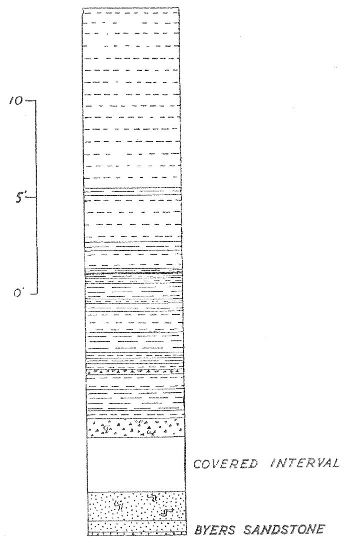
No fossils were seen in thin section or in the field.

The rock could best be described as a very fine sub-greywacke sandstone, with fair sorting only.

Jarvis Siltstone

The Jarvis Siltstone is that formation of siltstone exposed in Geiss Creek between the Byers Sandstone below and the Parramore Sandstone and Siltstone above. It is approximately 27 feet thick. It is Permian, probably Lower Artinskian, in age. It is named after Jarvis Creek, the mouth of which has the co-ordinates 504·0 E-736·3 N.

This formation consists in the creek exposure essentially of an alternation of fissile and non-fissile sub-greywacke siltstones which resemble the upper part of the Bundella Mudstone very much. This alternation is shown in the section (text figure 4) from which it will be seen that the two lower units are rather coarser-grained and in the field are a little better sorted than units higher in the formation.



SECTION OF JARVIS SILTSTONE

MT NASSAU SECTION

FIG. 4

(for legend see fig. 2)

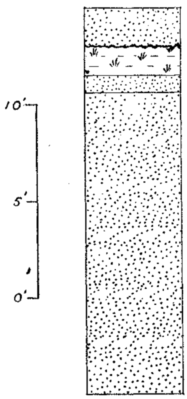
Erratics are absent in the lowest unit but in higher beds are always present and in one or two cases common. The first three units are non-fissile but higher beds show the alternation mentioned above, the fissile beds being usually slightly thicker than the non-fissile. The lowest unit is dusky-yellow, the next one light olive-grey and in the higher beds there is an alternation of mottled (olive-grey and dark-grey) and dark-grey beds, the mottled beds being the non-fissile, slightly coarser beds. Lithologically this unit is very like the Ferntree Mudstone higher in the sequence. Fossils are very uncommon and were observed only in the second and third units where only worm tubes were seen. The fissile units in the formation become progressively thicker upwards.

Examination of thin sections showed that the rock is composed of granules of quartz, quartzite and biotite in a matrix of very fine sand and coarse silt. The rock is poorly sorted but one slide showed signs of very rude bedding and even slump structure. In the other slide it is noticeable that the larger grains are clumped together. The grains are angular to cuspate except for some of the granules which show signs of rounding. The rock fragments include quartzite, micaceous quartzite, quartz muscovite and quartz biotite schist. The dominant mineral is quartz but plagioclase, muscovite, brown biotite and haematite are also present. The rock is a sub-greywacke siltstone.

Parramore Sandstone and Siltstone

The Parramore Sandstone and Siltstone is that formation of quartz sandstone and carbonaceous siltstone which outcrops in Geiss Creek between the underlying Jarvis Siltstone and the overlying Altamont Conglomerate. It is 20 feet thick. It is Permian, probably Lower Artinskian, in age. It is named after Parramore Creek, the mouth of which has the co-ordinates 505·2 E-736·8 N. It contains only plant fragments.

In the creek outcrop of this formation, of which text figure 5 is a columnar section, the basal unit is a micaceous quartz sandstone which appears to be very fine grained and well sorted.



SECTION OF PARRAMORE SANDSTONE AND SILTSTONE
MT. NASSAU SECTION
FIG. 5
(for legend see fig. 2)

It is a very pale greenish-yellow colour. Within the unit are five sets, each about eight inches thick, of fine-grained cross-bedded sandstone. The only fossils found to date are a few carbonaceous fragments. There are no erratics. The next unit is a fine-grained, cross-bedded sandstone and this is followed by a thinly bedded carbonaceous siltstone which contains lenses of cross-bedded or slumped sandsone. It is dark-grey in colour. The top surface of this unit is quite uneven suggesting some disconformity. The next unit is a thick to thinly bedded quartz sandstone with some feldspar and mica visible in the field and also a few pebbles of quartz and quartzite. Cross-bedding sets of up to two feet thick are present but the thickness of the sets varies considerably.

Thin sections were cut and examination of these showed that the siltstone consists almost entirely of quartz and muscovite with a few grains of biotite, both brown and green, plagioclase and tourmaline. Haematite is common. It is a very well sorted medium-grained siltstone.

This formation is similar in lithology to the Rathbones Sandstone and Siltstone. Again well sorted quartz rich sandstones are associated with quartz-rich carbonaceous siltstones. Cross-bedding and slumping are present in the sandstones in both and both contain plant fragments. The association of characters suggests similar conditions of formation to those applying during deposition of the Rathbones Formation and in this case there is a suggestion in the uneven surface of the second last unit and the basal fine-grained conglomerate of the top unit of penecontemporaneous erosion, producing a sort of scour and fill structure.

Altamont Conglomerate

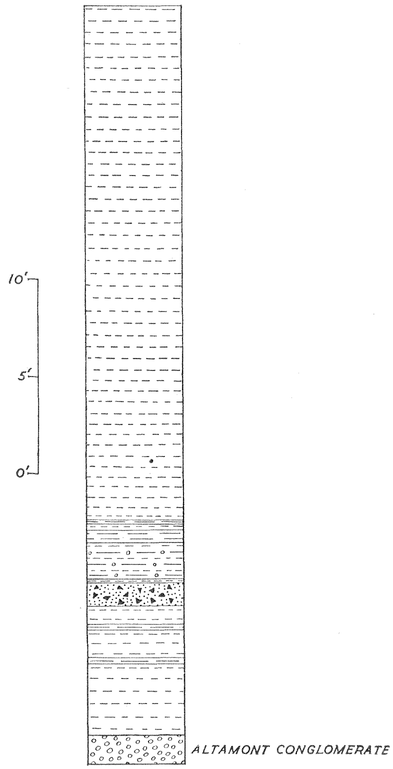
The Altamont Conglomerate is that formation of sub-greywacke conglomerate overlying the Parramore Sandstone and Siltstone and underlying the Fergusson Siltstone in Geiss Creek. It is 18 inches thick. It is Permian, probably Lower Artinskian, in age. It is named after the township reserve of Altamont about a mile to the west of Geiss Creek. The co-ordinates of the type section are 504·7 E-736·6 N.

This formation consists of a single bed of light olive-grey conglomerate composed of pebbles of quartz, quartzite and mudstone in poorly-sorted matrix of sand grade composed of angular to sub-angular grains of quartz, feldspar and mica. The pebbles are sub-angular to rounded. The rock also contains pellets of mudstone which are angular and suggest shallow water conditions with some penecontemporaneous scour.

Fergusson Siltstone

The Fergusson Siltstone is that formation of siltstone with minor conglomeratic bands which occurs in Geiss Creek between the Altamont Conglomerate below and the Rayner Sandstone above. It is 37 feet thick. It is Permian, probably Artinskian, in age. It is named after Fergusson Creek which is a tributary of Jarvis Creek to the west of Geiss Creek. The co-ordinates of the type area are 504·7 E-736·6 N.

This formation is essentially an alternation of fissile and non-fissile siltstone in which two of the non-fissile units are markedly conglomeratic. The lowest unit is a medium to dark-grey fissile siltstone containing some sub-rounded quartz pebbles in a fairly well-sorted groundmass of quartz, feldspar and abundant mica. This is succeeded by a fissile siltstone which appears to be otherwise like the first unit, then another similar alternation. The next alternation commences normally with a fissile siltstone but the other member is a very tough, thick-bedded, conglomeratic unit. It contains numerous erratics up to eight inches in diameter in a poorly-sorted groundmass of angular to sub-angular grains of quartz and feldspar. It is dark-grey to medium dark-grey. It might best be called a greywacke breccia and is very like the rock which Montgomery (1891) called a "tuff" on Maria Island. The next cycle is also abnormal although it again commences normally with a fissile siltstone. The top member is again a conglomeratic bed with erratics up to three and a half inches in diameter distributed through it. It is dominantly fissile but there are thin non-fissile bands in it. This is succeeded by a brittle, dark-grey siltstone after which is one normal cycle before the formation ends with a fissile siltstone in which there are rare marine fossils near the top. This succession is summarised in columnar form as text figure 6. The



SECTION OF FERGUSSON SILTSTONE
MT NASSAU SECTION

FIG. 6
(for legend see fig. 2)

formation thus consists of five complete alternations and the lower half of another. With the exception of the cycle involving the greywacke breccia all cycles have a thicker fissile than non-fissile component. In this respect the cycles are like those high in the Bundella Mudstone.

Lithologically the rocks in this formation are very like those in the Jarvis Siltstone and the top of the Bundella Mudstone and also like the Ferntree Mudstone. In the Fergusson Siltstone the presence of marine fossils in the upper part of the formation indicates that it at least is partly marine. As the lower beds in the formation are very similar to these higher fossiliferous ones except for the fossils it is probable that they were formed under similar conditions except for some factor, perhaps relative freshness of water.

Near the base of the formation is a well-sorted bed called a siltstone in the field. This was sectioned and seen to be composed of quartz, fresh and weathered plagioclase, muscovite, brown biotite, blue tourmaline, microcline, zircon and magnetite and fragments of quartz muscovite schist and biotite schist. The grains are mainly of sand size but there are a few granules and some silt. The rock is somewhat sorted, as there is only a minor amount in the silt grade. The sand grains are frequently in contact and have developed a mosaic texture in several places. The grains are mainly equant but a few are bladed. No bedding is apparent in the slide.

A fissile siltstone from higher in the formation contains a few grains of sand grade in a matrix which is dominantly fine to medium-grained silt. The grains are angular. There is a rude parallelism of the carbonaceous patches in the slide and the muscovite flakes. The main minerals present are quartz and muscovite but there is also much carbonaceous matter and haematite.

The greywacke breccia is very poorly sorted and consists of pebbles, granules and sand grade fragments in a groundmass which forms 20 per cent of the rock. The granules include large pieces of quartz, plagioclase, and brown biotite as well as quartzites. Magnetite is common. The grains are mainly angular to cuspate but a few are sub-rounded. The groundmass is mainly quartz but there is much other material present.

Cyclic Deposition in the Faulkner Group

It has been noted that the Faulkner Group consists of two distinctly different associations of lithological types, conglomerates, sandstones and siltstones of the sub-greywacke suite and sandstones and siltstone of the orthoquartzite (quartz sandstone suite). What is perhaps more interesting is that the rocks of these two suites occur in regular alternation and still further form parts of two cyclothems as will be seen from the following summary:

Top:

Sub-greywacke siltstone (Fergusson Siltstone)
Sub-greywacke conglomerate (Altamont Conglomerate)
Quartz sandstone and carbonaceous quartz siltstone (Parramore Formation)

Sub-greywacke siltstone (Jarvis Siltstone)
Sub-greywacke sandstone with erratics (Byers Sandstone)
Quartz sandstone and quartz siltstone (Rathbones Formation)
Sub-greywacke siltstone with erratics (Geiss Conglomerate)
Sub-greywacke siltstone (Bundella Mudstone)

It is further noteworthy that the base of the Bundella Mudstone and the top of the Fergusson Siltstone are fossiliferous while the top of the Bundella Mudstone and the base of the Fergusson Siltstone are unfossiliferous. Thus the Faulkner Group consists of two cyclothems beginning with a sub-greywacke siltstone, passing through a thin sub-greywacke conglomerate into quartz-rich sediments back into sub-greywacke sandstone with erratics and finally back into sub-greywacke siltstone when the whole cycle commences afresh, the second cycle however lacking the second unit in the cycle, the conglomeratic one, but showing the higher conglomerate, the fourth unit.

The fossiliferous nature of the two ends of the double cyclothem suggest that they began and ended under marine conditions, normal except for the presence of floating ice. The presence of the reworked quartz-rich rocks on two horizons with plant remains suggests two emergences so that the cyclothems could be interpreted as due to two emergences separated by a short submergence. Thus the fossiliferous marine sub-greywacke siltstones represent normal marine conditions in this area followed by rather shallower, perhaps brackish estuarine conditions, unfossiliferous sub-greywacke siltstone, then shoreline conditions, the conglomerates, and finally lacustrine and paludine conditions on a flat coastal plain with reworking of the underlying marine sediments (quartz sandstone and carbonaceous siltstone). Then the sea began coming in over the coastal plain till the Mt. Nassau area was again covered by a shallow, perhaps brackish sea. After a short period emergence began again and the second cycle commenced, ending with the return to normal marine conditions.

This interpretation requires that the sub-greywacke conglomerates should be shoreline deposits formed by advancing and retreating seas. Such deposits could be formed where the rate of advance and retreat was fairly rapid, so that time for sorting was short, and where the supply of detrital material was greater than the amount able to be winnowed by the sea before emergence or burial under later marine sediment.

This interpretation of the cyclothems seems to meet all the facts known in this restricted area but requires confirmation from detailed work in other areas. Of particular interest is the distribution of the conglomeratic members of the cyclothems and any variations in thickness and lithology that they show.

The Faulkner Group is possibly partly equivalent to the Porter Hill Beds of Johnston (1886) who used this term originally for shales with *Cythere* and *Gangamopteris*. The usage of the unit called "Porter Hill" has varied from one author to another and even Johnston (1888) included more beds in it than he had originally so that his second meaning became all the beds between the limestone on the shoreline at Sandy Bay and the Grange Mudstone. This unit is thought to be equivalent to the Bundella Mudstone, the Faulkner Group and the Rayner Sandstone of the Mt. Nassau section. Voisey's (1938) Porter's Hill Stage is the same as that of Johnston (1888) and this usage was followed also by Lewis (1946, Porter's Hill Beds) and David (1950, Porters Hill Stage). Banks (1952) used the term for those beds in the road cutting at Porter Hill which contain plants at road level and are probably equivalent to the Altamont Conglomerate and Fergusson Siltstone. Finally Banks, Hale and Yaxley (1955) used the term "Porters Hill" Siltstone for the siltstones and sandstones just above the limestone at Sandy Bay which are thought to be equivalent to the Bundella Mudstone. It will be seen that there are several interpretations of this unit and that the spelling has varied also. We are advised that Porter Hill or Porter's Hill is not a name recognized by the Topographic Nomenclature Board but that either name would be suitable as a Mr. Porter owned land in this vicinity during the last century. We propose to suggest to the Board that the spur on which the section is found should be called Porter Hill to revert to Johnston's original spelling. The exact position of the Porter Hill Beds in the sequence must await detailed stratigraphic work on the type section. This group is also partly equivalent to the Preolenna Coal Measures of Hills and Carey (1949) and Fairbridge (1953).

The Faulkner Group, representing emergence, can be correlated on this ground with the Liffey Sandstone of Wells (1957) and this has been correlated by Banks (1957*a*) with the Mersey, Preolenna and Mt. Pelion Coal Measures. This terrestrial interlude in the marine sequence corresponds approximately to the Greta Coal Measures of New South Wales but exact equivalence is not suggested. Detailed correlations both within and outside Tasmania must await more detailed stratigraphical and palaeontological work.

Rayner Sandstone

The Rayner Sandstone is that formation of sandstone outcropping on the hill slope west of Geiss Creek and overlying the Fergusson Siltstone and underlying the Cascades Group. It is about nine feet thick. It contains marine fossils and is Permian, probably Artinskian in age. It is named after Rayner Creek. The co-ordinates of the type area are 504·7 E-736·6 N.

This is the Bridgewater Sandstone of Banks in Hill (1955) which was established on the imperfect sections available in the Rayner Creek section and as formerly used included the Fergusson Siltstone. However, the name "Bridgewater" is not available as a stratigraphic name having been used by Lewis (1946) for the basalts near Bridgewater and earlier as the name of a phase in Pleistocene history of Tasmania. The better sections in and around Geiss Creek allowed this formation to be more correctly restricted.

The Rayner Sandstone is widespread in the Hobart area. It was first recognized on the hill slopes to the east of Rayner Creek, then on the slopes of Mt. Dromedary where it has since been mapped over several miles by I. McDougall. The Rayner Sandstone is also recognizable beneath the Cascades Group on the Berriedale-Collinsvale Road just below the limestone quarries. Brill (1956, p. 140) records a sandstone below his Berriedale Limestone section at Weily's Quarry, Glenorchy, and a sandstone occurs in road cuts on Porter Hill at the base of the Cascade Group. Finally a greywacke sandstone occurs in this same stratigraphic position on Maria Island.

In the Geiss Creek section the basal unit of the Rayner Sandstone is an olive-grey to light olive-grey, thick bedded, poorly sorted, medium grained sub-greywacke sandstone, with erratics in a groundmass of angular to sub-angular quartz and feldspar. Fossils are present, though rare and include plants and marine fossils, especially *Martiniopsis*. The next unit is similar but more friable and the next unit again is like the first. The top unit is similar to the first but fossils are common and are predominantly marine.

Examination of thin sections of this rock showed that except for the relative scarcity of rock fragments it is like the greywacke breccia in the Fergusson Siltstone. The dominant grade is sand with particles of quartz, plagioclase, muscovite, biotite and zircon up to 1 mm. in length. Most of the grains are bladed but some are equant, most of them are angular but a few are sub-rounded. Schists are present as rock fragments. The groundmass forms 20 per cent of the rock. It is a sub-greywacke sandstone.

In the section up Rayner Creek the Geiss Conglomerate is succeeded by the Rathbones Formation but then the section is covered and the next unit recognized is exposed in the road to the western quarry. It is lithologically very like the greywacke breccia in the Jarvis Siltstone which has been likened earlier to the "tuff" on Maria Island. It contains *Glossopteris* and other plant fragments. It is approximately the same distance below the Rayner Sandstone as the bed in Geiss Creek. The Rayner Sandstone outcrops on the access road to the eastern quarry, and in this locality is a coarse feldspathic sandstone with small erratics near the base and larger ones towards the top. The boulders are angular and frequently facetted. Fossils occur abundantly in patches and include bryozoa, *Strophalosia* spp., *Martiniopsis*, *Platyschisma* and *Mourlonia*, as well as ostracodes.

Cascades Group

The Cascades Group is here defined as consisting of all those formations between the Rayner Sandstone below and the "Woodbridge Glacial Formation" above, that is of the Nassau Siltstone, the Berriedale Limestone and the Grange Mudstone in that order from the base upwards. The name is derived from the Cascades district about two miles west of Hobart. The type area of the group is, however, on the eastern flank of Mt. Nassau where all three formations are exposed in succession. The co-ordinates of the type area are 506·3 E-736·8 N.

Lewis (1946, pp. 22, 25, 30, 90) was the first to use this term or its equivalent (Cascades Stage) for the rocks included in this group. Later Hills and Carey (1949, pp. 31-2) used the term "Cascades Formation" to include the Granton Limestone and Marl, Porters Hill Mudstone and the Grange Mudstones and in effect applied it to all formations between the Wynyard Tillite and "Woodbridge Glacial Formation" which is a much wider usage than that proposed here. Fairbridge (1953) used the term Cascades Group for the Cascades Formation of Hills and Carey (1949). Prider used the term "Marlborough Series" in 1948 for the beds under the Woodbridge Glacial Formation at Marlborough and included the Bronte, Granton and Grange Facies. The Cascades and Marlborough Groups overlap to some extent, but the exact situation is not yet known. The formations of this group have been referred to as the Lower Marine Beds by Stephens (1885, pp. 218-219) and Johnston (1888), and as the Lower Marine Series by Lewis (1927, pp. 3, 9, 10), Nye and Lewis (1928, p. 34) Nye and Blake (1938, pp. 43, 44, 100) and David (1950). Present correlations on the other hand, see Banks (1957*a*), suggest rather that the Cascades Group is equivalent to part of the former Upper Marine Series of New South Wales, now the Maitland Group. In fact, even in Tasmania, detailed stratigraphic work has indicated that there are two major sequences of marine sediments separated by a fresh-water sequence, and of these the Cascades Group is part of the higher marine sequence. The unfortunate confusion resulting from the old naming has been dealt with earlier.

The total thickness of the Cascades Group is normally of the order of 300 feet but the thicknesses of the constituent formations vary considerably. In places, e.g., Coles Bay, Seymour, the group consists dominantly of the Berriedale Limestone with some Grange Mudstone. On Maria Island there is an appreciable thickness of Nassau Siltstone and rather a greater thickness of the Berriedale Limestone than of the Grange Mudstone. At Mt. Nassau the Nassau Siltstone is thin and the Berriedale Limestone thicker than the Grange Mudstone while at the type area of the Grange Mudstone, at Porter Hill, Sandy Bay, there is no Nassau Siltstone known, the Berriedale Limestone is thin and the Grange Mudstone is the predominant formation. Further south neither the Berriedale Limestone nor the Nassau Siltstone can be positively identified and the group consisted of a single formation, the Grange Mudstone.

The group is known from as far north as Avoca and Bothwell to as far south as Mt. La Perouse and from Marlborough in the west to the east coast. The apparent absence of this group from the Cressy and Deloraine areas and probably all parts of the north-west coastal area is an interesting problem.

The variations within the Group are attributed to facies changes as will be developed later. As a summary it might be said that the group consists of an alternation of fissile siltstones with limestones or calcareous siltstone, the fissile siltstone members predominating in the Nassau Siltstone, the limestone in the Berriedale Limestone and the siltstone in the Grange Mudstone. In essence there is an increase in lime content up to some part of the Berriedale Limestone after which the lime content decreases.

Nassau Siltstone

The Nassau Siltstone is defined as that formation of siltstone and limestone, with the siltstone predominating, which overlies the Rayner Sandstone and underlies the Berriedale Limestone on the northern flank of Mt. Nassau, especially in Geiss Creek and along the access road to the eastern quarry. It is named after Mt. Nassau. The co-ordinates of the type section are 504·7 E-736·6 N. In the type section it is of the order of 40 feet thick. It contains numerous fossils, especially *Strophalosia* spp. and *Fenestella* spp. It is Permian, probably Artinskian, in age.

This formation had not been recorded until Banks in Hill (1955) reported it as the "Granton Siltstone". This name is, however, undesirable because of the previous use of the geographic term "Granton" for a limestone and a stage of the Permian, the synonymy of which will be dealt with later.

The formation consists of an alternation of fissile siltstones and non-fissile siltstones or limestone, with the siltstone members being thicker than the limestone members. The formation grades up into the Berriedale Limestone and in the absence of good sections it is impossible to define the top of this formation accurately.

In the Geiss Creek section this formation is poorly exposed. The lower 30 feet consist of an alternation of greenish-grey, fissile calcareous siltstone with tough medium-grey limestone. Both rock types are richly fossiliferous. There is then a gap of 15 feet before outcrops of limestone with some siltstones commence.

Thin sections of the siltstones were examined. The siltstone is composed of angular grains of quartz, some of which are strained, and contain rutile, and some show lines of inclusions outlining former rounded grains which had suffered regrowth before transport to their present site. Magnetite, muscovite, some biotite, calcite, carbonaceous matter, and chlorite are also present. Some grains of plagioclase were also noticed. The grains are equidimensional to bladed or even acicular and are angular, the only round material in the slide being productid spines. It is stratified in that there are fine-grained lenses of dark-coloured claystone and siltstone in a rock which is dominantly in the silt grade with some fragments up to fine sand grade. Sorting is poor with most of the grades present in about equal amount. Some rock fragments are present and include large pieces of quartzite, chlorite schist and a chloritic micaceous schist. However, only the fossil fragments are larger than sand grade and these are up to a couple of inches long. The fossil fragments include pieces of *Stenopora*, fenestellids, productid spines, echinoderm plates and pelecypods. A productid spine and a fenestellid zooecium were lined with granular calcite and the centre of the cavity filled with quartz. The rock is essentially an impure, productid, fenestellid siltstone.

Examination of a thin section of one of the limestones near the top of the Nassau Siltstone showed that it contained mainly fossil fragments and grains of quartz which were angular to sub-angular. Other minerals present include slightly kaolinised microcline, fresh plagioclase, muscovite, green biotite, brown biotite, magnetite, chlorite, and zircon. Fragments of quartz muscovite schist, limestone, and a fine-grained granite were also present. Fossil fragments include *Stenopora* productid spines and shells, foraminifera, pelecypods, ostracodes and echinoderm fragments. Several of the shells showed small tunnels filled with matrix suggesting the acvitity of some burrowing organism. There is some calcareous cement. The fossil fragments which were rather broken, were up to 15 mm. long but the largest non-fossil fragment was only a millimetre long and most rock and mineral fragments were a little less than this. The rock is a productid calcarenite with much mineral matter.

As will have been seen above, there are representatives of many phyla in this formation. The fauna is dominated by *Strophalosia, Fenestella* and *Stenopora*, especially the ramose forms with a small diameter. In the Rayner Creek section *Martiniopsis, Trigonotreta*, other spiriferids, *Schuchertella, Mourlonia* and *Euryphyllum* were identified.

Examination of Brill's section of the Berriedale Limestone in the Weily's Quarries (Brill, 1956, pp. 140) shows that above the sandstone at the base, correlated with the Rayner Sandstone, there is almost 17 feet of mudstone, shale, meta-bentonite and minor bands of limestone before the main body of limestone is reached. The authors suggest that this represents the Nassau Siltstone so that the Berriedale Limestone as defined here does not commence until Brill's unit 11. Brill noted the presence of aviculopectinids and *Dielasma* in this formation at Weily's Quarry. A formation, dominantly of siltstone, occurs below the Berriedale Limestone on Maria Island where it was called the Productus Zone by Johnston (1901) at St. Marys and Avoca, and it is suggested as a first approximation that these are equivalent to the Nassau Siltstone.

Berriedale Limestone

The Berriedale Limestone is defined as that formation composed dominantly of limestone which lies above the Nassau Siltstone, where that formation is present, or the Rayner Sandstone, in the absence of the Nassau Siltstone, and below the Grange Mudstone or where that formation is absent, the "Woodbridge Glacial Formation". In the Mt. Nassau section, here designated as the type section, it is about 150 feet thick. The co-ordinates of the type section are 506·3 E-736·8 N. It contains *Taeniothaerus subquadratus, Strophalosia jukesi, Lyroporella, Eurydesma cordatum* var. *sacculum, Pterotoblastus* and *Conularia derwentensis.* It is Permian, probably Middle or Upper Artinskian in age. The name is derived from quarries close to Berriedale where the limestone was quarried.

This formation has been referred to by a number of names and the synonymy is shown below:

Mt. Wellington Limestone
Gould (1866, p. 29).

Mountain Limestone
Wintle (1865).

Crinoidal Zone
Johnston (1901).

Berriedale Limestone
Voisey (1938, p. 315).
Brown (1953, p. 59).
Crockford (1951).
David (1950, p. 359).
Hale and Brill (1955, p. 231, &c.).
Brill (1956, pp. 131-140).
Ford (1956, p. 149).
Banks (1957*a* and 1957*b*).

Granton Stage
Voisey (1938, p. 313, &c.), includes Berriedale Limestone and other lower beds.
non Voisey (1949), probably part of Golden Valley Group.
David (1950), as Voisey (1938).

Granton Sub-Stage
Lewis (1946, pp. 22 *et seq.*).

Granton Limestone and Marl
Hills and Carey (1949, p. 31) for Berriedale Limestone and the limestone on the shoreline at Porter Hill (= Darlington Limestone).
Banks (1952, p. 66) as Hills and Carey with addition of correlation with the Lower Marine Series of New South Wales.

Granton Formation
Fairbridge (1953) as for Granton Stage of Voisey (1938).
Hosking and Hueber (1954) as Voisey (1938).

Granton Limestone
Hale (1953, pp. 107, 8, 10).
non Ford (1954, pp. 153, 157, 158) which is Woody Island Siltstone and contiguous formations.

Gray Stage
Voisey (1938, p. 323) limestone part only.

Peter Limestone
Banks in Hill (1955, p. 89).

The Berriedale is an important horizon for mapping in the Hobart district and for correlation in the eastern part of the state. It is richly fossiliferous and many of the fossils described from the Permian near Hobart come from it.

The formation consists essentially of an alternation of fissile siltstones and non-fissile limestone, the limestone predominating. In addition metabentonite is present (Hale and Brill, 1955) on several horizons. The siltstone is similar in field appearance to that in the Nassau Siltstone. The limestone types in the Berriedale Limestone are varied. There are productid-fenestellid limestones, stenoporid limestones, crinoidal calcirudites and calcarenites, spiriferid-pelecypod limestones and calcilutites of several types. The limestones are seldom pure, as there is usually much clastic material of sand grade or even larger with erratics of quartz, igneous rocks and metamorphic rocks up to a foot in length in the limestone (Brill, 1956). Only one of these showed striations when examined by Brill but many of them are facetted. Occasional nodules of pyrite are present. Usually bedding is thick to very thick with thin to very thin bedding in the intercalated mudstone. The bedding planes, where they are well exposed in quarries, are frequently wavy, probably due to ripple marking.

Thin sections showed that one bed of limestone was composed of fragments of *Stenopora, Fenestella*, productid brachiopods, spiriferids, pelecypods, ostracodes and echinoderms. Siliceous sponge spicules, monaxons, were recognized. Some of the fossil fragments show solution along narrow tunnels and infilling with groundmass suggesting the action of some burrowing organism. Some of the fragments, especially the echinoderm pieces, show rounding. Rare grains of sericitised feldspar, magnetite and rounded fragments of green biotite are also present. The rock is well sorted with most of the fossil fragments in the sand grade with a few fragments in the granule and one in the pebble grade. The mineral particles are of sand grade. Much of the groundmass is recrystallised and is now a mosaic of calcite grains. This rock is a bryozoal calcarenite.

The type section for this formation should be in the Berriedale Quarries or in that vicinity but the structure there is not yet clear. The longest quarry exposure is at Weily's Quarry, Tolosa Street, Glenorchy (see Brill, 1956, for section, also text figure 7), but the underlying and overlying sections are not well exposed. At Mt. Nassau the formations above and below the limestone are present but again not well-exposed so that only the total thickness of the Cascade Group can be measured with any accuracy at about 300 feet. Of this about 40 feet at the base is Nassau Siltstone and then there is at least 50 feet of limestone exposed in the quarries but neither the bottom or the top of the limestone is included in the quarries. From poor exposures on the hill slopes it would appear that there is about 50 feet of this formation above and below the quarries making a minimum thickness of 150 feet but there may be more than this due to the difficulty of finding the boundary between the Berriedale Limestone and its contiguous formations in the absence of cliff or quarry sections. Brill (1956) has published sections through this formation in a number of places in the Hobart district and gave the details of the section at Weily's Quarry. Of this section the present authors would include units 11-60 only as the Berriedale Limestone—the higher units being considered here as the Grange Mudstone. This section is reproduced here in columnar form as text figure 6 which includes also the section measured by the authors in Geiss Creek, which is poorly exposed.

Fossils are abundant in this formation and represent almost every animal phylum as well as plants. Fragments of leaves and stems and pieces of fossil wood occur in it in places, e.g., Black Snake Gully Quarries, Granton, and the Rathbones Quarries, Mt. Nassau. Foraminifera are present at least at Weily's Quarry but have not been identified. Sponges have been identified in a section from Rathbone's Quarries. Corals occur also in the Rathbone's Quarries and include *Euryphyllum*. The brachiopod fauna is very rich and includes *Schuchertella, Taeniothaerus subquadratus* (Weily's Quarry, Berriedale Quarry and Rathbone's Quarries at least), *Strophalosia jukesi, Grantonia hobartense, Trigonotreta stokesii, Martiniopsis,* and *Dielasma*. Bryozoa include *Polypora woodsi, Stenopora pustulosa, S. hirsuta and Steno-*

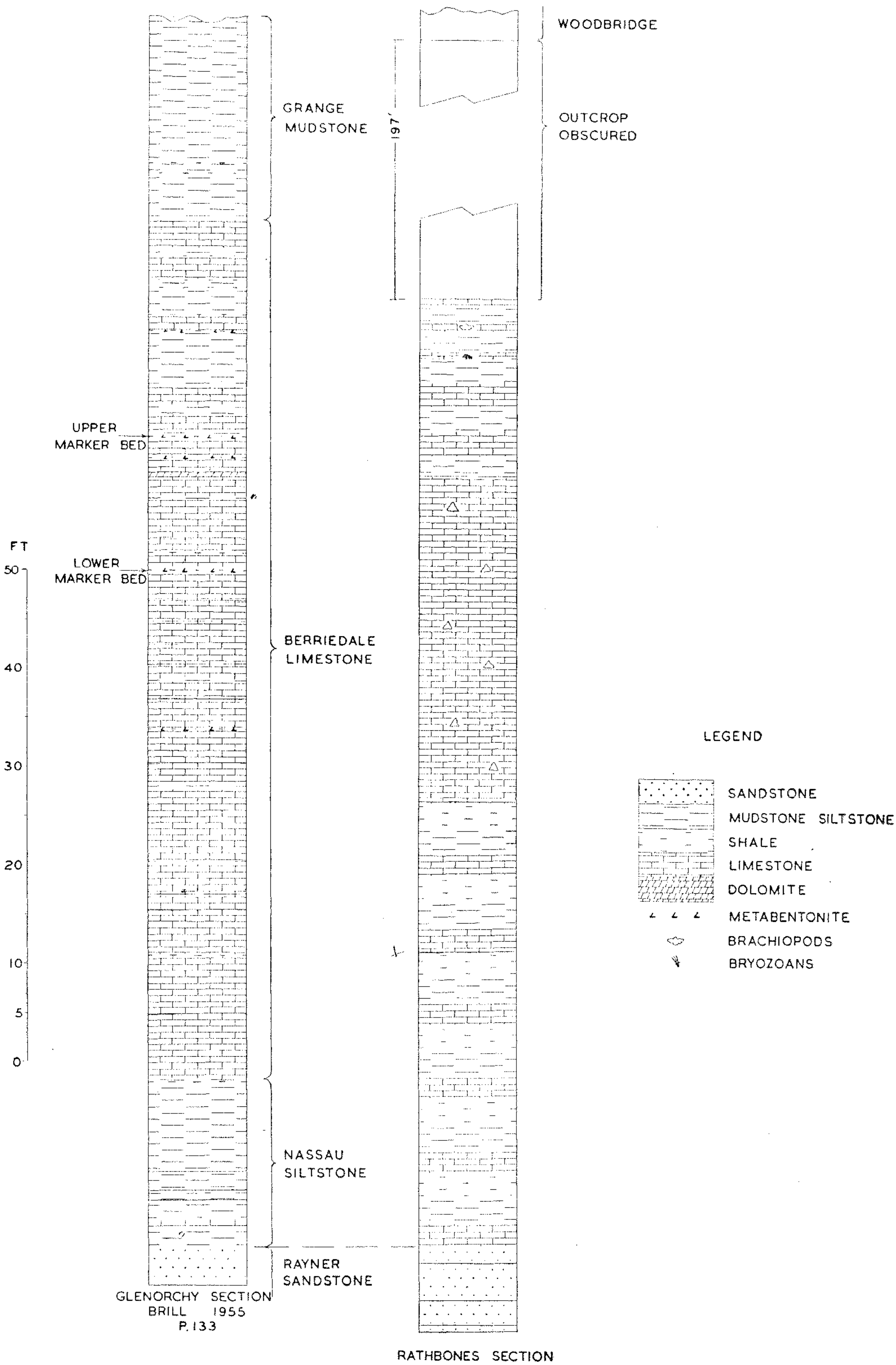

WOODBRIDGE
197'
OUTCROP
OBSCURED
GRANGE
MUDSTONE
UPPER
MARKER BED
FT
50
LOWER
MARKER BED
BERRIEDALE
LIMESTONE
40
30
20
10
5
0
LEGEND
SANDSTONE
MUDSTONE SILTSTONE
SHALE
LIMESTONE
DOLOMITE
METABENTONITE
BRACHIOPODS
BRYOZOANS
NASSAU
SILTSTONE
RAYNER
SANDSTONE
GLENORCHY SECTION
BRILL 1955
P. 133
RATHBONES SECTION

Fig. 7

discus moniliformis from the Berriedale Quarries and *Stenopora pustulosa, Polypora magnafenestrata,* and *Fenestella fossula* from Weily's Quarry. The bryozoa quoted are only those determined by Crockford in a series of papers summarized in 1951. Only one further bryozoan should be mentioned, *Lyroporella,* which has been found so far in the Hobart area at Rathbone's Quarries and at the Berriedale Quarries. Pelecypods are common and include *Astartila, Deltopecten limaeformis* and *D. subquinquelineatus, Aviculopecten englehardti, A. mitchelli, A. sprenti* and *A. squamuliferus,* from the Berriedale Quarries. *Eurydesma cordatum* var. *sacclum* has been found in the Mt. Nassau section and also in the Black Snake Gully Quarries. Many other pelecypods are present and have been recorded by authors last century, the only ones quoted being recent determinations. Gasteropods are not so common but many are present and include *Mourlonia morrisiana* from both Berriedale Quarries and the Mt. Nassau section. There are numerous undetermined ostracodes. A blastoid, probably *Pterotoblastus,* has been found at Rathbone's Quarries and at Berriedale Quarries. Crinoid elements are very common and have been identified as belonging to *Calceolispongia noetlingi,* and *Camptocrinus tasmaniensis* in the Mt. Nassau and/or Black Snake Gully Quarries. There are probably other species as well. Interambulacral plates and spines of *Archaeocidaris* have been found at Rathbone's Quarries. Although *Conularia* is not common it is represented by one large species, *C. derwentensis* which occurs at the Black Snake Gully Quarries and Rathbone's Quarries at least.

Of these fossils *Taeniothaerus subquadratus, Lyroporella* and *Pterotoblastus* can be easily identified and one or more of them are found in the Crinoidal Zone on Maria Island, the Peter Limestone at Coles Bay and the Gray Stage Limestone at St. Marys, the Enstone Park Limestone north of St. Marys, at Fingal, and at Avoca. In the Hobart sections these fossils occur low in the Berriedale Limestone. *Euryphyllum* in Tasmania is restricted to the lower parts of the Cascades Group and occurs in that position in the Mt. Nassau section, on Maria Island, at Coles Bay, St. Marys and north of St. Marys. Thus the limestones at these places are correlated with the Berriedale Limestone although exact equivalence is not suggested. The matter of the correlation of the Berriedale Limestone within Tasmania has been dealt with elsewhere in more detail (Banks, 1957*a*).

Some of the bryozoans, brachiopods, and pelecypods suggest a correlation of the Berriedale Limestone with some part of the Branxton Sub-Group in the Maitland Group of New South Wales and the Cattle Creek and/or Ingelara Stages in Queensland. The correlation with Western Australia is not at all certain for although there are some Westralian elements in the fauna these have not yet been studied. Interstate correlations have been dealt with by Banks (1957*a*) in more detail.

The comparative lack of clastic material in this formation probably indicates a lower land surface than during the deposition of the earlier formations. The erratics would indicate that icebergs were floating about in the sea and slowly melting. and their number and composition suggest derivation from a westerly or north-westerly direction (see Brill, 1956). As Brill has pointed out (1956), the cycles of limestone and mudstone in this formation could be due to several causes. In view of the common occurrence of glacial deposits in the Permian of Tasmania and the comparative rarity of pyroclastic deposits Brill's fourth hypothesis is thought to be the most likely. This is, namely, that the changes in the rate of sedimentation (or type of sediment, authors) may reflect the waxing and waning of glaciers. Thus the limestone (calcarenite) beds would represent times of increased current activity and shallower water and presumably also of increased supply of material from an uplifted surface on which glaciers are retreating and stream erosion is greater, while the mudstone beds represent periods of glacial advance, lower land surfaces and smaller stream capacities. Brill's observation that the erratics tend to occur in the mudstone or in the limestone close to the mudstone supports this hypothesis. The depth at which the limestone was deposited seems to have been variable. There is some evidence of ripple-marking, but this cannot be used as a depth criterion. The occurrence of calcarenites and crinoidal calcirudites suggests fairly strong currents as also does the weight and coarse ornamentation of the pelecypod and spiriferid shells. Stenoporid and fenestellid zoaria are usually broken. On the other hand the productids often occur in the mudstones with their spines still attached and some complete fenestellid colonies have been found associated with them. This indicates very quiet deposition for the mudstones. Normally limestone is considered as a warm water deposit but the presence of erratics suggests cold water condition. At the present time icebergs drift as far north as 35° S in the Atlantic where the surface temperature in the summer is about 20° and the bottom temperature about 10°. This provides some idea of the maximum temperature at which the Berriedale Limestone might have been deposited. In view of the number of erratics in the formation it is probable that the limestone was deposited closer to the edge of the Permian ice-sheet than this limit of 1600 miles. From the evidence of the areal distribution of the limestone and the nature of the erratics it is probable that the land with the ice-sheet was of the order of 100-200 miles away in which case the temperature would have been much lower on the sea floor, probably only a few degrees above zero centigrade. The simple horn corals which occur in this formation suggest deposition in cold, deep or murky water (Hill, 1948), and the foraminifera are mainly arenaceous types, again suggesting cold or deep water. The large size and weight of many of the pelecypod shells would normally be taken to indicate that they lived in warm water. However, it seems possible that some of the pelecypods, e.g., *Eurydesma cordatum,* and the brachiopods, e.g., *Taeniothaerus subquadratus,* may have been adapted to cold conditions and produced bigger, heavier shells in the colder seas. The consistent association of *Eurydesma* with glacial deposits throughout the Gondwana countries supports this, as also does the fact that the shells of *T. subquadratus* are thinner in Western Australia, where glaciation was less severe, than in Eastern Australia (see Prendergast, 1943). Thus the bulk of evidence suggests deposition in fairly quiet, cold water of varying depth.

Grange Mudstone

The Grange Mudstone is here defined as that formation of siltstone and calcareous siltstone which overlies the Berriedale Limestone, or where that formation is absent, the Rayner Sandstone, and underlies the "Woodbridge Glacial Formation". In its type area, at Porter Hill, Sandy Bay, it is about 290 feet thick. The co-ordinates of the type area are 521·5 E-715·5 N.

The formation is named after the Grange Quarry, the beds in which are continuous along the strike with the beds at Porter Hill, about half a mile to the north. It is richly fossiliferous, *Strophalosia* and fenestellids, including *Polypora woodsi*, being particularly abundant. It is Permian, probably Middle or Upper Artinskian, in age.

This formation has been known under one name or another since Johnston (1888, p. 118) referred to it as the "*Fenestella* Zone". Usage since that date is detailed hereunder:—

Fenestella Zone
  Johnston (1888, p. 118), Cascades, Porter Hill and Grange, *non* Maria Island.

non Fenestella Zone
  Montgomery (1891); beds below Crinoidal Zone on Maria Island.
  Johnston (1901); as Montgomery 1891.

non Fenestella Shales
  Gregory (1905), formation at top of Junee Group (Ordovician) at Gormanston.

Grange Stage
  Voisey (1938, p. 313).
  non Voisey (1949, p. 106), probably Golden Valley Limestone and Shale.
  David (1950, p. 359-360).

Grange Mudstones
  Hills and Carey (1949, p. 31).
  Banks in Hill (1955, p. 89).

Grange Sub-Stage
  Lewis (1946, pp. 22 *et seq.*).

Grange Facies
  Prider (1948, p. 173), probably partly equivalent.
  Fairbridge (1949, pp. 114, 5, 6), probably partly equivalent.

Grange Mudstone
  Banks (1952, p. 67).
  Hale (1953*a*, pp. 107 et seq.).
  Ford (1954, p. 154).
  Hale and Brill (1955, p. 233).
  Mather (1955, p. 193).
  Brill (1956, p. 135).

Grange Formation
  Fairbridge (1953).
  Hosking and Hueber (1954).

The Grange Mudstone consists essentially of siltstone, calcareous siltstone and minor beds of limestone, dolomite and nontronite. The section at the Grange Quarry which is the best exposure in the type area is here published in columnar form as text figure 8 with the kind permission of K. G. Brill, who measured it.

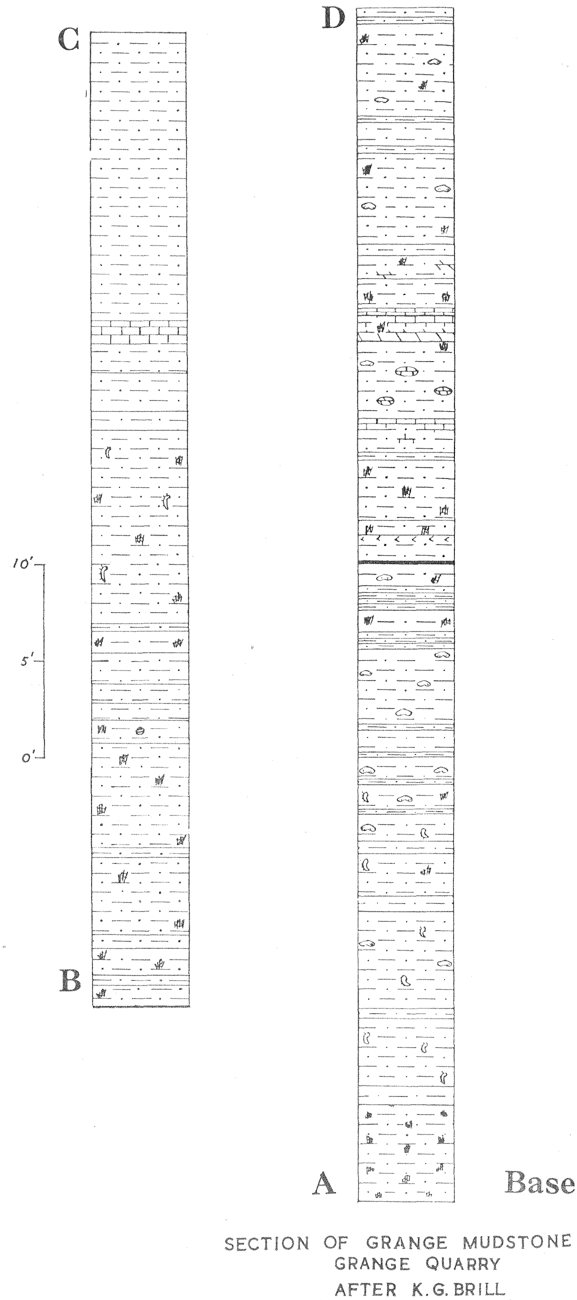


Fig. 8

This section is not quite as long as that at Porter Hill but is better exposed. The top of the section is missing at Grange Quarry, being replaced by a transgressive dolerite body. The lithology of the formation has been described by Voisey (1938), Lewis (1946), Banks (1952), Hosking and Hueber (1954) and Hale and Brill (1955). One of the characteristic features of the formation is the creamy (moderate yellow to greyish-yellow) colour of many beds and the abundance of *Strophalosia* and fenestellids which produce the appearance of lamination. The formation was apparently particularly susceptible to intrusion by dolerite with the production of contact metamorphic effects. As a result the calcite of the shells is often recrystallised and diopside and other calc-silicate minerals develop. In addition to this there is extensive silicification so that both calc-silicate and siliceous hornfelses are produced.

Thin sections were cut of two of the limestones of this formation from Mt. Nassau. Both are calcilutites with an abundance of *Strophalosia*. One section consists of numerous shell fragments up to pebble size, but mainly in the sand grade, with fragments of quartz of sand grade in a groundmass of silt and clay grade grains of calcite with a little quartz. The groundmass is not uniform in grain size, there being irregular areas of clay grade in the groundmass which is dominantly silt grade. Most of the grains of quartz are angular. Fragments of quartz muscovite schist and other rocks are also present. Angular, often bent, grains of green biotite, magnetite and small grains of zircon are present. The shell fragments which show resorption in some cases include those of productid spines, a perforate uniserial foraminifera, pseudopunctate brachiopods, pelecypods, *Stenopora* and rare fenestellids. The other section is that of a well-bedded limestone with beds of fine calcarenite and fine calcilutite. The calcite grains in the calcarenite are mostly recrystallised. Angular grains of quartz of fine sand grade are present. The shell fragments are mainly fenestellids but some braciopod spines and fragments of pseudopunctate shells, pelecypod fragments and *Stenopora* are also present.

At Porter Hill the Grange Mudstone overlies about 20 feet of medium-grey, richly fossiliferous, foetid limestone which is lithologically like the Berriedale Limestone. This thin limestone unit overlies a bed of sub-greywacke sandstone which is about ten feet thick and similar to the Rayner Sandstone. Over the thin limestone unit there is typical Grange Mudstone which continues upwards for about 290 feet (Abney level figure) but in several places contains beds of greyish limestone up to two feet thick. These limestone beds are quite subordinate as will be seen also from the columnar section, based on exposures at the Grange Quarry. Above the Grange Mudstone at Porter Hill is a conglomeratic sandstone with rare marine fossils and plant fragments, which is lithologically very like the sandstone at the base of the " Woodbridge Glacial Formation " at Mt. Nassau. At the Cascades there is again an association of creamy mudstone, rich in fenestellids and *Strophalosia* with medium-grey limestone with spiriferids and pelecypods. There the association, which becomes dominantly creamy mudstone near the top, is overlain by sandstone at the base of the " Woodbridge Glacial Formation ". This latter formation can be traced up into the Risdon Sandstone and Ferntree Mudstone in this area. At Weily's Quarry, Glenorchy, Brill (1956, p. 138) shows the Berriedale Limestone overlain by the Grange Mudstone. The authors would prefer to take the Grange Mudstone down to include unit 61 of Brill's section, taking as the base of the Grange Mudstone, the first bed above the point where mudstone becomes dominant over limestone in thickness. Grange Mudstone overlies the Berriedale Limestone and underlies the " Woodbridge Glacial Formation " at the Berriedale Quarries but the section at this locality is not at all clear. At Mt. Nassau the Berriedale Limestone in the quarries is overlain by about 50 feet of limestone before the Grange-type mudstones appear to become predominant. The exact horizon where this takes place cannot be determined due to poor outcrop but there is about 100 feet of Grange Mudstone in this section making the total thickness of the Cascades Group about 300 feet. The Grange Mudstone in this section is overlain by a sandstone at the base of the " Woodbridge Glacial Formation ". Throughout the Hobart area then, creamy, fenestellid, *Strophalosia*-rich mudstones with very subordinate limestones overly the Berriedale Limestone directly and underly the " Woodbridge Glacial Formation '. They increase in thickness from Mt. Nassau south to Sandy Bay at the expense of the lower formations of the Cascades Group which maintains a fairly constant thickness throughout this area. Thus while the Grange Mudstone always overlies the Berriedale Limestone where this latter formation is present, it also appears to occupy progressively more and more of the stratigraphical position of the Berriedale Limestone to the south until at Snug and other places in the south-east the Cascades Group consists only of the Grange Mudstone. Thus on stratigraphical evidence it is suggested that the Berriedale Limestone and the Grange Mudstone are to a considerable extent facies variants, the one of the other. On the stratigraphical evidence presented other interpretations are also possible, for example, it is possible that the Berriedale Limestone was deposited in its entirety before deposition of the Grange Mudstone began and that the areal distribution of the limestone and its thickness variations may be in no way related to the distribution and variation in thickness of the Grange Mudstone.

The Grange Mudstone is richly fossiliferous. It is interesting to note that Johnston (1888, p. 118) recorded *Taeniothaerus subquadratus* from his *Fenestella* Zone, now called the Grange Mudstone, at either Cascades, Porter Hill or the Grange. As this fossil is restricted to a narrow zone within the Berriedale Limestone in Tasmania, this record suggests that the two formations are at least partly equivalent. The present authors have not yet been able to verify this report, nor to find *Lyroporella* or *Pterotoblastus* in the Grange Mudstone, but there is a strong possibility that these fossils are restricted to the limestone facies in Tasmania. From the Grange Quarry, Fletcher (in Voisey, 1938) recorded *Deltopecten subquinquelineatus*, *Platyschisma oculus* and *Mourlonia morrisiana* as well as numerous other fossils. From Fletcher's list it will be seen that every species listed from the Grange Quarry, with the exception of *Platyschisma oculus*, occurs also in the Berriedale Limestone at Collinsvale Lime Kilns (referred to in this paper as the Berriedale Quarry) and at Granton (either the Black Snake Gully or Rathbone's Quarry, or both). Voisey's fossil localities 6 and 7 (1938, p. 326) are not now considered as equivalent to the Grange Mudstone but to the richly fossiliferous beds just below the top of the " Woodbridge Glacial Formation ". From the Grange Quarry, Crockford (1951) recorded the bryozoa *Fenestella dispersa, F. fossula* and *Polypora woodsi,* all of which also occur in the Berriedale Limestone (Crockford, 1951, pp. 110, 111). *Polypora woodsi* is restricted to part of the Branxton Sub-group in New South Wales but has a longer range in Queensland and Western Australia apparently. It is remarkable that although *Wyndhamia dalwoodensis* (equals *Strophalosia typica* is regarded as characteristic of the Grange Mudstone by Voisey (1938, p. 328), on the list of fossils in his paper it is recorded from the Berriedale Limestone in two places and from the richly fossiliferous horizon just below the top of the " Woodbridge Glacial Formation " on Mount Faulkner, but not from Grange Quarry. Both Voisey (1938) and Crockford (1951) suggest correlation of the Grange Mudstone with the Branxton Sub-group of New South Wales and Banks (1957*a*) has suggested that the Berriedale Limestone is also at least partly equivalent to the same subgroup. Recorded fossil evidence thus also supports the hypothesis that the Berriedale Limestone is at least partly a facies variant of the Grange Mudstone but further work is necessary before the hypothesis can be regarded as proved, Hills and Carey (1949, p. 31) state that there is considerable facies variation between sections of their Cascades Formation, but this term has a much wider meaning than the Cascades Group as here used, and it is not clear that they envisaged the facies variation postulated here.

" Woodbridge Glacial Formation "

It is not appropriate here to define the formation between the top of the Cascades Group and the base of the Risdon Sandstone as another worker who has studied the formation over a wide area hopes to do this shortly.

In the Mt. Nassau section the Cascades Group is overlain by a formation of sandstone and siltstone which is about 275 feet thick (measured with Abney level) and overlain by the Risdon Sandstone. At the base is a conglomeratic sandstone which contains numerous erratics and fossils, except bryozoa, which are rare. About 60 feet above the base the formation becomes finer-grained and is dominantly siltstone with numerous sandstone bands. In this part of the formation the fossils become uncommon, and although erratics are present they are not very common, and there is no really tillitic bed. About 50 feet from the top of the formation there is a bed of siltstone which is very rich in fossils, mainly productids but with some spiriferids and pelecypods. This bed is only a few feet thick. Lenses of limestone occur in the formation on Mt. Nassau from 23 feet to 21 feet 6 inches below the top of the Risdon Sandstone. The measurement is given in this form because the top of the " Woodbridge Glacial Formation " is hidden by talus. However, this would mean that the limestone lenses are between 13 feet and 11 feet 6 inches from the top of the formation. The limestone lenses are at least 18 inches thick and the rock is olive-grey, foetid and fossiliferous. The fossils include *Martiniopsis, Stenopora crinita, Strophalosia, Mourlonia* and fenestellids.

In the main part of the " Woodbridge Glacial Formation " the commonest fossils are spiriferids and pelecypods and plant fragments are also common. A very alate spiriferid is common in the formation and occurs in the excavations for the Lake Fenton Pipeline above Rathbone's Quarries.

Thin sections were cut of several rock tyes in the formation on the flanks of Mt. Nassau. The sandstone at the base contains much quartz, some feldspar (slightly weathered orthoclase, microcline and andesine), muscovite and green biotite. Accessory minerals include ilmenite, sphene, zircon, tourmaline (schorlite) and rutile. The groundmass is composed of quartz, muscovite, chlorite and limonite. Rock fragments are common and include micaceous quartzite, haematitic quartzite, mica schist, graphitic mica schist and muscovite gneiss. Some of the quartz grains contain zircon crystals, some contain muscovite, some show undulose extinction and some show regrowth, one piece having two rings of inclusions inside an angular grain. Rutile occurs as grains in the rock and also as crystals in quartz grains, one of these being twinned in the characteristic fashion. Most of the zircon is angular, but some is sub-rounded, some is in the form of crystals and some shows regrowth. The rock is a fine sandstone, average grain size about 0·25 mm. The largest grain present in the slide is a pebble (4·5 mm.) and there are small interstitial patches of very fine siltstone (0·015 mm.). The grains are mostly highly angular, and many have sutured boundaries with neighbouring grains, so that the overall texture is mosaic. There is no obvious preferred orientation. The rock is a conglomeratic, somewhat impure, partially recrystallised sandstone.

A siltstone from higher in the formation contains grains of quartz microcline, andesine, microperthite, chlorite, mica flakes and zircon. The total feldspar content is only about 5 per cent. Fragments of mica schist with tourmaline, quartz biotite schist (green biotite), and a rock with feldspar phenocrysts with rude flow structure are present. The grains are dominantly in the silt grade (about 0·015 mm.) but fragments up to 0·56 mm. long are present and much of the groundmass is probably in the clay grade. Sorting appears to be poor. The larger grains are mainly angular to sub-angular but some are sub-rounded. Rounding appears to be a little better in the finer grades. Most of the grains are equant, but a few, especially the micas, are bladed to almost acicular.

The limestone from close to the top of the formation is composed of fragments of quartz and shell material. The shell fragments are up to 2 mm. long but the quartz grains are smaller, from 0·03 to 0·25 mm. only. The groundmass is of calcite and quartz fragments mainly of fine silt grade but with some in the clay grade. There are angular fragments of quartz, plagioclase, green biotite, magnetite, chlorite, microcline and muscovite and some of the quartz grains are almost cuspate. Some of the quartz contains zircon. The shell fragments some of which show resorption, include productid spines, foraminifera, pelecypods and probably ostracodes. It is essentially a productid calcilutite.

No attempt will be made here to deal with the conditions of deposition of this formation except to point out the predominance of metamorphic types in the rock fragments and of the minerals derived from these. These appear to be more like the Precambrian rocks than any later rocks in Tasmania. There is evidence also of derivation of some of the sediment from pre-existing sediment and of some from a granitic and pegmatitic terrane. There has been extensive recrystallisation of the rock, particularly of the sandstone at the base with its mosaic texture.

Risdon Sandstone

The Risdon Sandstone is here defined as that formation of feldspathic sandstone which lies between the "Woodbridge Glacial Formation" below and the Ferntree Mudstone above, in the Mt. Nassau section. The type area is in a road cutting on the north-east side of the road up Risdon Creek near Bowen's Monument, about two chains from its junction with the Risdon-Richmond Road. The co-ordinates of the type area are 519·4 E-719·2 N. The name is derived from the village of Risdon. It is ten feet thick. It is Permian, probably Upper Artinskian or Lower Kungurian, in age.

This name was first used by Carey and Henderson in an unpublished report to the Mines Department in 1946 for the basal member of the Ferntree Mudstone. It has been used since in that sense by Carey (1947, p. 32) (the first published use of the term), Prider (1948, p. 134), Hills and Carey (1949, p. 32), Voisey (1949, p. 106), Banks (1952, p. 70), Hale (1953, p. 20; 1953*a*, p. 107) Ford (1954, p. 154), Hale and Brill (1955) and Mather (1955). It is a very widespread, easily recognizable and very mappable unit and for these reasons is here considered as a formation.

On the flanks of Mt. Nassau it is present as a bench-making horizon and shows the characters described earlier by Banks (1952, p. 71). One feature not noted earlier is the occurrence of tubicolar casts perpendicular or at a high angle to the bedding in the Mt. Nassau section.

A section of this rock was examined and showed the presence of quartz, much plagioclase (20-25%), muscovite, zircon, haematite and limonite, as well as a few pieces of microcline, ilmenite, brown biotite, and tourmaline. The plagioclase includes albite and andesine, and there is one piece of quartz and microperthite present. Rock fragments are not common but there are a few including a piece of quartzite. Most of the grains are about 0·16 mm. long with a few grains up to 1 mm. long and a small amount of finer material. Most of the grains are angular but there are a few sub-angular grains present. The grains are dominantly equidimensional but a few are tabular. Many of the grains have developed sutured outlines by regrowth so that a mosaic texture is produced. The rock on Mt. Nassau is a richly feldspathic sandstone.

Ferntree Mudstone

The Ferntree Mudstone may be defined as that formation consisting dominantly of an alternation of fissile and non-fissile siltstone which overlies the Risdon Sandstone and underlies the Cygnet Coal Measure or, where these are absent, the Knocklofty Sandstone and Shale of the Triassic System. It is 600 feet thick. The formation is named after the village of Ferntree where it outcrops (co-ordinates 512·6 E-715·9 N) and which should be the type area. The formation is Permian, probably Kungurian, in age.

This formation has received a number of different names since Johnston (1888, p. 118) referred to it as the Mudstone Zone. The synonymy is as follows:

Mudstone Zone
Johnston (1888, p. 118).

Upper Marine Series
Johnston (1888, p. 118).

Lindisfarne Stage
Voisey (1938, pp. 313 *et seq.*).
David (1950).
non Lewis (1946); for "Woodbridge Glacial Formation".

Lindisfarne Mudstone
Carey (1947).

Ferntree Mudstone Stage
Lewis (1946, pp. 22 *et seq.*).

Ferntree Mudstones
Carey (1947, pp. 32, 33, 36).
Hills and Carey (1949, p. 32).

Ferntree Formation
Prider (1948, pp. 127 *et seq.*).
Ford (1956, p. 150).

Ferntree Stage
Voisey (1949, pp. 106, 108).

Ferntree Mudstone Formation
Fairbridge (1949, pp. 114, 118).
Fairbridge (1953).

Ferntree Mudstone
Banks (1952, pp. 70 *et seq.*).
Hale (1953*a*, pp. 98 *et seq.*).
Brill and Hale (1954, pp. 279, 281).
Ford (1954, pp. 155 *et seq.*).
Ford (1954*a*, p. 185).
Hale and Brill (1955, pp. 233-4).
Jennings (1955, pp. 172 *et seq*).
Mather (1955, pp. 193 *et seq.*).

In the Mt. Nassau section the Ferntree Mudstone consists of an alternation of fissile and non-fissile siltstone but the exposures are not good and detailed stratigrahic work could not be done. Exposures in the Ferntree district are rather better because of the presence of numerous road cuttings but still not good enough for preliminary detailed measurement due to very complex faulting and a thick cover of vegetation. The best section availıble in the Hobart area is probably in the bed of Vew Town Creek and it is hoped to measure this in letail shortly.

In the Mt. Nassau section the Ferntree Mudstone s 600 feet thick but this may not represent the ıotal thickness of the formation as the next highest ormation, the Cygnet Coal Measures, does not ıutcrop in this section. This lack of outcrop may ɔe due to erosion before the deposition of the Triassic System or to non-deposition, but no choice ;an yet be made between the alternatives although he erosional hypothesis is supported by disconormities between the Ferntree Mudstone and the Triassic System in at least two places in the Huon listrict. Lewis (1946, p. 94) gives a section in Vew Town Creek and it is notable that in it there ıre 25-30 feet of Cygnet Coal Measures. The lack ıf Cygnet Coal Measures at Mt. Nassau may be ıpparent rather than real as the outcrop near the op of the Ferntree Mudstone is very poor and the ;oal measures could be covered by talus.

It is not proposed to give a full description of he Ferntree Mudstone on Mt. Nassau but to wait ill the detailed section is measured in New Town Creek. Observations on this formation in the Mt. Vassau section which have not earlier been re;orded are that marine fossils occur sparsely ıut are particularly noticeable just above the base ınd again about 400 feet above the base. Even at hese levels they are not common. Spiriferids ıre the commonest types. Worm tubes are comnon.

Examination of a thin section showed that the iltstone consists of rock and mineral fragments ıp to 1 mm. in length in a groundmass about)·02 mm. in average grade. It is not well-sorted ıs all intermediate grades appear to be present in ıbout equal amount. The fragments are very reguar to almost cuspate and tend to be tabular or ›laded rather than equant and a few are prolate. There are signs of rude bedding in the rough ›rientation of fragments. Quartz is the dominant nineral but microcline, plagioclase, muscovite and ı small amount of biotite are also present. The ;roundmass is haematitic. Rock fragments are ılso present and include quartzite and micaceous ıuartzite.

As has been remarked earlier, the beds at the top ıf the Bundella Mudstone, the Jarvis Siltstone, he Fergusson Siltstone and the Ferntree Mudtone are all lithologically very similar and this uggests recurrence of similar conditions at those evels. It has been suggested earlier (Banks, 1952) hat the Ferntree Mudstone was deposited in ›rackish, shallow, possibly estuarine conditions vith occasional access of ice-bergs. Such condiions would seem to satisfy all that is known about he other formations and also their position in the ;yclothems.

SUMMARY

On the northern slopes of Mt. Nassau about 1430 eet (1436 as measured) of Permian sediments are ›xposed in an uninterrupted sequence. This is the ›est section known in the Hobart district for the Permian succession but in other places exposures ıf individual formations are better. The Geiss Creek section is particularly noteworthy for the ine exposures of the formations below the Berrielale Limestone.

The succession is summarized in columnar form ıs text figure 9:

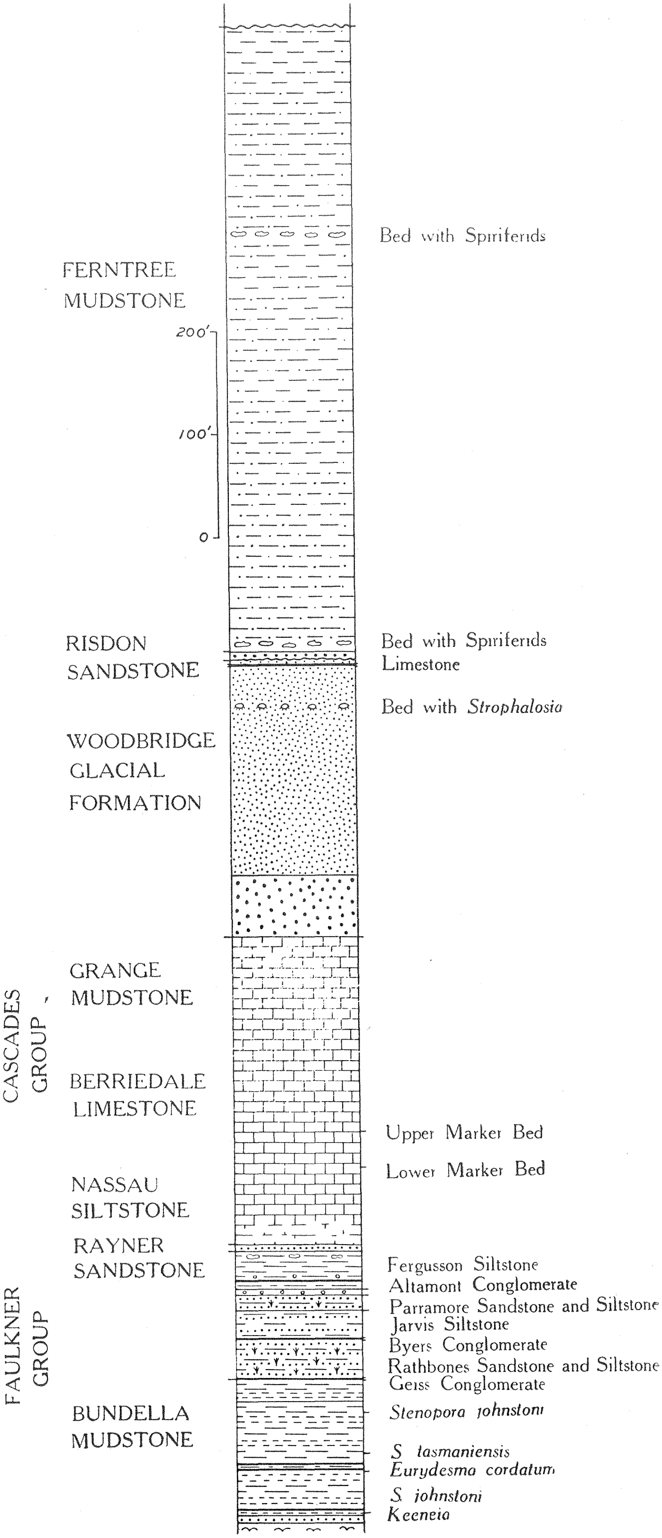


Fig. 9

Unfortunately the section does not reach the base of the Permian as developed in Tasmania but correlation of the basal formation in this section with beds on Maria and Woody Islands suggests that it is underlain at no great depth by the Darlington Limestone beneath which is the sequence on Woody Island, about 300 feet thick, and below that again the basal beds in the Florentine Valley, about 200 feet thick. On top of the section in some places is the Cygnet Coal Measures, about 300 feet thick, giving a maximum thickness for the south-eastern Permian as about 2250 to 2300 feet. The correlations involved, as well as the successions, have been dealt with by Banks (1957*a*).

The succession on Mt. Nassau probably begins in the lower part of Artinskian, judging from correlations of the Darlington Limestone with beds in New South Wales and Western Australia, and the ages determined on the beds in the other States, especially on the ammonities in the Western Australian succession. On bryozoan evidence Crockford (1951) considered the "Woodbridge Glacial Formation" at Eaglehawk Neck to be basal Kungurian, so that the higher formations are probably Kungurian or possibly younger.

Of special significance is the occurrence of the fresh water beds in the Faulkner Group, signifying a period of emergence, broken here by a minor submergent phase, in the general submergence during the Permian. The Permian succession in south-eastern Tasmania when considered as a whole show initial deposition of tillite on a land surface, then marine deposition, an emergence, followed by another submergence and finally an emergence. This sequence of events has considerable parallel with those in the Permian in New South Wales but whether similar events were actually contemporaneous in the two areas is not yet established. There is some evidence from correlation already made that they could have been roughly simultaneous. The parts played in the movements of sea level in Tasmania by glaciation and by tectonic activity cannot yet be elucidated. The Faulkner Group is considered to consist of two cyclothems.

While the Berriedale Limestone is overlain by the Grange Mudstone in many places, there is stratigraphical and palaeontological evidence that the Berriedale and Grange Formations are equivalent in age and that the Berriedale Limestone is replaced in stratigraphic position to the south-east by the Grange Mudstone. Thus the two formations are considered to be at least partly facies variants of one another.

Mineralogically the sediments in this section are remarkably constant and even in the limestones some of the characteristic minerals occur. There does not seem to be any change in overall mineral composition from bottom to top of the section. Quartz is the most common mineral and several varieties are present. Quartz with undulose extinction, quartz with rutile inclusions, quartz with zircon inclusions and quartz showing up to two zones of inclusions indicating regrowth are all present. The dominant feldspar present is microcline but orthoclase, albite, andesine and microperthite are also present, andesine being more common than the others. In most formations the feldspar forms less than 10 per cent of the rock, but in the Risdon Sandstone up to 25 per cent is present. The micas include muscovite, the commonest type, green biotite and brown biotite. Minor amounts of chlorite, clay minerals and carbonaceous matter occur in several formations and hydrated iron oxides occur in most formations. Heavy, accessory minerals include zircon, apatite, tourmaline (usually schlorite), garnet, ilmenite, magnetite, pyrite, epidote and rutile. Calcite is common on several horizons and dolomite has been noted in the Grange Mudstone. Montmorillonite occurs in the Berriedale Limestone and nontronite in the Grange Mudstone. The presence of up to 10 per cent of fresh feldspar in most formations, except the Rathbones and Parramore Formations, and up to 25 per cent in the Risdon Sandstone indicates some mineralogical immaturity in the sediments. The minerals suggest that the Permian sediments were derived from a terrain of granitic and pegmatitic rocks, quartzose sedimentary rocks and dynamically metamorphosed rocks. Contemporaneous volcanic activity is suggested by the presence of montmorillonite in the Berriedale Limestone.

Inferences based on the mineralogy of the sediments as to the provenance are confirmed and amplified by the types of erratics present.

The erratics include granite, feldspar porphyry and large pieces of vein quartz, limestone, mudstone, quartzite, micaceous quartzite, haematitic quartzite, slate, phyllite, muscovite schist, muscovite chlorite schist, quartz muscovite schist, quartz biotite schist (with green biotite), biotite schist, chlorite schist, graphitic mica schist, tourmaline-bearing mica schist, and muscovite gneiss. The metamorphic types are much commoner than the igneous or sedimentary types. The presence of these metamorphic rocks suggests a source within the Precambrian areas of Tasmania to the south-west, west or north-west of Hobart, and all of the rock types and minerals present could come from the Precambrian, Lower and Middle Palaeozoic rocks of the western half of Tasmania. There is on the other hand no evidence of rocks from the north-eastern part of the State. None of the erratics noted are such that specific localities of origin can be allocated to them.

With some exceptions to be dealt with shortly the rocks of the section all show some common textural features, namely the poor sorting, exemplified megascopically by the presence of erratics, lack of cross or graded-bedding, and marked angularity of grains, many of which are almost cuspate. In conjunction with the mineralogical immaturity these features could be taken to indicate tectonic instability in the source and depositional areas, but the shape of the beds (tabular) and known distribution of thickness of beds and formations indicates a fairly stable depositional area. The presence of numerous erratics and fresh feldspar indicate that disintegration predominated over decomposition in the source area and that glaciers and icebergs were important in transporation. This mode of transport is supported by the texture of the rocks. Deposition apparently occurred below wave base as shown by the poor sorting and lack of current or wave structures. This does not necessarily mean deep water. Slump structures are uncommon and graded bedding absent so that turbidity currents do not seem to have been important agents of transportation. The best explanation of most features of the sediments seems to be one involving glaciation and iceberg transportation. The exception to these remarks are the Rathbones and Parramore Formations which combine relative mineralogical maturity with good sorting, lack of erratics, cross-bedding ripple marking, slump structure and intraformational conglomerates. Except for the high degree of angularity of their grains they are normal members of the ortho-quartzite-limestone suite. It has been suggested earlier that they were produced mainly by reworking of earlier Permian sediments.

One feature of special interest is the development of a mosaic texture in several of the sandstones, e.g., Rathbones, Jarvis, "Woodbridge" and Risdon Formations, by the regrowth of quartz so that the quartz grains often have sutured contacts. This produces a texture similar to that of contact metamorphic hornfelses, but in this section there is at least 140 feet of sediment below the Rathbones Formation and 600 feet of sediment above the Risdon with no dolerite and the nearest dolerite laterally is over half a mile away. Because of this the mosaic texture is regarded as a product of normal lithification rather than contact metamorphism.

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LOCALITY INDEX

	Latitude	Longitude
Avoca	41° 47′	147° 43′
Bothwell	42° 23′	147° 01′
Coles Bay	42° 07′	148° 19′
Cressy	41° 01′	147° 05′
Deloraine	41° 31′	146° 40′
Eaglehawk Neck	43° 01′	147° 55′
Fingal	41° 36′	147° 53′
Florentine Valley	42° 35′	146° 30′
Gormanston	42° 04′	145° 35′
Hobart	42° 52′	147° 20′
Maria Island	42° 37′	148° 06′
Marlborough	42° 11′	146° 30′
Mt. La Perouse	43° 29′	146° 45′
St. Marys	41° 35′	148° 12′
Seymour	41° 45′	148° 16′
Snug	43° 04′	147° 15′
Snug Falls River	43° 04′	147° 15′
Woody Island	43° 19′	147° 13′

The following localities are all close to Hobart so that their co-ordinates are given in terms of the state grid system. Co-ordinates are given as thousands of yards east and north of the origin of that grid system.

	East	North
Altamont	502·6	735·6
Black Snake Gully, Quarries, Granton	509·1	735·3
Berriedale Quarry	508·5	727·4
Bundella Station	503·1	736·8
Byers Creek	506·3	737·5
Cascades	515·4	719
Fergusson Creek	504·3	735·5
Ferntree	512·6	715·9
Geiss Creek	504·7	736·6
Grange Quarry	521·05	714·67
Huon Road	513·5	717·6
Jarvis Creek	504·0	736·3
Mt. Dromedary	500·0	741·5
Mt. Faulkner	506·6	731·3
Mt. Nassau	506·0	733·4
New Town Creek	511·3	720·7
Parramore Creek	505·2	736·8
Porter Hill	521·5	715·5
Rathbone's Quarries, Mt. Nassau	506·3	736·8
Rayner Creek	505·8	737·3
Risdon	519·4	719·2
Sandy Bay	521·5	715·5
Weily's Quarry, Glenorchy	512·3	724·4