THE MALBINA SILTSTONE AND SANDSTONE

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ABSTRACT

The Malbina Siltstone and Sandstone overlies the Cascades Group and underlies the Risdon Sandstone in the Hobart area, Tasmania. This unit has been called "Woodbridge Glacial Formation" and other names. In the type section five members can be recognized:—"A", a basal sandstone; followed by "B", a siltstone; "C", a thin-pebbly sandstone; "D", a siltstone; and "E", the uppermost richly fossiliferous sandstone and siltstone. Some of the sandstone beds are poorly sorted and graded. The silts were deposited in fairly deep water and deposition of silt was interrupted from time to time by inrushes of turbidity currents bringing pebbles, sand and shells from shallower water. Erratics indicate the presence of rare icebergs. The formation is Upper Artinskian or Kungurian.

INTRODUCTION

This formation was first recognized by Voisey (1938, p. 313) who referred to it as the 'Woodbridge Glacial Stage". Lewis (1946, p. 22) called it "Lindisfarne Conglomerate Stage" but was not consistent (see Smith, 1959, pp. 148-149) so that Prider (1948, p. 34) suggested the retention of Voisey's term, which was amended to "Woodbridge Glacial Formation" by Hills and Carey (1949, p. 31) and used in that form by a number of later authors.

McKellar (1957) used the term "Woodbridge Group" for the rocks between the Liffey Group and the Ferntree Group in the Western Tiers. In terms of the Hobart succession his "Woodbridge Group" would probably be equivalent to the top of the Faulkner Group, the Rayner Sandstone, Cascades Group of Banks and Hale (1957) and the formation here called Malbina Siltstone and Sandstone.

The term "Woodbridge" was first used by Lewis (1937, p. 434) for rocks at Woodbridge which he correlated with rocks at Cape Lamanon on the basis of the presence of "erratics" in both. The "Cape Paul Lamanon Series" is probably equivalent to the Malbina Formation as here used but has not been carefully studied. The "Woodbridge Series" at Woodbridge is an unbedded, poorly-sorted, ungraded rock with numerous striated and facetted pebbles and is a true tillite. It is lithologically quite distinct from the bedded, fossiliferous, pebbly sandstones and siltstones of the "Woodbridge Glacial Formation" in the Hobart area. In the Woodbridge area the section is not clear but the tillite appears to be overlain at some distance by a mudstone identifiable on fossil evidence as Bundella Mudstone. In this same area rocks having the lithology and fossils of the Malbina Formation overly the Cascades Group which rests in turn on the Faulkner Group which contains typical carbonaceous siltstones near Oyster Cove Post Office. The Faulkner Group overlies, in turn, the Bundella Mudstone. It is, thus, very unlikely that the "Woodbridge Series" at Woodbridge and the "Woodbridge Glacial Formation" are the same formation or correlates. The "Woodbridge Series" is probably equivalent to the Wynyard Tillite at the base of the Permian successon in Tasmania.

It seems wisest to discontinue the use of the term "Woodbridge" except for the tillite at Woodbridge. The formation called "Woodbridge Glacial Formation" in the Hobart area is here named the "Malbina Siltstone and Sandstone" to which the "Cape Paul Lamanon Series" may be equivalent. The "Woodbridge Group" of McKellar should be given a different name.

When Banks and Hale described the Permian sequence in the Hobart area in 1957 they were unable to quote a suitable type section for the "Woodbridge Glacial Formation". Every section examined at that stage was unsuitable because of lack of outcrop, lack of base or top, or faulting.

During 1959 Read mapped the area west of Granton as part of an honours course in geology at the University of Tasmania. A good section in and around Jarvis Creek (see map, fig. 1, Banks and Hale, 1957) was found and then surveyed in detail by both authors. The section occurs on the hill slopes west of Jarvis Creek and in the bed of Fergusson Creek and the southern slope of the valley of Fergusson Creek just above its junction with Jarvis Creek. Thicknesses were measured by level and staff and thicknesses between stations on steep slopes or cliffs with a steel tape. A dip of 3½° degrees to the south-west was used in the thickness calculations. It is unlikely that any of the thicknesses are in error by as much as a foot and many of them are in error by less than an inch. The authors wish to acknowledge their indebtedness to Dr. E. Williams, now of the Geological Survey of British Guiana, for many stimulating discussions on the conditions of formation of the unit being discussed, and to Mr. A. H. Spry for assistance with the mineral identifications and helpful comments on the manuscript and to Professor S. W. Carey for helpful criticism.

STRATIGRAPHY

The Malbina Siltstone and Sandstone is defined as that formation of siltstone and sandstone 300 feet thick which conformably overlies the Grange Mudstone and underlies the Risdon Sandstone in Jarvis Creek (co-ordinates 50422.73528). The name is derived from the old Malbina Cemetery nearby. The formation contains *Stenopora crinita, Strophalosia typica* and *Strophalosia ovalis* and is Upper Artinskian or Kungurian in age.

In the type area the formation can be divided into five members, A, B, C, D, E, which can also be recognized in the South Arm area (see Green, 1961) and at Eaglehawk Neck.

Member A

The lowest member ("A") is composed of sandstone with subordinate siltstone and is about 130 feet thick. The detailed section is given as Appendix A.

Coarse sandstone occurs on four horizons, the main development being that of unit 19 which probably consists of three beds each of which have fossils and pebbles at the base. The coarse sandstone units vary from 0.10-5.00 feet in thickness, averaging 0.97 feet thick in Member A and 1.34 feet thick in the whole formation. Medium sandstone is more common (22% approx. of Member A, 11.5% approx. of whole formation) than the coarse sandstone. The beds of medium sandstone vary from 0.20-2.30 feet thick, averaging 1.34 feet thick in Member A, 1.20 feet in the whole formation and having a modal thickness of beds of 1.0 feet. Fine sandstone forms 46% of Member A, 29% of the whole formation. It occurs in beds from 0.10-4.40 feet thick, averaging 1.19 feet for Member A and having a modal thickness of 0.5 feet for Members A-D. Siltstone forms a relatively small proportion (about 13%) of Member A but almost half (about 49%) of the whole formation. The beds of siltstone in Member A vary from 0.05-1.10 feet thick, averaging 0.41 feet and having a modal thickness of 0.2 feet. The siltstone units in higher members are much thicker but each may consist of a number of beds. The bedding thicknesses are summarized in Table I.

Member "A" can be divided into two sub-members, the lower about 90 feet thick in which most of the medium and coarse sandstones occur and the higher about 40 feet thick which consists mainly of fine sandstone with some siltstone. The lower sub-member, and especially the lowest 35 feet of it (Units 1-19) in which the medium and coarse sandstone is concentrated, outcrops strongly in the Hobart area, e.g., Porter Hill, Glenorchy, Claremont, Mt. Nassau and Mt. Dromedary, and near New Norfolk, and has drawn the attention of a number of geologists for this reason (e.g., Brill 1956, Banks and Hale 1957, McDougall 1959, Woolley 1959). It outcrops somewhat similarly to the Risdon Sandstone, with low scarps backed by a bench. This sub-member conformably overlies the Grange Mudstone on the Sky Farm Road at Claremont (323092) and probably in the type area.

A sandstone from near the base of this member was briefly described by Banks and Hale (1957, p. 59). In connection with the present study, thin sections of the numbered specimens referred to in the detailed section above were examined using magnifications 24, 75, 340, and 750. Percentages were estimated by visual comparison with charts (Terry and Chillingar, 1955), the roundness of grains estimated by comparison with those figured on A.G.1. Data Sheet 7 (Geotimes, vol. III, No. 1) and sphericities by comparison with silhouettes

Table I

Relationship of Bedding Thickness to Grainsize in Malbina Siltstone and Sandstone.

	Member A.					Whole Formation.	
	Total Thickness	No. of Beds	Limits of Thickness of Beds	Av. Thickness	Modal Thickness	Total Thickness	Av. Thickness
Coarse Sandstone	9.71	10	0.10 - 2.60	0.97	....	14.71	1.34
Medium Sandstone	29.40	22	0.20 - 2.30	1.34	1.0 (members A + B)	34.80	1.20
Fine Sandstone	60.70	51	0.10 - 4.40	1.19	0.5 (members A — D incl.)	88.30	....
Siltstone	17.15	42	0.05 - 1.10	0.41	0.2 (member A only)	150.35	....

All figures quoted in feet.

shown by Krumbein and Sloss (1951, p. 81, f. 4-9). Grainsize was measured by micrometer ocular and referred to the Wentworth grade scale. The results of the examination of the thin sections are summarized in Table II (Appendix B).

The rocks all have a disrupted framework with phenoclasts in an abundant to predominant matrix. The main component of the phenoclasts is quartz. The quartz includes varieties with undulose extinction, lines of gas bubbles, inclusions of rutile, secondary regrowth, inclusions of crystallised zircon, inclusions of rounded zircon and some with inclusions of microcline. Rock fragments, mainly schist and quartzite but with some igneous rocks, are generally more abundant than feldspar phenoclasts. These latter include orthoclase, microcline, microperthite and soda-rich plagioclase. Muscovite occurs as detrital flakes in some of the sandstone but is only a minor constituent. Fossil fragments form a small proportion of several specimens. Opaque minerals are present in all sections and include ilmenite, magnetite and probably carbonaceous matter. Accessory minerals include euhedral and also rounded zircon, rutile and both brown and green tourmaline. In the stratigraphically higher sandstones the matrix is predominantly a mosaic of granular quartz with small flakes of muscovite and some limonite grains. Lower in the section nontronite (?) is an important component and in the basal 11 feet the mineral assemblage in the matrix is dominated by prehnite and calcite with quartz, nontronite and grossularite forming minor constituents. This assemblage is presumably due to contact metamorphism of the calcareous sandstones and a dolerite sill occurs less than 100 feet stratigraphically below the base of the formation in Jarvis Creek. This sill is, however, less than a foot thick. The composition of the phenoclasts indicates an ultimate source area with low and high grade metamorphic rocks, granites, quartz veins, aplites and volcanic rocks, a source area which was, however, predominantly siliceous. The composition of the matrix of the upper sandstones is in keeping with such a source area. Some reconstitution of the matrix of the higher sandstones is suggested by the occurrence of rims of very small flakes of muscovite around some quartz phenoclasts and the moulding of quartz in phenoclasts onto small flakes of muscovite which also project into the matrix. The authigenic reconstitution of the matrix of all the rocks examined has produced a rock with negligible permeability.

The texture of these rocks is characterised by the large range in grainsize of the phenoclasts which occur in from seven to 14 Wentworth grades. The rocks may thus be referred to as poorly to very poorly sorted. Examination of the thin sections gives the impression that in any one rock type the distribution is skewed towards the finer grades. Most of the phenoclasts are very angular or angular and have a high sphericity. In most of the thin sections examined only 2 or 3 per cent of the grains have sphericities less than 0.3 and over 75 per cent have sphericities over 0.7. In two of the lower sandstones there are patches in which the phenoclasts are separated by little if any matrix but the great majority of the material examined showed a disrupted framework with the phenoclasts well separated by matrix.

The structure of the rocks is best seen in polished sections. A common feature is the presence of stringers of darker material containing more matrix or more carbonaceous matter than the rest of the rock. These stringers are from a fraction of a millimetre to about three millimetres thick, have ill-defined boundaries both in hand specimen and thin section, are irregular in longitudinal and cross-section in that they are rarely straight for more than a few millimetres and some completely enclose ovoid or tear-drop shaped patches of coarser material and they branch and are discontinuous along their length. The stringers are roughly parallel to the bedding. In three specimens some of the stringers are very thin and so arranged as to suggest festoon cross-bedding. One specimen (1145) consists of a section across two sedimentation units totalling eight inches thick. At the base is sandstone with a few medium pebbles and almost free of stringers. A little higher is a zone in which stringers are more common and the grainsize somewhat smaller. Near the top of the first unit is a zone of light grey siltstone. This is followed upwards by sandstone with very fine pebbles then at the top light grey siltstone with stringers suggesting festoon cross-bedding. In both sedimentation units the zone of admixture includes vertical structures delineated by stringers and in the top unit a " Y "-shaped structure in sand defined by light grey siltstone which is probably a piercement structure produced by load (i.e., a flame structure). This specimen shows graded bedding in two poorly-sorted units and the texture and structure are best explained by deposition from turbidity currents.

The sediments examined in thin section all belong to the greywacke suite on textural and structural grounds and could be referred to as sub-labile greywackes (Packham, 1954) or more specifically as lithic and feldspatho-lithic sub-labile arenites (Crook, 1960).

Fossils are present but not abundant. They tend to be concentrated at the base of the sandstone units or associated with pebble bands above bedding planes within the sandstone units. The dominant fossil types in the sandstones are spiriferids ,including *Ingelarella,* but gastropods and fenestellids are also present. Many of the fossils appear to be fragmentary and some of the spiriferids have become disarticulated. Fossils are more common in the lower part of Member A than in the higher part. Fenestellids occur rarely in the sandstone units and somewhat more commonly in siltstones at the top of graded units and in siltstones interbedded with the sandstone. Some fragments which may have been plants occur near the top of the member (unit 90) associated with spiriferids.

The rock fragments which form up to 5% of the rock, are concentrated in the sandstone beds but occur rarely in the siltstones. Most of the rock fragments are rounded or sub-rounded and less than two cms. long. The longest rock fragment seen in this section was about 18 cms. long. The main fragments are of quartz and quartzite but phyllite, slate, vein quartz, quartz-mica schist, quartz feldspar porphyry, siltstone, shale and clay also occur. It is notable that many of the sandstone bands especially those near the base contain no " erratics " within the area examined in detail.

The pebbles in most beds show no obvious preferred orientation but in unit 97 some of the pebbles stand on end. Graded bedding was identified in the field in a number of units, e.g., 3, 13, 43, 53, 62, 73, 76, and suspected in others, e.g., 1.

The siltstones in some units are laminated and carbonaceous and in unit 2 contain pyrite, indicating deposition in quiet, somewhat stagnant, water. Some siltstones contain fenestellids.

From adjacent areas *Strophalosia typica, Grantonia, Neospirifer, Dielasma* and pectinaceans have been reported (McDougall, 1959, p. 62; Woolley, 1959, pp. 99-101) from the basal member.

Member B

The second member ("B"), 85 feet in thickness, consists predominantly of fissile and non-fissile siltstone with eight beds of medium or fine sandstone varying from 0.1 to 4.60 feet in thickness. Bedding is difficult to identify in the siltstones. Pebbles are uncommon except in unit 107 where they reach a length of 5 cms. No fossils were seen in the siltsstone but occur in the sandstones where they are associated with pebbles. The fossils noted are spiriferids, especially *Ingelarella*. Most of the sandstones are poorly sorted and unit 113 is clearly graded. The pebbles in unit 121 have long axes orientated sub-horizontally. The range of pebble types is similar to that in Member "A". The siltstones consist essentially of quartz with some feldspar, chlorite and mica flakes as well as very small rock fragments. Sorting which appears to be fairly good in hand specimen, is shown by thin-sections to be poor (Banks and Hale, 1957, p. 59). Fissile siltstones become more common near the top of the member. A detailed section through the member is shown as Appendix C.

Member C

Member "C", five feet thick, consists of very pebbly sandstone which is almost a conglomerate and is very similar in lithology to the basal part of the Risdon Sandstone. In addition to lithological similarity to the Risdon Sandstone, the member shows similarity in type of weathering, outcropping boldly as a low cliff backed by a narrow bench. It could easily be mistaken in field mapping for the Risdon Sandstone but it has no richly fossiliferous member below it as has the Risdon Sandstone. The lower contact has irregularities up to an inch or two in depth but no current direction could be deduced from the irregularities The pebbles which consist mainly of quartz and quartzite, are fairly well rounded and with the exception of a quartzite block over 30 cms. long are less than 10 cms. long. The matrix consists of particles of quartz and a small amount of feldspar of coarse sand grade.

Member D

The next member, "D", consists of 55 feet of fissile siltstone with some non-fissile bands. In hand specimen the siltstones appear to be fairly well sorted and composed mainly of quartz. Fossils and pebbles were not observed in this member.

Member E

The top member, "E", consists of 25 to 27 feet of fossiliferous fine-grained sandstone and siltstone. Fossils, which are not common near the base where spiriferids do occur, become very abundant in the top 10 to 11 feet and lenses of dark grey, foetid limestone occur on this level (Banks and Hale, 1957, pp. 59-60). Pebbles of quartz up to 2.5 cms. long were observed in this member; the sandstones are well-sorted and consist of poorly rounded particles of high sphericity. The rocks are compact and brittle or tough. The fossils in this member are spiriferids, including *Ingelarella, Strophalosia ovalis, Terrakea*, fenestellids, *Stenopora, Peruvispira* and a pectinacean. The bivalves are commonly complete, the spinose brachiopods still have spines attached to the shells, some of which are in growth position, and several funnel-shaped fenestellid colonies were observed to be complete and in growth position. On the whole the assemblage is biocoenotic in this member in contrast to the probably thanatocoenotic faunal assemblages in the other members. In adjacent areas this member contains *Strophalosia ovalis, Terrakea solida*, long-hinged spiriferids, fenestellids and pelecypods (McDougall, 1959, p. 62), *Protoretepora ampla* (Woolley, 1959, p. 100), *Ingelarella* ("*Martiniopsis*") and *Stenopora crinita* (Banks and Hale, 1957, p. 59).

CORRELATION

The Malbina Siltstone and Sandstone occurs widely in Tasmania and may be provisionally identified at Firewood Siding (south of Zeehan), in the north-west coastal area, at Coles Bay, Maria Island and at Mount La Perouse. Some facies variations ocur within Tasmania but cannot yet be fully assessed. Even in areas close to the type section, e.g., New Norfolk, the succession seems to be somewhat different from that in the type section (Woolley, 1959) but the stratigraphy is not so well known.

Voisey (1938, p. 326) recorded "*Spirifer*" *vespertilio*, "*Martiniopsis*" *oviformis*, "*M*" *subradiata*, "*Platyschisma*" *oculus*, *Astartila* and *Hyolithes* from this formation on the shore-platform at Lindisfarne where Member "A" is exposed. From Eaglehawk Neck he recorded *Fenestella fossula*, *F. internata* and *Stenopora crinita*. The richly fossiliferous beds at Eaglehawk Neck occur near the Blowhole or just north of the northern headland of Pirates Bay but in both places are above a coarse sandstone correlated on lithological grounds and place in the succession with member "C". The record of *S. crinita* was confirmed by Crockford (1951) who correlated the beds at Eaglehawk Neck with the Mulbring Sub-group in New South Wales. The occurrence of *Strophalosia typica* in the lower part of the Malbina Siltstone and Sandstone suggests correlation with some part of the Branxton Sub-group of New South Wales (Upper Artinskian-Lower Kungurian) and the Ingelara Beds of Queensland. The presence of *Strophalosia ovalis* in the uppermost member suggests correlation with the Mantuan Productus Bed in Queensland (Maxwell, 1954).

CONDITIONS OF DEPOSITION

The sources of the clastic material in this formation have been considered by Banks and Hale (1957, p. 60) to have been predominantly metamorphic rocks like the Precambrian rocks of Tasmania but some older sediments, granitic and pegmatitic rocks were included in the provenance. Observations in the type section give further evidence of these sources and also suggest some old volcanic rocks in the provenance.

All previous authors have postulated that the numerous "erratics" in the Malbina Siltstone and Sandstone were dropped from icebergs into marine sediments and that the abundance of them relative to that in the underlying formations indicated an increase in the intensity of glaciation. Observations in the type section did not reveal any abundance of undoubted erratics. The pebbles tend to be concentrated in bands and in a few cases show preferred orientation parallel to the bedding. Only in Unit 97 were pebbles seen to be standing on end. Unfortunately, exposure of this unit did not allow observation of broken laminae, indicative of dropped pebbles. Green (1961, p. 20) does, however, record one undoubted erratic in this formation on the shoreline west of Mount Mather. This erratic is elongated and orientated with the long axis almost vertical and clearly breaks the laminations of the siltstone enclosing it. Most of the pebbles in the type section are sub-angular to sub-rounded and no clear examples of faceted pebbles were observed.

Graded bedding was observed in a number of units. The graded beds are poorly sorted. It is noticeable also that in the sandstones the fossils tend to be large but fragmentary and associated with the pebble bands. The siltstones are better sorted than the sandstones. Some siltstones are laminated, most are carbonaceous and one pyritic, thus indicating deposition under quiet conditions with reducing conditions during deposition. Conditions were, however, favourable at times for growth of fenestellids in the silty environment.

The reconstruction which accounts most satisfactorily for observations made to date, is that of a relatively deep sea floor on which silt transported by slow currents from some distant source was being deposited while melting of comparatively rare icebergs contributed a few dropped pebbles to the sediment. In a shallower area gravel, coarse, medium and fine sands were being deposited and heavy-shelled spiriferids, pelecypods and gastropods were living. From time to time instability in the shallower area initiated turbidity currents which picked up the sediments and animals and after carrying them some tens of miles spread them as thin beds over the silts autochthonous to the Hobart area. This reconstruction suggests deposition in the outer iceberg zone of a wet-base glacier (Carey and Ahmad, 1961) but the occurrence of thick-shelled brachiopods in the turbidity current deposits near the base is anomalous if this interpretation is correct.

The change from the fine-grained richly fossiliferous sediments of the Grange Mudstone to the coarse, relatively unfossiliferous rocks of the Malbina Formation may be explained in terms of increasing frequency of turbidity currents. Green (1961) remarked on the occurrence of beds of coarse-grained sandstone as an increasingly important component in the upper part of the Grange Mudstone at Cape Deslacs. The boundary between the two formations may well be considered as occurring above the topmost cream-coloured, calcareous, richly-fossiliferous siltstone of the Grange type and below the lowest poorly-fossiliferous, grey, non-calcareous siltstone of the Malbina type. It is suggested that the change in faunal content does not necessarily reflect a significant change in physical or chemical conditions at the site of deposition but can well be explained as due to the mass killing of the benthonic fauna by suffocation under the sediments deposited by turbidity currents, the frequency of occurrence of which was too high to allow recolonisation of the area from parts of the sea-floor unaffected by these currents.

The increase in the sandstone and pebble content of the sediments from the Grange Mudstone into the Malbina Formation is thus not directly due to increasing intensity of glaciation but to greater instability in a source area probably in northwestern, western, or south-western Tasmania (Banks and Hale, 1957, p. 62) or beyond the present confines of Tasmania in those directions. The causes of the instability may have been climatic or tectonic and it is perhaps significant that similar rocks occur at about the same time in New South Wales and that orogenic movements are postulated in the Hunter River area of New South Wales at about this time (Browne, 1950, Vol. 1, p. 386). Dropped pebbles occur in the Hobart area in the Berriedale Limestone (quarries near Collinsvale) as shown by orientation of the pebbles and breaking of laminae. There does not seem to be any significant difference in the abundance of such pebbles in the upper part of the Cascades Group from that in the Malbina Formation. Thus there is no clear evidence of an increase in intensity of glaciation at this level as postulated by Lewis (1937) and later authors.

Member "C" and the Risdon Sandstone are also thought to be turbidity current deposits but more detailed work will have to be done to establish this. If they are, they again reflect instability in the source area.

The topmost member of the formation shows a return of abundant life to the area, and it is probably significant that this occurs after the longest interval of uninterrupted silt deposition in the area. Quiet conditions prevailed during deposition of the member and the faunal assemblage is dominantly biocoenotic. The dominant organism in this assemblage varies from place to place within Tasmania—*Strophalosia*, *Terrakea*, spiriferids, fenestellids and pelecypods or gastropods being the dominant forms in different places. Such variation would be expected if the faunas were biocoenotic. Local marine life was again destroyed by the widespread deposition of the Risdon Sandstone and reappeared only fitfully during deposition of the Ferntree Mudstone.

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Appendix A

Detailed Stratigraphy of Member A.

Top:—

Unit 102.
1.0 feet.—Fine sandstone—fissile—with a few small pebbles.

Unit 101.
0.6 feet.—Medium sandstone—similar to unit 100 but this unit is fissile.

Unit 100.
1.0 feet—Medium sandstone—very pebbly with pebbles of quartzite and slate up to 4 cms. in length—sorting poor, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 99.
0.8 feet.—Siltstone—top three inches fissile—pebbles up to 1.5 cms. long.

Unit 98.
1.25 feet.—Fine sandstone—quartzite pebbles up to 2 cms. in length—fissile—spiriferids near the base.

Unit 97.
0.55 feet.—Fine sandstone—pebbles up to 8 cms. in length—some pebbles in this bed standing on end—top of this bed fissile in places.

Unit 96.
1.0 feet.—Fine sandstone—similar to unit 93.

Unit 95.
0.05 feet.—Fissile siltstone.

Unit 94.
0.4 feet.—Fine sandstone—similar to unit 92—pebbles up to 0.5 cms.

Unit 93.
0.15 feet.—Fine sandstone—sorting good, sphericity high, roundness low—fissile.

Unit 92.
0.75 feet.—Fine sandstone—dominantly quartz and some feldspar—quartz pebbles up to 2 cms. in length—properties similar to unit 90 but with no fossils.

Unit 91.
0.1 feet.—Fissile siltstone with some pebbles.

Unit 90.
0.7 feet.—Fine sandstone—quartz—sorting poor, sphericity fair to high, roundness low—fragments of phyllite up to 5 cms. in length—fragments of spiriferids and ? plant fragments.

Unit 89.
0.4 feet.—Sandstone and siltstone—medium sandstone with a clay matrix—quartzite pebbles up to 2 cms. in length—most pebbles well rounded—top three-quarters of an inch of the unit fissile siltstone.

Unit 88.
0.9 feet.—Sandstone and siltstone—basal two and a half inches medium sandstone containing pebbles up to 2.5 cms. in length—overlain by 4 inches of laminated, non-fissile siltstone—overlain by 4 inches of fissile, laminated siltstone—medium grey.

Unit 87.
0.4 feet.—Fissile siltstone—similar to unit 77.

Unit 86.
1.05 feet.—Fine sandstone—similar to unit 78—pebbles up to 1 cm. at base of unit.

Unit 85.
0.65 feet.—Fine sandstone—quartz present—no fossils—sorting good, sphericity high, roundness low—compact and mostly non-fissile although the top 2 inches are fissile and with an increase in silt size material.

Unit 84.
2.8 feet.—Fine sandstone—pebbles of slate, quartzite and quartz—feldspar porphyry—pebbles up to 4 cms. in length—specimen 1150.

Unit 83.
0.35 feet.—Fissile siltstone—similar to unit 77.

Unit 82.
2.65 feet.—Fine sandstone—few pebbles up to 1.25 cms. in length—partings at 2, 5, 13, and 23 inches above the base.

Unit 81.
0.45 feet.—Fissile siltstone—similar to unit 77.

Unit 80.
2.6 feet.—Fine sandstone—similar to unit 78—parting 7 inches above the base.

Unit 79.
0.35 feet.—Fissile siltstone—similar to unit 77.

Unit 78.
3.0 feet.—Fine sandstone—about 40 to 50 per cent quartz—matrix not seen—rock fragments not seen—no fossils—sorting good, sphericity fairly high, roundness low—compact, brittle, non-fissile.

Unit 77.
0.2 feet.—Fissile siltstone—light bluish grey—sorting good—other properties not obvious.

Unit 76.
1.75 feet.—Medium sandstone at base with numerous pebbles of quartzite—grades into a fine sandstone at approximately 0.6 feet above the base.

Unit 75.
0.1 feet.—Fissile siltstone—similar to unit 72.

Unit 74.
0.25 feet.—Fine sandstone—similar to base of unit 73.

Unit 73.
0.75 feet.—Fine sandstone—similar properties to unit 71 but grades into a fissile siltstone in the top 0.1 feet.

Unit 72.
0.2 feet.—Siltstone—fissile—sorting good.

Unit 71.
1.0 feet.—Fine sandstone—quartz—matrix not obvious—rock fragments not obvious—no fossils—sorting good, sphericity high, roundness low—compact, brittle, tough.

Unit 70.
0.4 feet.—Laminated non-fissile siltstone—sorting good—compact, brittle.

Unit 69.
2.7 feet.—Fine sandstone—quartz and some feldspar—matrix not seen—rock fragments of quartzite at base and at 2.24 feet above base—one pebble measured 10 cms. in length—no fossils seen—sorting fair, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 68.
0.8 feet.—Siltstone—laminated—fissile—sorting good.

Unit 67.
1.5 feet.—Fine sandstone—properties similar to unit 65.

Unit 66.
0.4 feet.—Coarse sandstone—dominantly quartz with a little feldspar—clay matrix—no fossils—no rock fragments seen—some of the quartz fragments up to 3 mm.—sorting poor, sphericity high, roundness poor—compact, brittle, non-fissile.

Unit 65.
0.65 feet.—Fine sandstone—sorting good, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 64.
3.0 feet.—Fine sandstone—quartz with coarse grade quartz fragments which are very angular—pebbles in band at base up to 8 cms. in length—patch of pebbles 7 inches from top of unit with a parting under it.

Unit 63.
0.35 feet.—Siltstone—fissile—similar properties to unit 61.

Unit 62.
2.5 feet.—Sandstone and siltstone—40 per cent quartz, some feldspar—rock fragments rare but in the top part of the unit occurred one piece of slate 18 cms. by about 2.5 cms.—fossils include *Ingelarella* and other spiriferids in a band 1 inch thick about 9 inches above the base of the unit—fossils not oriented—sorting poor, sphericity high, roundness low—at the base is a graded layer, overlying this is another graded layer (1.9 feet thick) and then at the top another graded layer—sandstone grades from coarse grade to a siltstone—compact, brittle, non-fissile—white to light bluish grey—specimen 1149.

Unit 61.
0.3 feet.—Siltstone—sorting good—fissile bedding plane between this unit and overlying unit 62 is irregular.

Unit 60.
1.0 feet.—Fine sandstone with few fossils—similar to unit 58.

Unit 59.
0.1 feet.—Fissile siltstone—similar to unit 55 but without carbonaceous markings.

Unit 58.
0.4 feet.—Fine sandstone—quartz about 40 to 50 per cent—rare fragments of phyllite up to 5 mm. long—rare fossils (spiriferids)—sorting poor, sphericity fairly high, roundness low—compact, brittle, non-fissile—light bluish grey with white patches—specimen 1148.

Unit 57.
0.4 feet.—Siltstone and sandstone—consists of two fissile siltstone units and a fine sandstone between them.

Unit 56.
0.8 feet.—Fine to medium sandstone—about 40 per cent quartz—coarser at base than at top of unit—about 5 per cent of pebbles—some up to 2 cms.—no fossils—clay matrix (high percentage)—sorting poor, sphericity high, roundness low—compact, brittle, non-fissile—light bluish grey and weathers to greyish orange—specimen 1147 is specimen of coarser part of this bed.

Unit 55.
0.4 feet.—Siltstone—most properties not obvious—sorting appears to be fair—fissile—carbonaceous markings—light grey.

Unit 54.
8.2 feet.—Medium to coarse sandstone—quartz and feldspar in about equal proportion—fossils are elongate fibres (possibly sponge spicules)—sorting fair, sphericity high, roundness low—light grey—compact, brittle, non-fissile—contains pebbles of quartz, quartzite, vein-quartz, quartz-mica schist and siltstone—pebbles occur in bands at 2.2 feet above base, 3.4 feet above base, 4.2 feet above base, 5.5 feet above base, 7.3 feet above base—pebble bands at 2.2 feet and 4.2 feet are thick—about 4 inches—specimen 1146.

Unit 53.
0.7 feet.—Graded sandstone and siltstone—basal inch consists of a coarse quartz sandstone with clay fragments up to 1 cm. in diameter—this grades upward into a laminated siltstone at the top which is the same as unit 52—specimen 1145.

Unit 52.
0.9 feet.—Laminated siltstone—most properties not visible—sorting appears to be good—bedding is very thin—down to less than a millimetre—contains lenses of a white fine-grained material in a grey matrix—may be cross-bedded—compact, brittle, non-fissile—light bluish grey with white lenses—specimen 1144.

Unit 51.
2.3 feet.—Fine sandstone—quartz—quartz fragments coarser at base than at top—fragments abundant—no fossils—sorting poor, sphericity mediu mto high, roundness low—compact, brittle, massive—light grey blue.
11.4 feet.—No outcrop.

Unit 50.
1.1 feet.—Siltstone—fine-grained—most properties not obvious—fissile—grey-green.

Unit 49.
0.4 feet.—Fine sandstone—similar to unit 39.

Unit 48.
0.2 feet.—Siltstone—similar to unit 42.

Unit 47.
1.05 feet.—Medium sandstone—quartz—sorting, middling, sphericity high, roundness, low—compact, brittle, non-fissile.

Unit 46.
0.15 feet.—Siltstone—similar to unit 42.

Unit 45.
0.8 feet.—Fine sandstone—similar to unit 39.

Unit 44.
0.1 feet.—Siltstone—similar to unit 42.

Unit 43.
1.2 feet.—Medium sandstone—slightly coarser at base with 0.6 cms. long quartz fragments and rock fragments—at the top becomes a fine sandstone with some small quartz fragments—this may represent grading—sorting from middling at top to poor at base—sphericity fairly high and roundness low—compact, brittle, non-fissile.

Unit 42.
0.10 feet.—Siltstone—sorting middling—compact, non-fissile.

Unit 41.
0.45 feet.—Fine sandstone—similar properties to unit 39.

Unit 40.
0.15 feet.—Fissile siltstone—similiar properties to unit 28.

Unit 39.
1.2 feet.—Fine sandstone—quartz—sorting middling, sphericity medium, roundness low—compact, brittle, non-fissile.

Unit 38.
0.4 feet.—Siltstone—laminated—fissile, colour blue grey.

Unit 37.
2.3 feet.—Medium sandstone—quartz—few quartz particles and small rock fragments up to 0.3 cms.—clay matrix—sorting middling, sphericity high, roundness low—compact, non-fissile.

Unit 36.
0.5 feet.—Fine sandstone—fissile—similar to unit 34.

Unit 35.
2.0 feet.—Fine sandstone—quartz and a little feldspar—no rock fragments—no fossils—matrix not visible—sorting middling to good, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 34.
0.5 feet.—Fine sandstone—similar properties to unit 31 except this unit is fissile.

Unit 33.
0.7 feet.—Fine sandstone—similar properties to unit 31.

Unit 32.
0.6 feet.—Fissile siltstone—similar properties to unit 28.

Unit 31.
0.7 feet.—Fine sandstone—quartz—no rock fragments—no fossils—matrix not visible—sorting good, sphericty medium, roundness low—compact, fairly brittle, non-fissile.

Unit 30.
0.3 feet.—Fissile siltstone—similar properties to unit 28.

Unit 29.
4.4 feet.—Fine sandstone—quartz and rare particles of feldspar pebbles of vein quartz—matrix siliceous—compact, brittle, tough.

Unit 28.
0.6 feet.—Fissile siltstone—blue grey colour, most properties not visible.

Unit 27.
3.1 feet.—Fine sandstone—quartz, some feldspar—shale pebbles—matrix not visible—no fossils—sorting middling, sphericity high, roundness low—compact, brittle, tough.

Unit 26.
0.1 feet.—Fissile siltstone—olive grey colour—matrix not visible—no rock particles or fossils.

Unit 25.
1.5 feet.—Medium sandstone—quartz—clay matrix—at base small lenses of coarse grained quartz particles and rock fragments up to 0.15 cms.—slate pebbles—a few spiriferids—sorting middling to poor, sphericity medium to fairly high, roundness low—compact, brittle, non-fissile.

Unit 24.
0.6 feet.—Fine sandstone—quartz—carbonaceous laminations—matrix not visible—no rock fragments—no fossils—sorting good—sphericity high—roundness low—fissile.

Unit 23.
2.2 feet.—Medium sandstone—quartz with some particles up to 1 cm. long—matrix not visible—rock fragments mainly quartzite up to 1.25 cms.—spiriferids—sorting middling to poor, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 22.
1.0 feet.—Siltstone—quartz, some feldspar—rock fragments and fossils not seen—sorting middling to poor—sphericity fairly high, roundness low—compact, brittle, non-fissile—light bluish grey.

Unit 21.
1.6 feet.—Fine to medium sandstone—quartz with fragments and rock pebbles up to 0.6 cms. long—matrix siliceous—no fossils—sorting poor, sphericty medium to high, roundness low—light yellow brown.

Unit 20.
0.45 feet.—Fissile siltstone—quartz—matrix not obvious—rock particles not obvious—no fossils—sorting good, sphericity high, roundness low—olive grey.

Unit 19.
5.1 feet.—Coarse sandstone—quartz and about 10 per cent feldspar—matrix siliceous—pebbles up to 5 cms. in length at the base and rare pebbles and fossils in bands at 1.9 and 4.5 feet above base—sorting poor to middling—sphericity medium to high, roundness low—fossil and pebble bands may indicate the base of beds—compact, brittle, non-fissile.

Unit 18.
0.75 feet.—Light blue fissile siltstone—similar to unit 14.

Unit 17.
2.05 feet.—Medium sandstone—quartz, some large quartz fragments—matrix partly ferruginous—fossils (about 2 per cent)—spiriferids—sorting good, sphericity high, roundness low—compact, brittle, tough.

Unit 16.
0.25 feet.—Fine fissile sandstone—quartz—rock pebbles (quartzite) up to 2.5 cms. long—matrix not visible—no fossils—sorting poor, sphericity high, roundness low—blue grey.

Unit 15.
1.8 feet.—Fine sandstone—quartz—some quartz fragments up to 0.3 cms. long—no rock particles visible—matrix not visible—no fossils—bluish grey—grain size is coarser at bottom of unit than at top—may represent grading—sorting middling to good, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 14.
0.3 feet.—Light blue fissile siltstone—similar properties to unit 12—but in this unit there are no fossils.

Unit 13.
2.0 feet.—Fine sandstone with fissile siltstone layers—about 1 inch thick at 0.55 and 1.1 feet above the base—physical properties similar to unit 11—spiriferids occur just above each fissile layer—sandstone layers may show graded bedding into the fissile siltstone.

Unit 12.
0.3 feet.—Fissile siltstone—mottled light bluish grey—quartz—sorting middling, sphericity medium to high—roundness low—fossils are fenestellids.

Unit 11.
2.7 feet.—Fine sandstone—some quartz fragments up to 0.6 cms. long—quartz dominant mineral, some feldspar—rock particles not visible—matrix partly ferruginous—sorting middling, sphericity high, roundness low—fossils occur in bands—1.3 feet above the base of the unit bryozoans—2.15 beet above base fenestellids and spiriferids—2.6 feet above base spiriferids and gastropods—yellowish grey.

Unit 10.
0.6 feet.—Alternating fine sandstone and siltstone—quartz and feldspar—sorting middling, sphericity high, roundness low—rare calcareous fossils—rock particles not visible—compact, brittle, tough.

Unit 9.
3.1 feet.—Medium to coarse fossiliferous sandstone—properties the same as unit 7 but with fewer fossils—one pebble of quartzite over 8 cms. long.

Unit 8.
0.4 feet.—Alternating fine sandstone and siltstone—quartz and feldspar present—sorting middling, sphericity high, roundness low—rock particles not visible—compact, brittle, tough—contains some calcareous fossils—specimen 1143.

Unit 7.
3.6 feet.—Medium to coarse fossiliferous sandstone—70 per cent quartz, 10 per cent feldspar and 10 per cent calcareous shells—approximately 1 per cent rock particles—mainly quartzite up to 5 cms. in length—up to 10 per cent fossils—mainly spiriferids which occur in bands—10 per cent of partly ferruginous matrix—sorting middling to good, sphericity high, roundness low—bedding units about 7 inches thick—base of beds determined by coarser pebble concentrations—top 9 inches highly fossiliferous with abundant fenestellids—compact, brittle, non-fissile—light grey—specimen 1142.

Unit 6.
0.25 feet.—Fine sandstone—quartz and about 15 per cent feldspar—rock particles not visible—a few spiriferids—matrix partly ferruginous—sorting middling, sphericity is greater than 0.8, roundness less than 0.3—compact, brittle and non-fissile—yellowish grey.

Unit 5.
1.2 feet.—alternating fine sandstone with finely-laminated dark grey siltstone (½-inch units)—sandstone of quartz and feldspar with beds up to 2 inches thick—sorting middling, sphericity high, roundness low—compact, brittle, tough—yellowish grey—specimen 1141.

Unit 4.
1.8 feet.—Medium sandstone—60 plus per cent quartz, 20 to 30 per cent feldspar—rock particles not visible—rare *Ingelarella*—clay matrix—bedding plane 1.1 feet above base—sorting middling to good—sphericity greater than 0.8, roundness less than 0.3—compact, brittle—light bluish grey.

Unit 3.
1.4 feet.—Medium sandstone—70 plus per cent quartz—rock particles not visible—one bedding plane in centre of unit—ferruginous matrix in lower half and siliceous in top half—top half graded—rare spiriferids and fenestellids right at top of unit in some fissile material—sorting is middling sphericity greater than 0.7, roundness less than 0.3—light bluish grey—mainly unit is compact and brittle—specimen 1140.

Unit 2.
1.0 feet.—Siltstone—probably one unit—60 per cent quartz—20 per cent feldspar—pyrite—rock fragments and fossils not obvious—matrix not visible—sorting middling to poor—sphericity between 0.5 and 0.9—roundness less than 0.5—carbonaceous laminations present—compact, brittle, weathered to thin laminations—negligible porosity—light bluish grey.

Unit 1.
1.85 feet.—Medium sandstone—some particles in coarse sand grade—graded bedding may be present with fine sand grade at top of bed—80 per cent quartz particles—siliceous matrix—no rock fragments visible—sorting middling to good, sphericity high, roundness low—compact, brittle, non-fissile—spiriferids at base and band of fragmentary fossils 13 ins. above base—specimen 1139—yellowish grey.

There is a break of 4.63 feet below the lowest exposure of the Malbina Siltstone and Sandstone and the topmost exposure of the underlying Grange Mudstone.

Specimen numbers refer to specimens in the collection of the University of Tasmania, Geology Department. Grainsizes were measured in the field by comparison under a hand lens of the rock with a standard chart (similar to that illustrated by Chillingar (1956). Colours quoted refer to those listed in Goddard *et al* (1948).

Appendix B.

Table II — Tabular Summary of Microscopic Characters of Some Rocks in Member A, Malbina Formation

No.	COMPOSITION: Phenoclasts (percentages quoted on matrix-free basis)	COMPOSITION: % Matrix	COMPOSITION: Matrix (percentages quoted on phenoclast-free basis)	TEXTURE: Phenoclasts: Grainsize: Maximum	TEXTURE: Phenoclasts: Grainsize: Modal	TEXTURE: Phenoclasts: Grainsize: Minimum	TEXTURE: Phenoclasts: Roundness: Modal	TEXTURE: Phenoclasts: Roundness: Range	TEXTURE: Phenoclasts: Sphericity: Modal	TEXTURE: Phenoclasts: Sphericity: Range	TEXTURE: Matrix	TEXTURE: Others	STRUCTURE
1139 (Unit 1)	Quartz .. 85 Quartzite } 7 Quartz-schist } Plagioclase .. 1 Opaque .. 5 (Fossils formed about 2% of hand specimen)	50	Quartz .. 10 Prehnite .. 70 Nontronite 15 Grossularite 5	Coarse sand	medium sand	very fine silt	very angular	very angular to sub-angular	0.9	0.1 to 0.9	Mosaic of quartz grains with laths and plates of prehnite, euhedral crystals of grossularite and plates and spherulites of nontronite	mainly disrupted framework but some patches of mosaic texture of phenoclasts	
1140 (Unit 3	Quartz .. 85 Quartz-schist } 3 Quartzite } Fossil Frags. 8 (in hand specimen) Orthoclase .. 1 Zircon ..<1 Albite ..<1 Opaque .. 2	60	Quartz .. 10 Prehnite .. 50 Nontronite 10 Gossularite 10 Calcite .. 20	Coarse sand in thin section but medium pebble in hand specimen	Medium sand	Fine silt	Very angular	Very angular to sub-angular	0.9	0.1 to 0.9	Order of development—quartz, prehnite, calcite, nontronite, garnet	Mainly disrupted framework but some patches with mosaic texture	Crude bedding seen in thin section with suggestion of flame structure; in hand specimen bedding shown by stringers richer in matrix
1141 (Unit 5)	Quartz .. 90 Opaque .. 5 Feldspar incl. } Andesine, } 2 Microcline } Quartz schist } Musc. schist } Quartzite } Graphic granite } 1 Aplite } Chlorite schist.. } Muscovite < 1 Zircon .. < 1	40	Quartz .. 60 Muscovite .. 35 Limonite .. 5	Medium sand	Fine sand	Very fine silt	Very angular	Very angular to sub-rounded	0.7	0.1 to 0.9	Mosaic texture with laths of muscovite with no preferred orientation noticeable	Disrupted framework	Swirl structure shown by stringers of very fine, opaque material; stringers partly limonitic but not entirely so
1142 (Unit 7)	Quartz.. ..92 Fossil frags. .. 5 Quartzite .. 1 Rutile .. < 1 Opaque .. 2	40	Calcite .. 30 Prehnite .. 28 Quartz .. 30 Grossularite 8 Limonite .. 2 Nontronite 2	Very coarse pebble-sized fossil frags; rock and mineral frags to very fine pebble	Fine sand (30% of rock in modal grade)	Fine silt	Very angular	Very angular to sub-rounded	0.8	0.3 to 0.9	Mosaic of granular quartz in some areas; large plates of calcite moulding crystallised quartz and with inclusions of quartz and prehnite; otherwi e as in 1139	Disrupted framework; large plates of calcite with inclusions of quartz	Fossil fragments recrystallised

No.	COMPOSITION: Phenoclasts (percentages quoted on matrix-free basis)	% Matrix	Matrix (percentages quoted on phenoclast-free basis)	TEXTURE: Phenoclasts: Grainsize: Maximum	Grainsize: Modal	Grainsize: Minimum	Roundness: Modal	Roundness: Range	Sphericity: Modal	Sphericity: Range	Matrix	Others	STRUCTURE
1143 (Unit 8)	Quartz .. .. 90 Quartz schist, Quartz muscovite schist, Chlorite rock, Quartz-albite rock .. } 2 Feldspar— Microperthite .., Orthoclase, Microcline, Acid plag. } 1 Opaque .. 3 Fossil frags. .. 2 Rutile .. < 1 Zircon 1	75	Quartz .. 62 Calcite .. 10 Prehnite .. 7 Nontronite 5 Limonite .. 1 Muscovite .. 15	Very coarse sand, but in hand spec. quartz grains to very fine pebbles and fossil frags. to coarse pebble	Fine sand	Fine silt	Angular	Very angular to sub-angular	0.7	0.1 to 1.0	Mainly mosaic of granular quartz with flakes of muscovite and spherulites and plates of nontronite; calcite interstitial moulding laths of prehnite in places; granules of limonite	Disrupted framework	Stringers shown in hand spec.; in thin section stringers marked by opaque material; bedding shown by lines of phenoclasts and changes in grain size
1144 (Unit 52)	Quartz .. .. 88 Quartz schist, Quartz musc. schist .., Musc. schist } 3 Plagioclase (acid), Microcline } 2 Muscovite .. 3 Opaque .. 3 Zircon .. < 1 Tourmaline < 1	35–40	Quartz .. 70 Muscovite .. 20 Limonite .. 10	Coarse sand	Very fine sand (more than 50% in this grade)	Fine silt	Very angular	Very angular to sub-angular	0.9	0.5 to 1.0	Mainly mosaic of quartz with laths of muscovite, limonitic granules	Disrupted framework	Stringers of dark material in hand specimen appear in places to delineate festoon cross-bedding; contains intertonguing patch of coarser, more disrupted sand
1145 *A*, *B*, *C* (Unit 53)	Quartz .. .. 85 Quartz-Microcline rock .., Micaceous quartzite, Muscovite schist .., Chlorite, Trachytic rock } 7 Muscovite .. 3 Microcline, Microperthite, Acid plagioclase .. } 2 Zircon .. < 1 Tourmaline < 1 Rutile .. < 1 Opaque .. 2	60 60 50	Quartz .. 90 Muscovite .. 10 Nontronite < 1	*C*— medium pebble *B*— Very coarse sand *A*— Very fine pebble	Fine sand Fine sand Very fine or fine sand	Fine silt Very fine silt Very fine silt	Angular Very angular	Very angular to sub-rounded Very angular to sub-angular	0.9 0.8	0.1 to 0.9 0.1 to 0.9	Mainly mosaic of quartz with laths of muscovite; rim of muscovite around some quartz phenoclasts	Disrupted framework Disrupted framework Disrupted framework	*C* is at base, *A* towards top of bed; stringers of light grey material in hand spec.; forms two graded beds, bedding shown by preferred orientation of elongate phenoclasts in places and by lines of phenoclasts

No.	COMPOSITION: Phenoclasts (percentages quoted on matrix-free basis)	% Matrix	Matrix (percentages quoted on phenoclast-free basis)	TEXTURE: Phenoclasts — Grainsize: Maximum	Grainsize: Modal	Grainsize: Minimum	Roundness: Modal	Roundness: Range	Sphericity: Modal	Sphericity: Range	Matrix	Others	STRUCTURE
1146 (Unit 54)	Quartz . . . . 86 Muscovite schist . . } Musc. quartz schist } Quartzite } 5 Plagioclase . . 3 Muscovite . . 3 Opaque, incl. Ilmenite . . 2 Tourmaline < 1 Zircon . . < 1	60	Quartz . . 68 Nontronite 15 Muscovite . . 7 Limonite . . 10	Coarse sand	Very fine sand	Very fine silt	Very angular	Very angular to angular	0.9	0.1 to 0.9	Mosaic of quartz with laths of muscovite, spherulites and plates of nontronite and limonitic granules	Disrupted framework	Bedding shown by concentration of matirx and by limonitic staining body of fine sand oriented almost at right angles to bedding in very fine sand . .
1147 (Unit 56)	Quartz . . . . 80 Muscovite schist . . } Quartz mica schist . . } Quartzite } 10 Muscovite . . 4 Feldspar microcline albite . . } 2 Tourmaline . . 1 Zircon . . < 1 Opaque . . 2	40	Quartz . . 60 Muscovite . . 38 Nontronite 2	Hand specimen has small cobble; thin section has grains to coarse sand	Very fine sand	Fine silt	Angular	Very angular to subrounded	0.8 to 0.9	0.1 to 1.0	Mosaic of quartz with laths of muscovite; nontronite as radiating fibres or hexagonal plates	Disrupted framework	
1148 (Unit 58)	Quartz . . . . 80 Muscovite schist . . } Quartzite } Muscovite quartz schist } 10 Muscovite . . 2 Opaque . . 2 Tourmaline < 1 Zircon . . < 1 Feldspar— Plagioclase (acid) Orthoclase Microcline } 5		Quartz . . 93 Muscovite . . 5 Limonite . . 2	Hand specimen has fine pebbles							Mosaic of quartz grains with laths of muscovite and limonitic granules		Section shows two portions, *A* very fine sand and *B* fine sand with a bulge from *B* extending into *A*
		75		*A*—Medium sand	Fine to very fine sand	Very fine silt	Very angular	Very angular to subrounded	0.9	0.1 to 0.9		Disrupted framework	
		40		*B*—Very coarse sand	Fine sand	Very fine silt	As *A*	As *A*	0.8 to 0.9	0.3 to 1.0		Disrupted framework	

No.	COMPOSITION: Phenoclasts (percentages quoted on matrix-free basis)	% Matrix	COMPOSITION: Matrix (percentages quoted on phenoclast-free basis)	TEXTURE: Phenoclasts: Grainsize: Maximum	Grainsize: Modal	Grainsize: Minimum	Roundness: Modal	Roundness: Range	Sphericity: Modal	Sphericity: Range	TEXTURE: Matrix	TEXTURE: Others	STRUCTURE
1149 (Unit 62)	Quartz .. .. 88 Muscovite schist .., Quartz mica chist .., Micaceous quartzite, Quartzite } 7 Opaque .. 2 Tourmaline < 1 Zircon .. < 1 Feldspar—microcline, Acid plagioclase } 2	40	Quartz .. 95 Muscovite .. 5	Hand specimen has wood fragment of fine pebb'e size; very fine pebble in slide	Very fine sand	Very fine silt	Angular to very angular	Very angular to subrounded	0.9	0.1 to 0.9	Mosaic of quartz grains and muscovite flakes	Disrupted framework	Bedding shown by areas richer in matrix than others, by lines of limonitic material and by some preferred orientation of elongate fragments
1150 (Unit 84)	Quartz .. .. 84 Musc. quartz schist .., Trachytic rock .., Quartzite, Sheared quartzite, Musc.-haematite rock } 10 Quartz-feldspar porphyry, black slate in hand specimen) Muscovite .. 1 Tourmaline < 1 Zircon .. < 1 Feldspar—& Acid plagioclase, Microperthite .., Orthoclase } 2 Opaque .. 2	60	Quartz .. 94 Muscovite .. 3 Limonite .. 3	Hand specimen has coarse pebbles	Very fine sand with patches of fine sand	Very fine silt	Very angular or angular	Very angular to subrounded	0.9	0.1 to 0.9	Mosaic of quartz grains and muscovite flakes, and, in places, limonitic granules; some quartz phenoclasts rimmed by fine muscovite flakes; some quartz phenoclasts appear moulded onto muscovite flakes	Disrupted framework	Pebbles occur in patch in one specimen; very fine cross-bedding may be present; bedding in section shown by lines of coarser grains with less matrix and preferred orientation of elongate fragments

Appendix C

Detailed Stratigraphy of Member B.

Top:—

Unit 124.
12.6 feet.—Fissile and non-fissile siltstone—similar in properties to unit 110.

Unit 123.
4.6 feet.—Fine to medium sandstone—pebbles up to 4 cms. in length—pebbles of quartz and quartz feldspar porphyry.

Unit 122.
10.6 feet.—Fissile siltstone—similar to unit 110.

Unit 121.
0.9 feet.—Medium sandstone—rounded pebbles up to 5 cms. long near base—pebbles of quartz, quartzite, phyllite—long axes of pebbles are sub-horizontal.

Unit 120.
5.2 feet.—Fissile siltstone—similar to unit 110.

Unit 119.
0.1 feet.—Fine sandstone with a few rounded pebbles.

Unit 118.
5.2 feet.—Fissile siltstone—similar to unit 110.

Unit 117.
0.3 feet.—Medium sandstone—fossils are rare, *Ingelarella*, and rare small pebbles.

Unit 116.
18.15 feet.—Fissile siltstone—similar to unit 110.

Unit 115.
0.25 feet.—Fine to medium sandstone sorting fair to good, sphericity high, roundness low—compact, brittle, tough.

Unit 114.
1.6 feet.—Fissile siltstone—similar to unit 110.

Unit 113.
0.3 feet.—Medium sandstone—graded bedding—very poorly sorted, sphericity high, roundness low—pebbles up to 2.5 cms. in length.

Unit 112.
1.95 feet.—Fissile siltstone—similar to unit 110.

Unit 111.
0.25 feet.—Medium sandstone—rare fossils (spiriferids)—pebbles up to 2.5 cms. in length—sorting poor, sphericity high, roundness low—compact, brittle, non-fissile.

Unit 110.
3.1 feet.—Siltstone—sorting good—fissile.

Unit 109.
1.1 feet.—Medium sandstone—quartz—sorting poor, sphericity high, roundness low—matrix not visible—contains quartzite pebbles up to 5 cms. in length—no fossils—compact, brittle, non-fissile.

Unit 108.
1.9 feet.—Siltstone—sorting good—no pebbles visible—fissile.

Unit 107.
9.0 feet.—Siltstone—sorting fair to poor—abundant pebbles—mostly quartzite—some up to 5 cms. in length—fissile.

Unit 106.
3.0 feet.—Siltstone—sorting good—compact, brittle, massive—light grey—partings at 1.5 and 2.4 feet above base.

Unit 105.
1.6 feet.—Siltstone—sorting poor—contains abundant sand grade quartz fragments—non-fissile—light grey.

Unit 104.
1.6 feet.—Siltstone—sorting middling to poor—pebbles (well rounded) up to 2.5 cms. in length—contains sandy lenses of quartz particles.

Unit 103.
2.0 feet.—Siltsone—most properties not visible—sorting appears to be good—contains rare pebbles up to 0.1 inches in length—compact, brittle, non-fissile—light grey.