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PETROLOGICAL EXAMINATION OF SAMPLES OF ROCKS FROM THE SOUTH-EAST END OF CARNARVON BASIN, W.A.

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INTRODUCTION

A number of rock samples, which were collected from the outcrops by the Carnarvon Basin Field Party in 1955, were submitted by M.C. Konecki for petrological examination in thin sections.

All specimens have been named according to the method proposed by M.A. Condon (B.M.R. Records 1953/131) to which reference should be made, particularly with respect to various types of "greywacke" described herein.

?LYONS GROUP BASE

(UNCONFORMABLY OVERLYING THE PRECAMBRIAN)

Spec.W.B. 14 (Base of the ?Lyons Group unconformably overlying the Precambrian)

Chloritic Quartz Greywacke.

Point 117, Photo 5081, Run 13, Glenburg, W.A.; Glenburg 4-mile coordinates 352, 792.

The hand-specimen is a medium to coarse-grained, pale brownish-grey, weakly conglomeratic sandstone without visible bedding. It is soft, friable, porous and highly permeable. Occasional large, ferruginous pebbles up to 2cm long are carried in the sandy rock, but unfortunately the thin-section does not include any of these bodies, so that it is not possible to identify them conclusively at this stage. Under examination with a hand-lens (X10) they have the appearance of an indurated limonitic quartz-sandstone. Thus, it is possible that they may simply be ferruginous concretions. However, they generally have an elongated, "jelly-bean" shape rather uncommon in concretionary bodies. W.B. Dallwitz has suggested that they may be highly altered fossil remains or coprolites.

In thin-section it is seen that the rock consists largely of very poorly sorted, angular to rounded quartz grains (40%) and various accessory minerals (1%), in a felted, yellowish-brown, chloritic matrix (59%), The quartz grains range from 1.6mm to 0.04mm across. The average grain diameter is about 0.2mm. Some grains are highly angular, while others are rounded and even corroded and embayed. It is thought that this corrosion of the grains has taken place during diagenesis, and in many such cases the quartz is actually veined and replaced by chlorite matrix material. The quartz is commonly strained, and in some cases has an aggregated quartzitic texture. Other grains contain vein-like inclusions of leucoxene and altered iron ore minerals.

Accessory grains include small chips of blue tourmaline, crystals of zircon, and grains of altered iron oxide.

The matrix is of very uniform, yellowish-brown, felted to spherulitic chlorite. The texture of the chlorite gives this rock a very distinctive appearance, so that if it should have a large areal extent it would be of great use for purposes of correlation.

Spec.W.B.16 (Base of the ?Lyons Group unconformably overlying the Precambrian Breccia.

Chloritic Arkose Breccia

Point 69, Photo 5081, Run 13, Glenburg, W.A.; Glenburg 4-mile 357, 793

This is another very distinctive rock, both in hand-specimen and thin-section. In hand-specimen the rock is a fine-grained breccia of a general pinkish-white colour, made up of easily recognised , angular fragments of white feldspar and grey quartz in a fine, cream-coloured matrix. Larger grains reach up to 1.5cm across, but most are about 0.5cm. Bedding planes or other directional textures cannot be detected in the specimen provided. This rock also differs from most of those previously described in being hard, non-porous and practically impermeable on fresh surfaces.

In thin-section it is seen that the rock consists of poorly sorted, angular fragments of quartz and quartzite (20%), various feldspars (40%) and accessory quantities of sphene and leucoxene, in a felted chloritic matrix (40%). With such a high proportion of matrix material the rock might well have been termed a chloritic arkosic greywacke breccia. In thin-section the clastic fragments range from 7.0mm down to 0.04mm across, but from the hand-specimen it is seen that larger grains reach up to 15.0mm.

Quartz occurs as clear, highly angular grains with undulose extinction, and as large fragments of completely recrystallised quartzite. The feldspars present are orthoclase, microperthite, microcline and microcline microperthite. All varieties are about equally abundant and fairly fresh. There are also a few small chips of well-twinned andesine, Both quartz and feldspar show some tendency to be marginally by the chloritic matrix.

The matrix is almost entirely chloritic, and the chlorite is of the same kind as that in W.B.14. In this case, however, it is never spherulitic, but more commonly coarsely flaky lamellar.

WOORAMEL SANDSTONE

W.B.30. (330 feet above the base of the Wooramel Sandstone.)

Quartz Greywacke.

(Point 86, Photo 5007, Run 13A, Glenburg W.A.: Glenburg 4 mile 348, 786.

A medium to fine-grained, white, sandy sediment composed mainly of grains of quartz (80%) in a fine, argillaceous/siliceous matrix (15%). The rock is without detectable bedding and there is no preferred orientation of grains. The detrital grains average 0.2mm in diameter, with a maximum of 0.5mm and a minimum of about 0.05mm. Despite this rather wide variation in grain-diameter the sorting is generally rather good, with few grains departing from the average. It is also probable that many of the apparently smaller grains are, in fact, tangential sections of larger grains - such a condition must apply in all thin-sections of sediments. The rock is soft, friable and permeable.

The detrital quartz grains are generally of sub-angular to sub-rounded outline. The more angular ones have suffered some abrasion at the corners. Most are of sub-circular section, but some have the form of elongated chips and plates. In general, the quartz is clear, but some grains are charged with minute, bubble-like inclusions which, because of their very strong negative relief, appear isotropic under low magnification. However, when highly magnified, they are clear and transparent. Tiny acicular crystals of rutile also occur as rare inclusions in the quartz. Many grains show moderately strained extinction phenomena. There is no indication of secondary enlargement of the quartz.

Other detrital minerals, altogether amounting to no more than 2%, include rare grains of finely crystalline quartzite, small sheets of muscovite, and grains of limonite-like, opaque material, often with octahedral form and reaching up to 0.1mm across. These are probably altered pyrite.

The matrix consists of very fine, intergranular clay minerals, but not all of the pore-spaces are so filled and many remain open. Much of the matrix is so fine as to be very weakly birefringent but quite commonly shows aggregate polarisation. There appear to be two distinct species of clay mineral, one brown and almost isotropic with low positive relief, and the other colourless, more crystalline and with a higher relief. A small proportion of very fine sericitic material is found amongst both types, and both clay minerals are commonly intermixed. In some instances the colourless clay mineral has crystallised into curved, rectangluar sheets up to 0.24mm long, and in such cases is almost certainly kaolinite. Little can be established with respect to the relations between the two clay minerals, except to observe that the brown species shows a tendency tobe confimed to the smaller intergranular spaces and, therefore, has more of the character of a cement. No carbonate mineral could be detected in the matrix.

W.B.29. (120 feet above the base of the Nunnery Member of the Wooramel Sandstone)

Slightly Ferruginous Quartz Greywacke with Carbonate Concretions.

Point 86, Photo 5007, Run 13A, Glenburg, W.A.; Glenburg 4-mile 348, 786.

A fine-grained, pale brown, sandy sediment. Iron enrichment has been rather irregular and now shows up as pale brown lenses and foliations parallel to the indistinct bedding of the rock. The specimen is soft and friable, and almost plastic when wet. Permeability is high, so that large quantities of water are absorbed and, on drying out, the specimen exhibits numerous, tiny contraction cracks.

Thin-section examination shows that the rock is a fine-grained sandstone consisting of detrital quartz (30%) and mica (2%)), a finely divided matrix (55%), aggregates of limonitic material (8%), concretionary concentrations of carbonate (4%) and minor accessory minerals.

The average detrital grain-size is about 0.14mm with about 20% larger and 50% smaller. The maximum observed grain diameter was 0.3mm. The grains are highly angular and commonly have the form of elongated chips lying parallel to the bedding. The quartz is only lightly strained and generally clear, apart from occasional included globules and tiny rods, probably rutile. One detrital grain, measuring 0.135mm across, of clear, unaltered microcline feldspar was detected.

Detrital mica is not common, but small, ragged sheets of muscovite are found. They usually lie between quartz grains and are of smaller size. The muscovite grades into sericite in the matrix. Relatively large sheets of colourless chlorite as were present in many of these rocks are absent from this specimen.

Accessory detrital tourmaline (blue) is present in very small quantity, while small grains of magnetite are rather more abundant.

The very finely divided matrix appears to consist largely of a colourless chlorite with a little admixed sericite and very subordinate argillaceous matter. Thus, the matrix is quite transparent and very weakly birefringent, being almost isotropic in many places.

In some parts of the rock (the pale brown lenses and bands observed in hand-specimen) the matrix, is small part, replaced by finely granular to massive limonite. The degree of iron enrichment varies from a mere limonitic stain to complete replacement of patches of the matrix.

In other parts the matrix is replaced by finely crystalline to weakly spherulitic carbonate (siderite). This concentration of carbonate is strictly confined to circular areas with a maximum diameter of 1.2mm in thin-section, and it is apparent that in three dimensions, rather than the two of a thin-section, these bodies would be of sub-spherical form. Such areas probably represent a concretionary concentration of carbonate rather than organic remains in fabric or proportions.

W.B.13.(Base of the Wooramel Sandstone.)

Argillaceous Quartz Greywacke.

(Point 58, Photo 5080, Run 13, Glenburg W.A.: Glenburg 4 mile 353, 719)

The hand-specimen is a medium-grained, coherent, though porous and permeable, light grey sandstone. There is no indication of bedding in the hand-specimens provided.

In thin-section it is seen that the rock consists largely rounded to sub-rounded quartz grains (80%) in an argillaceous matrix (20%). The average quartz grain-size is 0.3mm, with a maximum of 0.6mm and a minimum of about 0.1mm. Thus, the sorting is quite strong. The quartz itself is clear, but considerably strained . This strain is a pre-depositional feature. Minute inclusions are common but different to identify; some are of (?) zircon, others are opaque, but most are of fine dust. Very rare grains of detrital blue tourmaline up to 0.1mm long have been found.

An important feature of the rock is a certain degree of secondary enlargement of the quartz grains. The secondary rims are occasionally continuous between two or more grains and, though very thin, it is to this secondary silica that the tenacity of the rock is due.

The matrix is of fine, argillaceous material which, in many cases, has crystallised into distinct flaky and fibrous clay minerals. There is no directional fabric in thin-section.

WOORAMEL SANDSTONE.

ONE GUM MEMBER.

(Type area)

W.B.39. (62 feet below the eroded top of One Gum Member of the Wooramel Sandstone.

Fine Pebble Conglomerate

(Point 216, Photo 5008, Run 13A, Glenburg W.A.; Glenburg 4 mile 349, 784.

A medium-grained "dirty brown", highly porous pebble conglomerate consisting of quartz pebbles up to 7 mm across in a coarse, sandy, highly ferruginous matrix. Bedding is only poorly expressed in the hand-specimen, mainly by a weak colour-banding and variation in the proportion of coarse material. The rock is moderately soft and friable.

In thin section it is apparent that the pebble phase (35%) consists of a coarse-grained quartzite in sub-rounded to sub-angular grains, often containing abundant dusty inclusions, rare tourmaline, rare flakes of sericite, and very rare sheaf-like aggregates of acicular (?) sillimanite. The pebbles are highly variable in size, reaching up to 7mm across, but averaging about 2mm. The matrix consists of rounded to sub-angular quartz grains (50%) averaging about 0.4mm in diameter. However, the grain-size is variable and there appears to be all gradations between pebbles and matrix quartz. Here again the quartz grains are often fragments of coarse quartzite, almost always exhibiting strain phenomena. Other detrital grains in the matrix include brown chloritised mica which is always squashed into the interstitial spaces (5%), rare tourmaline, and rare zircon.

The cementing matter (10%) consists mainly of iron stained clay, brown chlorite, (?) hematite, sericite and fine quartz. The hematite is commonly granular and may represent original detrital iron oxide. The brown chlorite has probably been derived from original mica.

W.B.40. (115 feet above the base of One Gum Member of the Wooramel Sandstone.

Fine Quartz Greywacke

(Point 216, Photo 5008, Run 13A, Glenburg, W.A.; Glenburg 4 mile 349, 748.

A fine-grained, moderately soft, highly permeable sandy sediment of general white colour, but with bedding indicated by rather darker grey laminae. There is some suggestion of cross-bedding in hand-specimen. Surfaces parallel to the bedding show a fine micaceous lustre.

In thin-section it is apparent that the rock is a fine grained quartz greywacke consisting of quartz grains (74%) altered mica (3%), muscovite and sericite(3%), leucoxene (3%), and other accessories (1%) in a fine chloritic-argillaceous matrix (16%). The grain-size of the detrital constituents is fairly even with an average diameter of about 0.1mm and a maximum of 0.2mm. Most grains are angular and many have the form of elongated chips laying parallel to the bedding.

The quartz grains are clear and only slightly strained. A few fine inclusions of sericite and dusty material are found. No secondary enlargement was observed. Flakes of brown chloritic material are considered to represent original detrital mica. In some bands the chlorite is almost colourless. Bent and shredded flakes of muscovite and sericite are quite common, particularly in some laminae where the quartz content is reduced.

Accessory minerals include grains of leucocene-coated ilmenite, tourmaline and zircon. They are distributed throughout the rock but in some laminae are concentrated so as to make up some 10% of the band. Such are the darker grey laminae seen in hand-specimen.

The matrix consists of very finely divided colourless chlorite, brownish argillaceous material, fine sericite, and powdery leucoxene. It is essentially similar to the matrix of the previously described quartz greywackes.

NB. In all of the above descriptions the heavy and accessory minerals described are those detected in thin-section. No attempt has been made at specific heavy mineral separation.

W.B.24. (85 feet above the base of One Gum Member of the Wooramel Sandstone)

Micaceous Quartz Greywacke.

(Point 209, Photo 5008, Run 13A, Glenburg W.A.; Glenburg 4 mile, 348, 785)

In hand-specimen of this rock is a fine-grained, brownish white, distinctly micaceous sandstone. It is fairly coherent and moderately permeable to water. Irregular bedding is quite distinct, being displayed by thin, darker grey streaks through the rock. The micaceous character of the rock is most evident on surfaces parallel to the bedding planes.

In thin-section it is seen that the rock is a fine-grained, micaceous quartz greywacke consisting of grains of quartz (40%), sheets of muscovite (15%), sheets of clay mineral ?3%), grains of hydrated iron oxide (2%), and accessory zircon and blue tourmaline, in a finely divided seritic, siliceous-argillaceous matrix (40%).

Quartz grains are angular to sub-rounded,and only moderately sorted, ranging from 0.35mm to 0.05mm across. The average grain diameter is around 0.1mm. Sheets of mica up to 0.5mm across are abundant. Most are oriented parallel to the bedding, and many are altered to a brown, iron-stained chlorite, Sheets of a colourless to pale yellow-brown clay mineral with very low birefringence are conspicuous.

The matrix appears to consist of finely divided sericite, siliceous material,and clay. Bedding is clearly indicated in thin-section by parallel laminae of varying grain-size. Some laminae are of highly micaceous quartz siltstone or shale. Micaceous minerals are very much more abundant in the fine-grained laminae than in the coarser parts of the rock. They are also generally more altered and iron-stained in the finer phases.

W.B.25. (65 feet above the base of One Gum Member of the Wooramel Sandstone.

Argillaceous Quartz Sandstone

(Point 209, Photo 5008, Run 13A, Glenburg W.A.: Glenburg 4-mile 348,785.)

The hand-specimen is a soft, friable, highly permeable, pale brownish-white, medium-grained sandstone without distinct bedding. The rock is so soft as to practically disintegratein the hand while washing, during which process the "cement" is rapidly removed. This "cement" is no more than an intergranular deposit of incoherent argillaceous matter, and it might be said that the sediment is almost unconsolidated.

In thin section it is apparent that the rock is a well sorted, medium-grained sandstone consisting of sub-rounded quartz grains (90%) and minor accessories, cemented together by an incoherent sericitic-argillaceous paste.

The detrital grains average 0.3mm across in thin-section, though examination of the hand-specimen shows that some grains reach up to 1mm in diameter. The quartz grains carry abundant dusty inclusions and rare included crystals of blue-brown tourmaline. They are not significantly strained or fractured.

Accessory minerals observed were rounded grains of hematite, bent and shredded flakes of muscovite and colourless chlorite, and relatively large (0.2mm) crystal fragments of blue-brow tourmaline.

The cementing material is a pale yellow-brown paste of clay and lesser sericite. There may also be a small quantity of colourless chlorite present. There is no indication of stratification in thin-section and much of the volume of the rock is open pore space.

W.B. 34. (48 feet above the base of One Gum Member of the Wooramel Sandstone.

Argillaceous Quartz Sandstone.

(Point 210, Photo 5008, Run 13A, Glenburg, W.A., Glenburg 4-mile 348, 786)

A very soft, white to pinkish white, highly permeable sandstone with light colour banding, white bands being broad and pinkish bands being narrow. This banding may or may not represent bedding, and there is no other indication of stratification either in hand-specimen or thin-section.

In thin-section it is apparent that the rock is a well sorted, fine grained sandstone with an average diameter of 0.2mm. Owing to the extremely friable and practically uncemented nature of the specimen it was not possible to prepare a satisfactory thin-section and many grains were lost in the process. Quantitative estimations are thus of little value in this case. However, it is evident that the rock consists very largely (80%) of well sorted , rounded quartz grains set in a subordinate, unconsolidated argillaceous cement.

Other detrital (accessory) minerals include zircon, magnetite and leucoxene in relatively great abundance, together totalling some 3%, and less abundant tourmaline. Most grains of accessory minerals are also well rounded. The quartz contains numerous fine, needle-like inclusions, probably rutile, and is often quite cloudy. Some also has secondary quartz outgrowths.

There is no indication of grain orientation, but the rock is so weakly coherent that any original fabric could easily have been destroyed in making the section.

Spec.W.B.26.(42 feet above the base of One Gum Member of the of the Wooramel Sandstone.

Slightly Micaceous Quartz Sandstone.

(Point 209, Photo 5008, Run 13A, Glenburg W.A., Glenburg 4-mile 348, 785.

In hand-specimen this rock is a clean, white, porous, highly permeable, slightly pebbly sandstone. There are no obvious bedding features in the specimens provided. The lustre of mica flakes is clearly visible on fresh surfaces, but the rock is by no means highly micaceous.

In thin-section it is seen that the average grain-size of the rock is about 0.2mm. Generally speaking, the sediment is well sorted, so that the grainsize ranges between 0.3mm and 0.1mm. However, the rock is characterised by the presence of larger quartz grains and fine pebbles of quartzite ranging between 1.5mm and 3 mm. across. These belong to an entirely different phase since there is no gradation between such scattered large grains and the general rock material. The sediment may be said to be microconglomeratic.

Mineralogically, the most abundant clastic grains are of quartz (85%). These are moderately strained and sub-angular to angular in outline. Detrital sheets of muscovite, fresh and altered, are common (5%). Grains of hydrated iron oxide make up perhaps 2% of the rock and are undoubtedly of detrital origin.

Accessory detrital minerals include zircon and blue tourmaline.

Such cementing material as has been preserved in the thin-section is a fine paste of flaky argillaceous material with a smaller proportion of admixed sericite. In some parts the argillaceous material has crystallised into large (up to 0.3mm) sheets of a colourless, very weakly birefringent clay mineral.

Though bedding is not conspicuous either in hand-specimen on thin-section, it has been noted that a few of the quartzitic "pebbles", particularly the more eliptical ones, have a tendency to be oriented on sub-parallel arrangement.

W.B.33. (35 feet above the base of One Gum Member of the Wooramel Sandstone)

Ferruginous Quartz Sandstone.

(Point 210, Photo 5008, Run 13A, Glenburg, W.A.; Glenburg 4-mile 348, 786)

A coarse-grained, red-brown sandstone of high porosity and permeability, and with bedding weakly indicated by colour banding. The rock is moderately soft and friable, though harder than the fine, white sandstones. Its colour is obviously due to a high iron content.

In thin-section the rock is evenly coarse-grained and fairly well sorted, the average grain diameter being about 0.4mm with a maximum of 1.4mm. There are also rare pebbles up to 1cm across but generally about 3mm, so that the rock has a very weakly conglomeratic nature. Such pebbles do not make up more than 1% of the rock.

The detrital constituents, then, consist of well rounded grains of quartz and quartzite (84%), rare pebbles of quartzite and decomposed volcanic rock (1%) with a cement of brown chlorite and limonite (15%). The quartz grains are somewhat fractured and considerably strained. This is an original feature; the present sediment has not been subjected to notable stress. Inclusions of tourmaline and fine, acicular (?) rutile are occasionally found, but small dust - and bubble-like inclusions are quite common. There is some indication of secondary outgrowth on the quartz grains. The quartzite is a coarse-grained type and it is probable that the rounded quartz grains were derived from such a rock. Only one pebble of decomposed volcanic rock was observed in the specimen. It consists of finely divided, altered feldspar, clay minerals, sericite and leucoxene, and contains occasional quartz grains and chips. It is thought likely to have been a fine tuff.

The cementing matter consists of limonite and brown chlorite in approximately equal proportions. The limonite appears to have preceded the chlorite. There are also numerous unoccupied pore spaces.

W.B.36(a) (31-35 feet above the base of One Gum Member of the Wooramel Sandstone.

Micaceous Quartz Greywacke.

(Point 212, Photo 5008, Run 13A, Glenburg, W.A.; Glenburg 4-mile 348, 785.

A moderately hard, fine, white, sandy rock of considerably reduced permeability, with a platy lamination and showing the effects of differential weathering parallel to this structure.

In thin-section it is apparent that the rock is a fine greywacke-type sediment consisting of detrital quartz (40%), chlorite after mica(15%), muscovite (2%) and various accessory minerals (3%) in a very finely divided chloritic-argillaceous matrix (40%). One grain of highly altered feldspar was detected.

The detrital grains are highly angular but rather well sorted. The average grain diameter is about 0.14mm and there is little significant departure from this, though some of the mica flakes reach up to 0.6mm in length. Only the longer micaceous flakes are oriented parallel to the bedding.

The quartz grains exhibit the effect of strain and are often composite in structure, actually being fragments of coarse quartz aggregates. Fine, dusty inclusions are common. Curved and frayed-out sheets of muscovite are conspicuous because of theirhigh bire - fringence Other micaceous sheets of grey to brown colour and with very low birefringence are considered to be of essentially chloritic nature and probably an alteration product of original mica. In this case, and in the case of the colourless chlorite described in other specimens, the chlorite may actually be one of the vermiculite group. Accessory detrital minerals include hematite (after magnetite), leucoxene, zircon and very rare, small grains of blue tourmaline.

The matrix is pale brown and very finely divided. It appears to consist largely of argillaceous and colourless chloritic material but is too fine to be satisfactorily determined. Occasional spherulitic aggregates of a finely fibrous mineral may be zeolitic in character. There is little unoccupied pore space, hence the relatively low permeability of the specimen.

Spec.W.B.31 (20 feet above the base of the One Gum Member of the Wooramel Sandstone.

Thinly Interbedded Quartz Greywacke and Quartz Greywacke Siltstone.

(Point 213, Photo 5008, Run 13A, Glenburg, W.A.; Glenburg 4-mile 348, 785)

In hand-specimen this is a thinly laminated, white fine-grained, soft but coherent, weakly permeable sediment with thin lines of iron staining parallel to the bedding. The bedding is planar and quite uniform. On cut surfaces it is seen that the specimen consists of alternating laminae of fine and very fine grained nature. The fine-grained laminae are white, while the very fine ones are pale grey-brown, just off-white. The thickness of individual laminae varies from 6mm. to less than 1 mm.

In thin-section it becomes apparent that the fine-grained laminae consist of a fine-grained quartz greywacke, while the very fine-grained laminae are of quartz greywacke siltstone type.

The fine quartz greywacke has little in the way of internal bedding features. It consists of angular chips of quartz (60%) averaging 0.1mm across, fine flakes of sericite, and muscovite (2%), grains of hydrated iron oxide (1%) and accessory zircon, in an argillaceous matrix (37%) containing masses of brownish chlorite and sheets of colourless clay mineral.

The siltstone phase consists of sub-parallel oriented, elongated, angular chips of quartz (50%) averaging 0.04mm across. flakes of sericite (20%) and grains of hydrated iron oxide (3%) in a finely divided argillaceous matrix (27%) containing brown chlorite and opaque stringers of what may be carbonaceous matter. The matrix exhibits a distinct, fine lamination within itself.

Thin-section examination also shows that there is a fine scale intertonguing of the sand and silt phases, so that a sandy bed may be partly split by a silt tongue, and vice versa.

WOORAMEL SANDSTONE

(Daurie Creek Area.)

Spec. W.B. 152

Micaceous Quartz Greywacke (8 feet above the base of the formation)

(Point 276, Photo 5122,Run 9, Glenburg, W.A.: Glenburg 4-mile 394, 823.

In hand-specimen this is a pale grey, almost white, fine-grained, sandy sediment containing diffuse bands of dark grey iron oxides. Apart from these dark bands the rock shows little indication of bedding. Hand-lens examination shows that there is quite a high proportion of silvery-white mica. The specimen is hard, well cemented, and only slightly porous and permeable.

In thin-section it is seen that the rock is a rather poorly sorted micaceous quartz greywacke consisting of angular detrital grains of quartz (60%), very abundant mica (15%), grains of altered magnetite and ilmenite (2%), and relatively abundant accessory tourmaline and some zircon and(?) sphene in an essentially argillaceous matrix (23%). No feldspar was detected. The grainsize ranges from 0.004 mm to 0.9mm, the average being around 0.1mm. Most grains are highly angular, but a few are sub-rounded. The more elongated grains are oriental parallel to the bedding, as also is much of the micaceous material.

The quartz grains are clear and only slightly strained. Some contain small, more or less globular inclusions of tourmaline, grains of leucoxene, possible fluid inclusions, and indeterminable dust. Rare grains are very heavily charged with such inclusions. Mica occurs as plates, sheets and shredded aggregates of muscovite, in places highly altered to clay minerals and heavily iron-stained. Magnetite has been largely altered to hematite. though some unaltered grains remain. The presence of leucoxenic grains indicat the presence of an original titaniferous oxide. However, it is apparent that at least some of the leucoxene has come from detrital sphene.

The matrix is almost entirely argillaceous in part semi opaque, and in other places composed of plates and sheets of weakly birefringent clay minerals. Some fine, sericitic material is also present in the matrix. An interesting feature of the rock is that the quartz grains appear to have reacted with the matrix, so that grain boundaries become diffuse. This probably explains the hardness of the hand-specimen.

Spec.W.B.153 (36 feet above the base of the formation.)

Quartz Greywacke.

(Same locality as W.B. 152)

In hand-specimen this is a fine, soft friable, highly permeable, practically non-bedded sandstone . Its colour is very pale, slightly brownish white. Irregular patches have taken on a red iron-stain.

In thin-section it is apparent that the rock is a fine-grained sandy sediment with an average grainsize of about 0.1mm, ranging from 0.04mm to 0.4mm. Sorting is thus moderately poor. All grains are highly angular in outline.

It is apparent that the detrital phase of the rock consists mainly of grains of quartz (60%), sheets of mica (5%), grains of leucoxenised ore (2%), and accessory grains of tourmaline, zircon, sphene and leucoxene. These grains are embedded in a flaky, felted, argillaceous matrix (33%).

The quartz grains are mildly strained and generally clear, though some grains contain inclusions of tourmaline, sericite, and fine, opaque dust. The mica is a colourless musconite in sheets and distorted or shredded aggregates. In some cases it is seen to be altering to sheets of a very weakly birefringent clay mineral.

The matrix consists of a finely felted mass of fibrous and platy clay minerals with a small amount of admixed sericite and sparse opaque dust.

Spec.W.B.154. (108 feet above the base of the formation).

Quartz Greywacke.

(Same locality as W.B. 152).

A fine-grained, white, sandy sediment with slightly micaceous, though indistinct bedding planes. The specimen is very soft and incoherent, finely porous and highly permeable.

In thin-section it is seen that this rock is essentially similar to W.B. 153 in mineralogical composition and general texture The main difference is that W.B.154 is coarser grained and better sorted. The average grain diameter is 0.2mm, grainsize ranging from 0.1mm to 0.5mm.

Spec.W.B. 155.(150 feet above the base of the formation)

Quartz Greywacke.

(Same locality as W.B.152)

In hand-specimen this is a much coarser-grained sandstone interbedded with a fine, micaceous siltstone. Both phases of the rock are of clean, whitish grey colour and are both permeable to water, the coarser phase particularly so. The sandy part is soft and friable, while the siltstone bed is harder and very much more coherent. The micaceous nature of the siltstone is most apparent on surfaces parallel to the bedding.

In thin-section it is seen that the sandy part of the rock is a medium-grained quartz greywacke having an average grain-size of 0.6mm, while the silty bed is in fact a finely sandy, micaceous greywacke siltstone. The detrital grains of the sandy phase range from 0.1mm to 1.5mm across, so that sorting is rather poor. They vary in outline from quite angular to well-rounded , most being sub-angular to sub-rounded. This part of the rock then, consists of such grains of quartz (50%), sheets of mica (3%) and accessory ilmenite, tourmaline, hematite and (?) apatite, in a dominantly argillaceous matrix (47%).

The quartz grains are clear but strained. Some consist of an aggregate of smaller, sutured grains, while a few have a sugary texture suggestive of crushing. Inclusions of tourmaline, sericite, very fine (?)rutile, small opaque bodies and streams of bubble-like inclusions are present but not abundant. Mica occurs as sheets and finely shredded aggregates, commonly passing into fibrous to micaceous, very weakly birefringent clay minerals.

The matrix consists mainly of pale brownish, fibrous argillaceous matter with a small amount of admixed sericite. In a few places aggregates of sheaf-like bundles of a colourless, fibrous clay mineral form clots in the matrix.

The siltstone is a finely laminated rock consisting of small (0.06mm and less), angular grains of quartz (50%), sheets and fibres of muscovite and sericite (10%), and accessory tourmaline and leucoxene, in a fine argillaceous matrix (30%), Mica shreds and the more elongated quartz grains are highly oriented parallel to the bedding. Within this essentially silty rock are highly angular quartz sand grains (10%) varying from 0.08mm to 0.3mm across. They are the same as the quartz grains of the quartz greywacke.

Spec. W.B. 156. (215 feet above the base of the formation)

Fine Quartz Sandstone

(Point 274, Photo 5121, Run 9, Glenburg, W.A.: Glenburg 4-mile 393, 823.

In hand-specimen this is a fine, white, sandy sediment, very poorly cemented, very friable and soft, and highly permeable. Bedding is not apparent in the hand-specimen.

In thin-section it is apparent that the rock is fine grained, rather well sorted quartz sandstone, in parts approaching quartz greywacke. There is no indication of bedding in thin-section. The rock consists of detrital grains of quartz (85%), leucoxene and ilmenite (2%), accessory tourmaline, mica, zircon, possible monazite, and possible sphene, all in remarkable abundance (totalling perhaps 3% of the rock), with a fine argillaceous cement, inplaces assuming the character of a matrix (10%).

The detrital grains average 0.1mm in diameter, ranging between 0.05mm and 0.3mm. However, extremes are rare and the rock is well sorted. The grains are sub-angular to sub-rounded in outline. Quartz grains contain inclusions of tourmaline, sericite, opaque grains, rare (?) monazite, and indeterminate dust. The quartz is lightly strained and compound grains of interlocking quartz anhedra are found.

The cementing material is a very fine, in part almost isotropic argillaceous aggregate. In some places it becomes more abundant, so constituting a matrix. In such places it tends to be more crystalline, containing distinctly fibrous and micaceous sheets of clay mineral.

Accessory tourmaline is a blue variety, and the accessory mica is a clear muscovite, in many cases altering to sheets of weakly birefringent clay mineral

Spec.W.B.157. (224 feet above the base of the formation)

Laminated Fine Quartz Greywacke Siltstone.

(Same Locality as W.B. 156)

In hand-specimen this is a very fine-grained, thinly bedded, sediment containing clearly visible larger sand grains. The rock is white where fresh but iron stained on some surfaces. It is also soft, somewhat friable, and moderately permeable.

In thin-section it is seen that the rock is fine, sandy siltstone made up of small, silt-sized grains in an argillaceous matrix. Within this siltstone fabric are found about 10% of coarser, fine to medium sand grains constituting a kind of "micro-pebble phase". Such grains range from 0.15mm to 1.2mm across. Bedding is indicated in thin-section only by a sub-parallel alignment of the more elongated grains.

Mineralogically, the rock consists of grains of quartz (75%), muscovite and sericite (2%), grains of magnetite and leucoxene (3%), with accessory zircon, tourmaline and possible monazite, in a fine argillaceous matrix. The quartz grains are moderately strained and contain rare inclusions of the above-mentioned accessories. Some particularly in the coarser "micro-pebble phase" are made up of a sutured aggregate of anhedral quartz grains. One large sand grain, 1.1mm across, consists of a large sheet of muscovite containing poikilitic quartz inclusions. It is probable that this grain at least was derived from a granitic parent rock. Some of the aggregate quartz grains contain fine sericite inclusions.

Spec.W.B.159.(285 feet above the base of the formation).

Micaceous Quartz Greywacke Siltstone.

(Point 278, Photo 5122, Run 9, Glenburg, W.A.: Glemburg 4-mile 391, 821.

In hand-specimen this is a very fine-grained, pale brownish, thinly bedded sediment containing thin (5mm), lenticular beds of white coloured fine sand. The rock is soft, moderately coherent and only slightly permeable. Hand-lens examination shows that it is distinctly, though finely, micaceous. This feature is particularly apparent on surfaces parallel to the bedding.

In thin-section it is seen that the rock is a highly micaceous quartz greywacke siltstone consisting of grains of quartz (70%), shreds of mica (15%) and accessory grains of magnetite, leucoxene, blue tourmaline, (?)apatite, and (?) zircon, in a fine argillaceous matrix (15%).

The quartz grains are highly angular in outline and range from 0.01mm to 0.1mm across. Most average about 0.03mm and sorting is fair. Many of the quartz grains are angular chips which are oriented, parallel to the bedding. The mica is mainly fine muscovite and sericite oriented more or less parallel to the bedding. In many cases it has been altered to a brownish, weakly birefringent clay mineral.

The matrix is of very fine, unresolvable argillaceous matter containing some fine sericite. In some laminae it is moderately iron-stained.

KEOGH FORMATION

Spec.W.B.19.(Near the base of the formation)

Fine Quartz Greywacke

(Point 205, Photo 5052m Run 14, Wooramel W.A.; Glenburg 4-mile 346, 784

In hand-specimen this is a fine-grained, pinkish-grey sandstone with irregular, brown iron stains. It is quite coherent, but finely porous and permeable. Bedding is not apparent.

In thin-section it is evident that the rock is a well-sorted, fine sandstone with an average grain diameter of 0.1mm. The largest grain observed was 0.4mm across, but these are rare . The rock consists mainly of quartz (60%), altered potash feldspar (15%), and accessory amounts of muscovite, tourmaline, altered grains of magnetite, chips and crystals of zircon, and powdery leucoxene, all totalling to about 3% of the rock, embedded in a chloritic-argillaceous matrix (22%). Most grains are angular but some are sub-rounded.

The quartz grains are clear, strained, and commonly contain dusty inclusions. Larger inclusions of tourmaline and zircon are also found. Most grains are single of crystal fragments, but some have an aggregated, quartzitic texture. The feldspar is mostly albitised (?) orthoclase, though microcline is not uncommon.

The matrix is a fine, pale brown, aggregate of colourless chlorite and brownish clay. The distribution is somewhat uneven, so that there are commonly patches of dominantly chloritic, or dominantly argillaceous character. Bedding is indicated in thin section by narrow lenticular areas in which the proportion of matrix is considerably increased relative to the main bulk of the rock. In such areas the quantity of matrix material may reach up to 40%.

Spec.W.B.21. (Near the base of the formation)

Fine Sandy Shale.

(Point 207, Photo 5052, Run 14, Wooramel W.A., Glenburg 4-mile 346, 783.

The hand-specimen is a fine-grained, thinly bedded, slightly sandy, pinkish-grey to yellow-brown sediment. It is very soft and friable, and highly permeable. Bedding tends to be somewhat lenticular,and there is slight indication of small-scale current bedding.

In thin-section it is seen that the rock is a finely sandy greywacke siltstone in which the fine sand occurs as thin, lenticular beds and discontinuous laminae. Occasional, very weakly expressed, micro-scale current bedding can be observed in some of these sandy layers.

The sandy bands are actually on the boundary between fine sand and silt, having an average grain diameter of 0.04mm. They are of highly siliceous composition, consisting mainly (85%) of small, angular quartz grains and intergranular (?) sericite (5%), chlorite (5%), and hematite (5%). The shaly bands are approaching silt in grain-size, but have a distinctly shaly texture, being finely but distinctly laminated, and consisting of about 20% fine quartz chips (often elongated parallel to the bedding), 10% sericite, 5% hematibe, and streaks of iron stained organic matter (5%), in a very finely divided, chloritic-argillaceous matrix (60%).

Spec.W.B.23. (Near the base of the formation)

Ferruginous Sandstone

(Point 207, Photo 5052, Run 14, Wooramel W.A.; Glenburg, 4-mile 346, 783.

The hand-specimens supplied are of rather variable character. The specimen from which the thin-section was cut is a hard, non-porous and impermeable, highly ferruginous, deep brown, fine-grained sandstone in which bedding is emphasised by differential iron impregnation. The other specimen, of which no section is available, is a bright yellow-brown, moderately soft, porous and permeable, weakly bedded, fine sandstone. It is much less ferruginous in character and, from hand-specimen evidence, has a dominantly clayey matrix.

In thin-section the highly ferruginous specimen consists of angular grains of quartz (40%), feldspar (30%), iron-stained mica (3%), iron-stained sheets of a clay mineral (2%), and accessory blue tourmaline, in a matrix of dark, red-brown hematite containing relic patches of limonite and argillaceous matter.

Even though the detrital grains are well sorted, with an average grain-diameter of 0.08 mm, all are highly angular in outline. This is due to an irregular replacement by the hematite. Bedding is not apparent in thin-section.

The quartz is clear and strained, and in most cases has suffered more or less replacement by hematite. The feldspar, though quite fresh, is difficult to determine. Most of it, however, is a potassic variety (including microcline and microperthite), but it is possible that a small quantity of albitic plagioclase is also present. Some of the muscovite flakes are quite fresh, but most are altered to a greater or lesser extent. The less altered flakes are colourless chlorite. With further alteration the mica is replaced by limonite and argillaceous matter.

Bent, laminated sheets of clay mineral are thought to be relics from the original argillaceous matrix which has been almost completely replaced by ferruginous oxides. This replacement is most probably a surface phenomenon of similar nature to lateritisation.

Spec.W.B. 52 (a). (48 feet above the base of the formation)

Feldspathic Quartz Sandstone.

(Point 605, Photo 5074, Run 14, Glenburg, W.A.; Glenburg 4-mile 350, 783

In hand-specimen this is a medium to fine-grained, slightly microconglomeratic, bedded sandstone having a grey-white colour when fresh, but generally stained brown by hydrated iron oxide. The rock is soft, moderately friable, porous, and highly permeable. The main body of the rock is of fine sand, in which are carried numerous quartz grains of medium sand size, thus giving the rock a micro-conglomeratic texture. In some parts these larger grains are concentrated in narrow bands parallel to the bedding.

In thin-section it is seen that the work is a feldspathic quartz sandstone consisting of quartz (70%), feldspar (18%), mica (2%), magnetite (1%), and accessory tourmaline and zircon, in a subordinate, brown, chloritic-argillaceous matrix (9%). The detrital grains are angular to sub-angular in outline, and those of the main body of the rock average 0.15mm across, ranging from 0.04 mm to 0.4 mm, but with the great majority falling between 0.1 mm and 0.2mm. The larger sand grains making up the microconglomeratic phase are of variable size, ranging from 0.6 mm to 2.1 mm across. The average diameter, however, is about 1 mm. These large grains are of quartz,

coarse quartz aggregates, and alkali feldspar. The alkali feldspar consists mainly of microcline, microcline microperthite and albite. It is weakly kaolinised along cleavages and fractures, and in some cases lightly sericitised. The quartz of the microconglomerate phase is considerably strained, and contains streams of tiny, dust-like inclusions. Inclusions of magnetite, tourmaline, zircon and sericitic mica are fairly common, though in very small total quantity. In rare cases, some quartz grains are seen to include or partly include anhedra of feldspar. One "pebble" of fine, dusty chert was also found.

The fine sand fraction is of essentially similar composition, differing only in grain-size. Here, however, mica figures more prominently, some being clear, fresh muscovite in shredded sheets and long, thin films, and some being altered, brown material derived from a micaceous mineral. The opaque grains are generally slightly leucoxenised, and in some cases highly so, indicating a somewhat titaniferous composition.

The matrix consists of a finely felted, brown aggregate of argillaceous material with probable admixed, altered chlorite. It is apparent that most of the clastic grains were derived from a granitic (in the widest sense) terrain, and the largely unweathered nature of the feldspar could be taken to indicate that they were not exposed to weathering processes for any great length of time.

Spec.W.B.52(b) (55 feet above the base of the formation.)

Fine Quartz Greywacke (somewhat micaceous)

(Same locality as W.B.52(a).)

In hand-specimen this is a fine-grained, bedded, light brown, sandy sediment with moderate porosity and permeability. Surfaces of bedding planes are notably enriched in mica flakes and therefore have a distinct micaceous lustre. The rock is soft and fairly friable. The hand-specimen is remarkable in that it contains smooth, slightly iron-impregnated, leaf-shaped areas lying parallel to the bedding and having very vague parallel striations along their length. One such area was carefully cleaned up and is now exposed on the surface of the specimen.

In thin-section it is apparent that the rock is a micaceous, slightly feldspathic, fine quartz greywacke. Grain-size is fairly even, ranging around an average of 0.1mm, with a maximum of 0.26mm and a minimum of 0.06mm. Some of the mica flakes, because of their inherent shape, reach up to 0.6mm long, but are usually quite thin. Grain shape is almost invariably angular. Bedding is clearly indicated by the sub-parallel orientation of the more elongated quartz and feldspar chips, and particularly by a marked orientation of mica flakes parallel to the bedding.

The rock consists of clastic quartz (45%), mica (15%), feldspar (20%), and accessory tourmaline, hematite, magnetite, leucoxene and very rare zircons, in a fine, iron-stained argillaceous matrix (20%). Quartz grains are slightly strained and commonly contain dusty inclusions as well as some larger tourmaline crystals. Feldspar is mainly orthoclase, microperthite, microline, microline microperthite, and some albinite. All of the feldspar is quite fresh. Sheets of mica are very common, in most cases being bent, distorted and frayed out around other clastic grains. Many flakes are of fresh, clear muscovite, but others are altered to a greater or lesser extent to a turbid, platy mineral with low birefringence, usually heavily iron-stained. This might well be a kaolinite-type mineral. Accessory magnetite is usually hydrated, but some fresh grains remain.

The matrix is a fine, brownish aggregate of argillaceous minerals, in some cases heavily limonite-impregnated.

Spec.W.B.53 (80 feet above the base of the formation).

Thinly Interbedded Quartz Greywacke and Greywacke Siltstone.

(Point 606, Photo 5075, Run 14, Glenburg, W.A.; Glenburg 4-mile.351,783.)

A fine grained, thinly laminated sediment consisting of alternating laminae of fine sandstone and siltstone. The rock is of off-white colour, and is moderately permeable, changing to a pale brown colour when wet. The silt laminae, in particular, become quite deep brown. Flakes of white mica are very conspicuous on surfaces parallel to the bedding. The rock is moderately soft and friable.

In thin-section it is seen that the rock is made up of alternating thin beds of fine-grained felspathic quartz greywacke and a somewhat micaceous greywacke siltstone. Both types of laminae are of approximately equal thickness, varying between 6 mm. and 2 mm across. The thickness of an individual bed also varies along its length. There is no gradation between sand and silt laminae; the junction is always quite sharp. Thus, the bedding is rhythmical, but not graded. Nor is there any interfingering of the two.

The quartz greywacke phase of the rock is made up of small, angular grains of quartz (50%), feldspar (20%), Mica (10%), magnetite and leucocene (2%), and accessory zircon, in a very fine, almost colourless argillaceous matrix (18%). The detrital grains are well sorted, having an average diameter of 0.15mm, ranging between 0.4mm and 0.06mm. Bedding is rendered apparent in these bands by a parallel disposition of mica flakes, and by a general parallel orientation of the more elongated quartz grains. The quartz is generally clear, slightly strained, and carries rare inclusions of brownish tourmaline. Feldspar grains are mainly of microcline, orthoclase and (?)albite. It is quite fresh in nearly all cases. The mica is as in the previous specimen.

The silt bands consist of small (0.06mm and less), angular grains of quartz and feldspar (20%) in a fine matrix (80%) of oriented sericite, pale brown argillaceous material, flakes of clay mineral, and granular strings of leucoxene. This phase of the rock might be better regarded as a silty shale.

Spec.W.B.54.(85 feet above the base of the formation)

Interbedded Micaceous Quartz Greywacke and Siltstone.

(Same locality as W.B.53).

A very fine-grained, sandy sediment interbedded with thin bands of siltstone. The rock has a very pale brownish colour, the finer grained bands being considerably darker than the sand phase. The hand-specimen is rather similar to W.B.53, but in this case the siltbands are more widely spaced and less regular. The narrower silt bands, in particular, show a strong tendency to intertongue with the sand. Bedding is not perfectly planar, but tends to be undulatory. On surfaces parallel to the bedding planes the specimen has a distinctly micaceous lustre. The rock is moderately hard and coherent, and only slightly permeable.

In thin-section itis apparent that this rock is finer-grained than the preceding specimen, having, for the sandy phase, an average grain diameter of0.06mm, with a maximum of 0.15mm and a minimum of 0.02mm. Since most of the sand grains fall close to the average, this phase of the rock may be considered to be quite well sorted. In view of the extremely small grain diameter of the sand, it is apparent that even the coarser phase of the rock is closely approaching silt grade. All grains are of angular outline.

The arenaceous bands are of very fine, slightly feldspathic, micaceous quartz greywacke consisting of detrital quartz (60%), mica (15%), feldspar (5%), and accessory iron oxides tourmaline and rare zircon, in a fine, argillaceous matrix (20%) containing numerous aggregates of almost opaque kaolin and some chloritic material derived from the detrital mica. The feldspar is mainly a potash variety, possibly with some albite. Detrital muscovite is commonly altered to sheets of iron-stained (?) kaolinite, while other brown, pleochroic sheets are probably altered biotite. The micaceous and chloritic constituents are commonly concentrated in certain thin laminae parallel to the bedding.

The silty bands of the hand-specimen are shown in thin section to differ from the arenaceous bands in that the quantity and grain-size of the arenaceous phase is considerably decreased, while the proportion of argillaceous and sericitic material is correspondingly increased. The average grainsize of the clastic fragments in these bands is about 0.04mm - well within the silt range.

This rock further differs from W.B.53 in that here the junction between siltstone and fine sand laminae is not sharp, but gradational, though the gradation is quite a rapid one.

Spec. W.B.55. (108 feet above the base of the formation.)

Fine Quartz Greywacke

(Point 159, Photo 5074, Run 14, Glenburg, W.A.; Glenburg 4-mile 351, 782.

This is a fine grained, sandy sediment with indistinct bedding. Its pale brown colour is due to highly irregular iron-staining. This rock is notably harder and more coherent than the preceeding specimens but is still moderately porous and permeable.

In thin-section it is seen that the rock is a fine-grained, somewhat feldspathic quartz greywacke with an average grain diameter of 0.15mm, ranging from 0.06mm to 0.4mm. Most grains, however, fall close to the average, so that sorting is good. All grains are angular in outline and many are in the form of distinctly elongated chips oriented more or less parallel to the bedding.

The rock consists essentially of clastic grains of quartz (50%), feldspar (20%), mica (5%), magnetite and hematite (5%), and rare accessory tourmaline and zircon, in a fine, patchily iron-stained argillaceous matrix (20%). Quartz grains are only slightly strained, and are quite clear apart from rare inclusion of zircon and brown tourmaline. The feldspar tends to be slightly kaolinised, but is otherwise similar to that of the two preceding specimens, consisting of orthoclase, microcline, microperthite and ?albinite. Detrital mica is quite abundant, some of it being in the form of fresh sheets and shreds of muscovite, but most is an altered brown, micaceous substance transitional to a platy clay mineral. This material is commonly iron-stained to a greater or lesser degree. Rarely the brown sheets are pleochroic and possibly represent altered detrital biotite.

The matrix consists of very fine, pale brownish argillaceous material, in places tending to re-crystallise to a flaky clay mineral. The matrix is patchily and very unevenly iron-stained, some parts of it becoming almost opaque.

Spec. W.B.56. (133 feet above the base of the formation)

Fine Quartz Greywacke.

(Point 160. Photo 5074, Run 14, Glenburg W.A.; Glenburg 4-mile 351, 781)

In hand-specimen this is fairly soft, but remarkably coherent, fine, sandy sediment of very high porosity and permeability. Its colour is an all-over pinkish grey, and the bedding is very indistinct, being indicated more by the shape of the specimen than by any internal features.

In thin-section it is seen that the rock is a fine-grained, highly porous quartz greywacke with an average grainsize of 0.1mm. The thin-section is a very poor one (owing to the highly porous nature of the rock) and it is not possible to make observations on the texture of the rock or the proportions of minerals present. However, it would appear that grain sorting is moderately good, but there is no indication of bedding in thin-section.

The rock consists dominantly of clastic quartz, with some alkali feldspar (orthoclase, (?) microcline and albite), granular magnetite and hematite, highly altered mica, and accessory tourmaline (blue), in a fine, pale brown argillaceous matrix.

Spec.W.B.57(a). (35 feet below the top of the formation.

Micaceous Quartz Greywacke Siltstone.

(Point 161, Photo 5074, Run 14, Glenburg, W.A.: Glenburg 4-mile 349, 781.)

In hand-specimen this is distinctly bedded, deep brown to chocolate, very fine-grained sediment made up of wide (1 to 1.5cm), deep chocolate-brown bands alternating with narrow (1 to 3mm), pale grey-brown bands. The rock is very soft, but owing to its fineness of grain, is only slightly porous and permeable.

In thin-section it is seen that the wide, chocolate-coloured bands are of finely laminated, slightly carbonaceous micaceous siltstone consisting of silt-sized grains (0.04mm) of quartz (30%) and altered feldspar (10%), flakes of micaceous material up to 0.2mm long (20%), and grains and films of opaque, carbonaceous matter (5%), in a very fine argillaceous-sericitic matrix (35%). The micaceous minerals and carbonaceous films are elongated parallel to the bedding.

The pale grey bands are of distinctly coarser grainsize, being within the range of fine sand. Their lower contact with the micaceous silt is quite sharp, but the upper contact is gradational, so that by a decrease in grainsize and an increase in argillaceous and micaceous material, it passes into the overlying silt. The fine bands, then, consist of angular grains of quartz (50%), feldspar (15%), mica (10%), leucoxene (1%), and rare accessory tourmaline, in a fine argillaceous matrix (24%). The clastic grains range from 0.03mm to 0.2mm across, with the average about 0.08mm. Sorting is rather poor. Quartz is mainly in the form of single grains, sometimes lightly strained. Rare sutured quartz aggregates (fine metaquartzite) have been detected. Feldspar is of alkaline varieties with low refractive indices..

Spec.W.B.57(b). (Same horizon as W.B. 57(a)

Grey Silty Shale

(Same locality as W.B.57(a).)

In hand specimen this rock is very similar to the chocolate-brown, silt bands of W.B.57(A). It is very soft, but only slightly permeable, and is thinly laminated.

In thin-section, however, it shows considerable differences. The overall grainsize is much finer, silt sized grains are much reduced in quantity, while micaceous and (?) carbonaceous matter is increased in quantity.

Thus, the rock consists of fine silt-sized grains of quartz (10%), alkali feldspar (5%), and flakes of altered mica (20%), in a very fine sericitic-argillaceous matrix with grains and films of carbonaceous matter. The clastic silt grains average 0.035 mm across, and very rarely exceed 0.063 mm, while occasional sheets of highly altered mica reach up to 0.09mm. across.

Spec. W.B.58. (30 feet below the top of the formation).

Medium-grained Conglomeratic Sandstone.

Point 161. Photo 5074, Run 14, Glenburg, W.A.; Glenburg 4-mile 349, 786)

In hand-specimen this is a light red-brown, highly porous and permeable, medium-grained sandstone carrying numerous very coarse grains up to 3mm.across. Bedding is not apparent in hand-specimen.

In thin-section it is apparent that the rock consists of sub-rounded to sub-angular grains of quartz (60%) and feldspar (15%) averaging 0.2mm across, flakes of micaceous material (5%), and coarse grains of quartz (10%), those included in the area of th section average about 0.7mm across and reach up to 1.2mm. Accessory detrital constituents include blue tourmaline, zircon, staurolite, and grains of hematite.

The quartz grains are only lightly strained and carry a few inclusions of tourmaline and zircon, as well as opaque dust and bubble-like bodies. The coarse quartz grains are usually single grains, but in some cases are made up of a quartz aggregate of possible igneous origin. Also, though there are none in the area of the section, it is obvious from examination of the hand-specimen that some of these grains are of feldspathic composition.

The feldspar grains in the finer sand fraction are lightly kaolinised and are of alkali composition (orthoclase, microcline and possible albite or microperthite). The micaceous material consists mainly of a brown, sometimes pleochroic mineral probably allied to nontronite.

The cementing material is largely argillaceous, and very commonly highly iron stained, passing into an almost entirely limonitic cement. There is no indication of bedding or other directional features in the thin-section.

Spec.W.B.59. (16 feet below the top of the formation)

Ferruginous Quartz Greywacke.

(Point 226, Photo 5074, Run 14, Glenburg, W.A.; Glenburg 4-mile 349, 786.

In hand specimen this is a bedded, pale purple-brown, sandy sediment containing lenticular masses of yellow-brown sandy material up to 2 cm. across, and thin (1.5cm) beds of white, rather coarser sandstone. The rock is soft, highly porous and permeable.

In thin-section the darker, purple-brown part of the rock is seen to consist of angular to sub-rounded grains of quartz (50%), feldspar (25%), mica (2%) and accessory tourmaline, zircon, staurolite and magnetite, in a very heavily iron impregnated argillaceous to almost purely ferruginous matrix (23%). In some places the clastic grains are well sorted, having a fairly constant average grainsize of about 0.15mm, while in other parts they are poorly sorted and range from 0.02mm to 0.3mm. The distribution of well and poorly sorted areas seems to be quite irregular. The more elongated clastic grains tend to lay parallel to the bedding of the rock.

The quartz grains are clear and slightly strained. Rare grains are made up of a fine, sutured aggregate of quartz anhedra. Feldspar is all of alkaline composition, comprising orthoclase, microcline, microperthite and possible albite. It is usually kaolinised to a greater or lesser degree, in some cases almost completely so. The mica, too, is in many cases altered to sheets of(?)kaolinite and possible montronite.

The yellow-brown areas of the rock are identical in clastic mineral content and texture, but differ in that the matrix is non-ferruginous, being composed of pale brown argillaceous and sericitic matter.

The contact between the ferruginous and non-ferruginous phases of the rock is of considerable interest. For a distance of some 2 mm. from the contact the argillaceous matrix of the yellow-brown phase is charged with tiny (0.005mm) globules of deep red - brown iron oxide, decreasing in concentration away from the contact. Nearer to the contact they show a stronger and stronger tendency to coalesce into dense hematitic masses taking the place of the argillaceous matrix, and so grading into the ferruginous phase. Thus, it would seem that the iron oxide has been introduced into these parts of the rock, i.e. it is not an original constituent. From this, it may be possible to postulate that most of the iron contained in the rock as a whole has been introduced secondarily. However, there is insufficient evidence to state that this is definitely the case.

The thin-section does not include the interbedded white sandstone.

Spec.W.B.160. (2 feet above the base of the formation).

Greywacke Siltstone.

(Point 278, Photo 5122, Run 9, Glenburg, W.A.; Glenburg 4-mile 391, 821.)

In hand-specimen this is a thinly bedded lightly iron-stained, very fine sandy sediment. The rock is moderately hard and coherent, but tends to be fissile along bedding planes. It is only moderately permeable. Bedding planes tend to be slightly micaceous.

In thin-section it is seen that the rock is a siltstone in which the clastic grains average 0.04mm in diameter. The maximum grain diameter is about 0.06mm and the minimum about 0.02mm, so that the detrital grains are well sorted. Bedding is indicated in thin-section by the presence of interbedded laminae of higher than average mica content, by bands of iron staining parallel to the bedding, and by a sub-parallel orientation of the more elongated detrital grains.

The rock consists of small, angular grains of quartz (50%), small sheets of muscovite and sericite (4%), and accessory hematite, (?) leucoxene, tourmaline and zircon , in an argillaceous matrix (46%).

Individual quartz grains, though very small, clearly show the effects of pre-depositional strain. The mica is a clear muscovite, commonly altered to small sheets of iron-stained clay minerals. The matrix consists largely of an unresolvable argillaceous aggregate, but containing numerous sheets of a clear, colourless, very weakly birefringent, micaceous clay mineral. The dimensions of such sheets commonly exceed the diameter of clastic grains. Fairly intense limonite staining occurs in irregular patches, so that the rock contains numerous, red-brown limonitic clots. These have probably formed as a result of weathering processes at or near the surface.

Spec.W.B.161. (31 feet above the base of the formation)

Thinly Interbedded Quartz Greywacke and Sandy Greywacke Siltstone.

(Same locality as W.B.160).

In hand-specimen this is a pale grey, lightly iron-stained, thinly bedded sediment made up of alternating irregular, thin bands of sand and silt. The thickness of different bands vary considerably, but they seldom exceed 1 cm. The sandy bands vary from fine-grained to coarse-grained, some containing sand grains up to 2 mm. across, and some sand-bands expand into pockets of quite coarse sand grains, individual pockets being up to 2 cm.across. The rock is soft, but coherent, and while the sandy bands are highly permeable, the silt bands are only slightly so.

In thin-section it is apparent that the sandy bands are of quartz greywacke, while the silty bands are of slightly sandy greywacke siltstone. The quartz greywacke is a poorly sorted, medium-grained sandy sediment with an average grainsize of 0.15mm. Grain diameters range from 0.04 mm up to 1.1mm in thin-section, but larger grains are found in the hand specimen. It consists of angular grains of quartz (50%), flakes of mica (5%) and accessory tourmaline, zircon, leucoxene and hematite, in a fine argillaceous matrix (44%). Many of the quartz grains are strained, and some contain inclusions of tourmaline, semi-opaque dust, and tiny fluid bubbles. The matrix is of very pale brownish argillaceous material, commonly containing sheets of an almost uniaxial, optically negative clay mineral, and fine flakes of sericite.

The siltstone bands are of very finely divided argillaceous and sericitic matter carrying about 20% of small angular, silt-sized quartz grains, a few sand grains, pockets or greywacke, a few sheets of muscovite. This part of the rock shows a moderate degree of mass polarisation due to a sub-parallel orientation of the micaceous constituents.

The junction between the sand and silt phases is fairly sharp, there being little indication of any degree of graded-bedding. The bedding of both phases is somewhat lenticular.

Spec. W.B. 162. (45 feet above the base of the formation)

Medium to Coarse-Grained Quartz Greywacke.

(Point 279, Photo 5122, Run 9, Glenburg, W.A.; Glenburg 4-mile 391, 821.)

In hand-specimen this is a rather coarse-grained, light brown sandy sediment becoming deeper brown on exposed surfaces. Individual sand grains are seen to reach up to 3mm across, but most are nearer to 1 mm. Bedding is not apparent in the specimen provided.

The rock is hard, coherent, and only slightly permeable. Despite the low permeability, porosity appears to be fairly high. Hand-lens examination shows that the sand grains are mainly white, while the matrix is a pale reddish-brown. Dark tourmaline grains are conspicuous, but few in number.

In thin-section it is seen that the rock is a medium to coarse-grained sandy sediment made up of angular to sub-rounded clastic grains averaging 1.0mm. across, and ranging between 0.1mm and 2.6mm. Most fall between 0.6mm and 1.6mm across. Bedding is not apparent in thinsection and the detrital components are moderately poorly sorted.

The rock consists mainly (77%) of quartz sand grains of various types, about 2% of grains of fine-grained quartzite and fine phyllite, and accessory tourmaline and magnetite, in a matrix (20%) of brown argillaceous matter and shredded muscovite.

The quartzose grains are individual angular chips, and grains consisting of a "welded", sutured aggregate of quartz anhedra resembling a medium grained quartzite. Both contain inclusions of biotite, tourmaline and possible epidote. Narrow streams of semi-opaque inclusions are also common, while strongly undulose extinction is indicative of strain in nearly all grains. The phyllite is a very fine-grained (0.025) pelitic rock consisting of quartz, sericite and unidentified components with a semi-schistose fabric.

The matrix is of brown, limonite-stained clay, in part isotropic but also containing abundant sheets of very weakly birefringent clay mineral. The matrix also includes perhaps 3% of finely shredded muscovite, in many cases tending to alter to an iron-stained clay mineral.

Spec.W.B.163. (55 feet above the base of the formation)

Fine Quartz Greywacke.

(Same locality as W.B.162)

In hand-specimen this is a fine-grained, thinly bedded, pale brownish-white sandy sediment with distinct small-scale cross-bedding emphasised by differential iron-staining along the foreset bedding planes. The rock is moderately soft, coherent, and fairly permeable.

In thin-section it is seen that the rock is a fine to very fine-grained quartz greywacke having an average grain-size of 0.1mm. Sorting is good, and there is quite a marked degree of grain orientation, since many of the grains are somewhat elongated in outline and usually lie with their longer axes in sub-parallel alignment with the bedding. All detrital grains are angular in outline.

The rock consists of detrital grains of quartz (40%), flakes of muscovite (2%), aggregate of leucoxene (1%), and accessory quantities of pale blue tourmaline, hematite (often with leucoxene), (?)sphene and (?)rutile, in an argillaceous matrix. The quartz grains generally contain a few indeterminable semi-opaque inclusions Some are slightly strained, and many consist of compound aggregates of several sutured grains, rather like fragments of a fine-grained meta-quartzite. Mica sheets are commonly bent and/or shredded, but some are undamaged. The mica is a normal muscovite, in part-tending to alter to an iron-stained clayey material.

The matrix (57%) is almost entirely argillaceous, in places limonite-stained. Only a very small quantity of sericitic material is present. The clay of the matrix is mostly very finely divided and more or less colourless. There are, however, some large sheets of clay mineral (some of which appears to be kaolinite). Some of this more coarsely crystalline material may have formed by re-crystallisation of the argillaceous matrix, but other very distinctly bounded sheets probably represent altered original mica.

Spec.W.B. 164. (134 feet above the base of the formation).

Sandy Quartz Greywacke Siltstone.

(Point 280, Photo 5122, Run 9, Glenburg, W.A.; Glemburg 4-mile 390,822)

In hand-specimen is a very fine, pale brownish grey sediment of siltstone type containing a few macroscopically visible sand grains up to 2 mm axross. Bedding is very indistinct in the specimen provided, and the rock is fairly soft and friable. Permeability is not very great.

In thin-section it is apparent that the rock is a slightly sandy quartz greywacke siltstone consisting of about 20% quartz silt grains (0.04mm. average diameter) and 20% silt-sized mica flakes in a fine, argillaceous matrix of (55%). The thin-section contains about 4% of variously sized sand grains . Accessory minerals include tiny grains of magnetite, leucoxene, tourmaline, zircon and possible (?)apatite. One large (0.9mm) grain of microcline was detected.

The silt fraction of the rock is moderately well sorted. The sand fraction, however, varies from very fine sand (0.1mm diameter) to coarse sand (1.5mm diameter). Such sand grains are all of angular outline and are commonly strained.

CURBUR FORMATION

Specimen W.B. 282 (Base of the Curbur Formation)

Quartz Greywacke Conglomerate.

(Point 923, Photo 5086, Run 4, Byro, W.A.; Byro 4-mile 395, 740)

In hand-specimen this is seen to be a strongly conglomeratic sediment of pale brown colour, moderate permeability and fair coherence. Pebble-size is highly variable, ranging from 1.mm to 2 cm. in hand-specimen.

In thin section it is seen that the rock consists of sub-rounded to rounded pebbles of fine quartz-greywacke, greywacke siltstone, chert, quartzite and quartz with a cement of brown, chloritic-argillaceous material containing numerous rounded and angular quartz sand grains.

The quartz greywacke pebbles are similar to many such rocks already described, in that they consist of small (0.02 to 0.4 mm) angular grains of quartz and quartzite (45%), in a very fine, argillaceous matrix (55%) containing areas of a finely fibrous clay mineral with a strong negative relief. These are by far the most abundant pebbles.

Less common greywacke siltstone pebbles consist of few quartz grains (0.02mm) in a laminated base of sericitic and argillaceous material. The quartz and quartzite show evidence of considerable strain, but it is qite obvious that such strain-features were produced in the quartz in its source environment, and not after deposition.

The cementing matter of the conglomerate consists of turbid, mesh-textured, brown chloritic clay containing angular to rounded quartz grains ranging from 0.02 to 1.4 mm across.

It is quite apparent that this sediment has suffered no post-depositional deformation. Some quartz grains are highly strained, but this is a pre-depositional feature. All mineral grains are embedded in a relatively soft argillaceous or chloritic-argillaceous matrix which would yield to deformational forces long before the harder mineral grains. It is also of such a nature that any deformational processes would be very readily recorded in its structure.

The rock is essentially a conglomerate; it could, perhaps, be an uncommonly well-rounded sedimentary breccia, but never a tectonic breccia or fault gouge. Any possibility of its being of tectonic origin is precluded in that a rock of such a composition and texture would most certainly exhibit unmistakable evidence of distortion, especially in the matrix.

PINDILYA FORMATION

Spec.W.B.7c. (Base of the formation)

Laminated Silty Claystone.

(Point 13, Photo 5076, Run 14, Glenburg W.A; Wooramel 4-mile 342,786

The hand-specimen is a very fine, smooth, white rock containing perfectly planar and very thin, red limonitic bands parallel to the bedding. On fresh surfaces the rock is decidedly unctuous and possesses the peculiar property of changing from an almost pure white to a distinctly pink colour when wet. The fracture is smooth and conchoidal, but the rock is easily distinguished from a white chert by its relative softness.

In thin-section it is seen that the rock is, on the whole, very fine-grained (less than 0.001 mm). Thus, the main body of the rock is so fine that it is not possible to directly determine its composition. Its all-over refractive index is higher than that of canada balsam and much the same as that of quartz. In addition, this fine material exhibits a marked aggregate polarisation, so that the whole section appears to extinguish in two planes, one parallel to the bedding and another normal thereto. It is therefore apparent tha the clay particles are definitely oriented and probably flaky or fibrous.

There is, altogether, about 3% of coarser (silty) material mixed with the clay. This consists mainly of angular grains of quart averaging 0.02mm across, flakes of sericite about 0.01 mm long, sheet of unidentified clay mineral up to 0.05 mm across, and semi-opaque, indeterminable dust.

The thin, red bands seen in the hand-specimen consist of angular chips of quartz, altered mica, sheets of clay mineral, and abundant dusty, hydrated iron oxides (to which the colour is due) set in a clay matrix. Such bands seldom exceed 0.3mm in width, though the iron-stain may extend for a greater distance. Individual bands have the composition of a quartz greywacke siltstone.

Spec.W.B.8a (Near the base of the formation).

Fine Quartz Greywacke.

(Point 14, Photo 5076, Run 14, Glenburg W.A.; Wooramel 4 mile 342,785

The hand-specimen is a fine-grained, white, soft, permeable sediment looking more like a silt or claystone than a fine sandstone, and there is no apparent bedding in hand-specimen. On wetting and drying the specimen exhibits numerous contraction cracks.

In thin-section it is seen that the rock consists of detrital grains of quartz (40%), mica (2%), colourless chlorite (1%) and/or a platy clay mineral (both of which probably represent highly altered mica), and aggregates of cryptocrystalline silica (2%), all embedded in a very fine, argillaceous matrix (54%). Accessory minerals includ small grains of magnetite, hematite, zircon, very rare tourmaline and a little apatite, rutile and sphene. The accessories together total no more than 1%.

Grainsize is variable from 0.6mm to less than 0.02mm, but despite this range the sorting is only moderately poor since most detrital grains fall between 0.2mm and 0.1mm in diameter. Grain rounding is poor and there is no indication of secondary enlargement.

The quartz grains grade down in size into the matrix which is thus both siliceous and argillaceous. In many places the argillaceous material appears to have recrystallised into patches of an almost pure, flaky clay mineral. In other parts there are rare aggregates finely fibrous, radiated, partly spherulitic and foliated (?) sericitic material of probable authigenic origin.

Spec. W.B.8b (Near the base of the formation).

(Same locality as W.B.8a)

Fine sandy claystone.

The hand-specimen is very fine, white, structurless rock with conchoidal fracture and a moderately unctuous feel. Irregular iron-staining is common, but not of notable intensity. The rock is only weakly porous and almost impervious to water. There is no indication of bedding in the hand-specimen provided.

In thin section the true character of the rock becomes readily apparent. It is a fine, weakly oriented claystone, approaching shale texture, and carrying about 10% of poorly-sorted, fine sand. Bedding is well indicated by the oriented polarisation of the dominant argillaceous material of the rock, and by a sub-parallel disposition of numerous, fine sericite flakes.

The fine sand fraction consists of angular grains of quartz and quartzite averaging about 0.08mm across, but ranging from 0.4 down to less than 0.01. The quartz is generally clear of inclusions, but is commonly moderately strained. Other detrital constituents include ragged sheets of muscovite up to 0.1mm long, and accessory grains of zircon and (?) hematitic iron oxides. Opaque minerals include tiny cubes of pyrite and aggregates of leucoxenic material.

The matrix is largely of closely felted, slightly oriented, flaky argillaceous material, chlorite (?), sericite, and dusty opaque grains. Rare crystals of zircon and blue tourmaline have been detected. One 0.1mm wedge-shaped crystal of kyanite was found in the section.

Spec. W.B.20. (Exposed top of the formation).

Chloritic Quartz Greywacke.

(Point 207, Photo 5052, Run 14, Glenburg, W.A.; Glenburg 4-mile 346, 783)

A fine-grained, brown and white, sandy sediment with distinct though somewhat irregular and discontinuous banding, probably representing bedding, but now emphasised by differential brown iron oxide concentration. On surfaces parallel to the bedding planes the rock shows the distinctive lustre of finely divided white micaceous matter. The rock is moderately hardened, slightly friable and quite permeable.

In thin-section it is apparent that the rock consists largely of quartz (60%), sheets of chlorite (15%) and muscovite (1%), and grains of various accessory minerals (2%) in a very fine, argillaceous matrix (22%).

The detrital grains are well sorted, having an average grain diameter of 0.1mm with a rare maximum of 0.3mm and a few smaller grains going down to 0.03mm. All grains are distinctly angular and there is no evidence of secondary enlargement.

Quartz grains are generally clear, but commonly contain minute, semi-opaque inclusions of (?) spinel. There is little indication of strain in the quartz. In outline, the grains are highly angular and about 25% of them have the form of elongated chips, many of which lie with their longer axes more or less parallel to the bedding. A common, though by no means universal feature of the quartz is its indefinite junction with the surrounding matrix. Many grains, however, have quite sharp outlines.

Ragged and bent sheets of a weakly birefringent, colourless chlorite are conspicuous in thin-section. They are of variables dimensions, but the larger and more conspicuous sheets average 0.2 to 0.3mm across, while the smaller ones grade into the matrix, from which they are indistinguishable. This chlorite is particularly abundant in certain laminae, where it may even exceed quartz in quantity. It is this micaceous chlorite which is observed in hand-specimen, and it is thought to have formed by the alteration of original detrital mica.

Actual detrital muscovite is rare, but where found as thin elongated, often bent flakes it is quite unaltered, so that it seems unlikely that the chlorite described above was derived from this variety of mica. Lamellar aggregates of limonitic material probably represent original biotite.

The accessory detrital minerals include small grains of limonitic material, iron-stained leucoxene, rare magnetite, brown and blue tourmaline, zircon and (?) apatite and zircon.

The abundant matrix is very finely divided and, therefore, difficult to resolve satisfactorily. However, as far as can be determined, it appears to consist mainly of very fine, colourless chloritic material similar to that described above, indeterminate clay minerals, and a little sericite, quartz and limonite.

NADARRA FORMATION.

Spec.W.B.253

Slightly Sandy Fine-grained Limestone.

(Point 759, Photo 5052, Run 6, Glenburg, W.A.; Glenburg 4-mile 365,848.

In hand-specimen this is a pale brownish-grey, aphanitic limestone with a deeply solution-pitted surface. Bedding is indistinct, but appears to be represented by discontinuous, brownish clay bands. Acid treatment of a smooth surface results in differential etching so that the clayey parts of the rock stand out in positive relief.

Thin section examination shows that the rock is a very fine-grained limestone containing sparsely distributed (1%) quartz sand grains, patches and pockets of a colourless weakly birefringent clay mineral, and being cut by veins of more coarsely crystalline carbonate, commonly with an argillaceous central filling.

Acid tests show that the carbonate is dominantly calcite, but surface etching with dilute hydrochloric acid shows that some of the more coarsely crystalline carbonate may be dolomitic.

Under the microscope, the main body of the rock is a very finely divided calcareous paste. The coarser carbonate crystals mentioned above range from 0.04mm to 0.2mm across, while the "floated" sand grains range from 0.03mm to 0.3mm across and are fairly well rounded.