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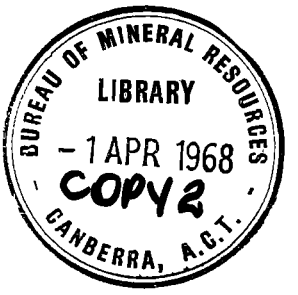

RECORDS:

RECORD NO. 1968/23

A Petrographic Study of Field Samples from the Otway Region and Barrabool Hills, Victoria

by

P.J. HAWKINS

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ABSTRACT

Samples were collected from type localities during an ANZAAS field excursion to the Otway Region; a number of these samples were selected for detailed petrographic study. Two additional samples were studied from the Barrabool Hills area. The objectives behind this investigation were to determine the mineralogy of these sediments and attempt to relate them to the subsurface sediments recognized from a recent B.M.R. study. Results showed that similarities in framework and mineralogy did exist between surface and subsurface sediments of the Otway Group, Eastern View Coal Measures and Pebble Point Formation. In the upper Tertiary however, correlations between the surface and subsurface units are very tentative.

INTRODUCTION

This independent investigation was prompted first by the general lack of published petrological data of type sections in the Otway Region, and secondly, by the author's interest in this area as a result of his recent petrological studies of the subsurface stratigraphy of the Otway Basin. In January 1967 during an ANZAAS field excursion led by O.P. Singleton the opportunity was taken to collect samples from well known type localities in the Otway Region.

A macroscopic examination was carried out on all the samples collected. In addition, detailed thin section studies of selected samples were undertaken. The objectives behind the petrographic study were: to determine the mineralogy of the sediments and the framework of the sandstone; and to compare as far as possible the mineralogy of these sediments with those observed in the subsurface study of the Otway Basin.

DISCUSSION OF PETROGRAPHIC RESULTS

The petrography of these sediments in discussed under their respective formations, commencing with the oldest. General remarks about the location (see Figure 1) and description of the lithology will be made; detailed petrographic descriptions of the samples will be found in Appendix I and Table I. Ages referred to in the text, Appendix I and Table I have been taken from Table I in Excursion Notes, Otway Region, by Singleton (1967).

I Lower Cretaceous Sediments

Otway Group
(equated with Eumeralla Formation)*

These sediments, first referred to as the Otway Group by Medwell (1954a) and later by Leslie (1966), are well exposed in coastal sections along the south eastern flank of the Otway ranges; in the Barrabool Hills area the sediments are referred to as the Barrabool Sandstone by Medwell (1954a). Monoclinal flexures in this sequence were observed at Castle Cove and Skene's Creek. An unconformable relationship can be seen in a coastal section south east of Princetown; here the Otway Group is overlain with a small angular discordance by grits of the Pebble Point Formation. The unconformity comprises a flat surface suggesting planation of the Otway Group sediments prior to deposition of the Pebble Point Formation.

General Lithology

This sequence consists of massive fine-grained lithic sandstone and mudstone which often grade into one another.

The sandstone studied - chiefly of the subgreywacke type - is greenish grey, angular, very fine to fine-grained and moderately sorted. Important compositional characteristics are: low quartz content; abundant (30%) oligoclase and andesine; abundant (45%) lithics of siliceous aphanitic fragments, chloritic fragments, volcanic flow rock fragments and low grade metamorphic fragments. Chloritic clay matrix and diagenetic siderite cement occur. Other minerals present include muscovite, rare garnet and penninite. Alteration and welding of rock fragments is common.

*Name proposed by B.M.R. 1966.

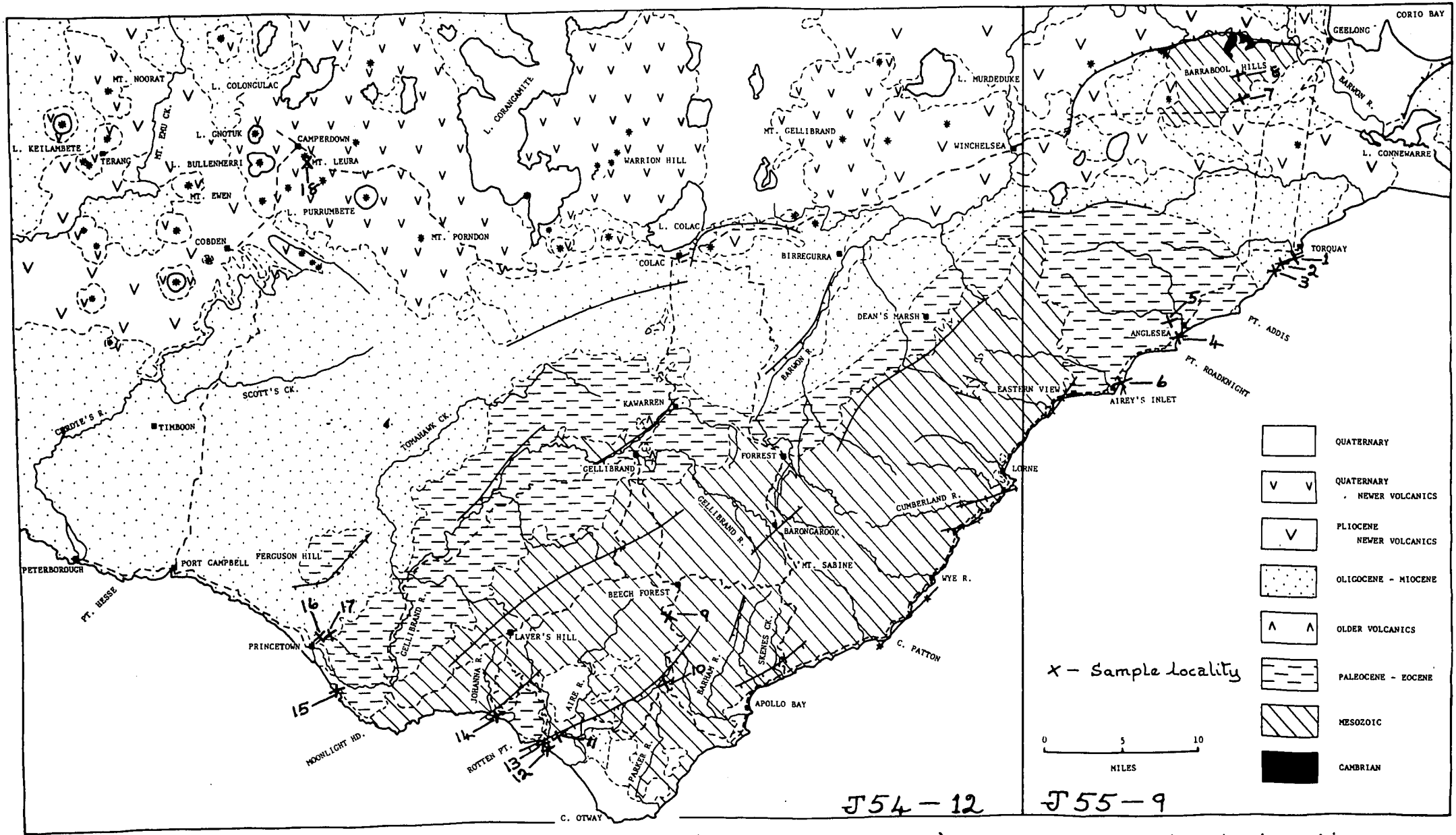

Figure 1. Surface Geology of Otway Region (after Singleton 1967) and approximate Sample Locations.

Fracturing is evident in the sandstone particularly near monoclinal flexures and is sometimes accompanied by calcite. Numerous "cannon ball" concretions (up to 12" in diameter) of calcite and siderite were observed in the sandstone. At Castle Cove the sandstone exhibits ripple marks and thin dark clay laminations; some of the laminations show imbricate structures due to microfaulting. Carbonaceous clay lenses and thin coal seams are present in these sediments.

The mudstone consists mainly of chloritic clay with disseminated carbonaceous matter, and silt-size grains of quartz and minor plagioclase feldspar. Carbonized plant fragments are common.

Observations of the framework and mineralogy of surface sandstone samples examined, suggest that it is identifiable with sandstone observed during the subsurface studies. From a comparison with other wells studied in the Otway Basin it was noted that in Fergusons Hill No. 1 and Anglesea No. 1 there was an increase in the amount of siderite present in these sediments; this is supported by surface evidence. The chloritic nature of this sequence was also observed during subsurface studies.

II Tertiary Sediments

Pebble Point Formation

This formation, first referred to as the Pebble Point Formation by Baker (1953), is well exposed in a coastal section between Princetown and Moonlight Head and, in particular, at Pebble Point which is the type locality. These sediments rest with slight angular discordance upon the Otway Group. In outcrop the Pebble Point Formation appears to be conglomeratic only at the base, becoming finer-grained towards the top.

General Lithology

Dark brown, friable and hard pebbly sandstone occurs at the base; this grades into a finer-grained clayey sandstone above.

The sandstone studied is dark brown, angular to rounded, bimodal, very fine to granule size with pebbles (4-7 mm. in diameter) and poorly sorted. Important mineralogical characteristics are: abundant (50%) undulose and composite quartz; rare untwinned feldspar; minor metaquartzite and chalcedony fragments; green chamosite pellets and ooliths and iron oxide pellets. In the friable sandstone, chloritic and illitic clay matrix predominates. The hard sandstone contains abundant siderite with iron oxide aggregates and minor calcite cement. The pellets are often obliterated due to recrystallization of the siderite.

The mineralogy of this sandstone is similar to that observed in Unit Dd during subsurface studies. Chamosite pellets and ooliths together with siderite and chloritic clay are characteristic features of both the surface and subsurface sandstone examined.

Eastern View Coal Measures
(equated with Curdies Formation)*

These sediments, defined as the Eastern View Coal Measures by Raggatt and Crespin (1952), are well exposed to the north east of the Otway Ranges, and at Eastern View, where they rest with a slight angular unconformity on the

* Name proposed by B.M.R. 1966.

Otway sediments. At the opencast Anglesea Brown Coal Mine a thick coal sequence is exposed.

General Lithology

The sequence examined consists of a thick lenticular brown coal seam overlain by clays and sands. Coal seams also occur near the top of the sand section. The coal is dark brown, dull, earthy, with an uneven fracture, and containing up to 40% moisture. Rare limonite pellets are present, and plant remains were observed.

A greater development of coal exists in this part of the basin than further westwards; this was observed during subsurface studies. Similar coal to that observed at the surface was recognized in Anglesea No. 1 well (Dellenbach 1965b).

Brown's Creek Clay

This sequence, referred to as the Brown's Creek Clay by Thomas (1957), can be seen at the Johanna River coastal section, Castle Cove and Hamilton Creek road cutting. The sediments occur to the south east of the Johanna monocline and on the downthrow side of the Castle Cove fault.

General Lithology

The Brown's Creek Clay consists of sandy, glauconitic clay, buff calcarenite and brown fossiliferous clay.

The glauconitic clay observed at the Johanna River coastal section comprises 60% glauconite with finely dispersed calcite; limonitic pellets and ooliths constitute about 30% of the rock; detrital quartz grains are rare; fragments of bryozoa, foraminifera, molluscs, and echinoid debris are present.

The buff sandy clay at Castle Cove has the texture of a calcarenite; it contains abundant fine-grained fossil debris of molluscs, echinoid spines and foraminifera; very fine-grained green glauconite pellets, together with some quartz grains are also present.

The light brown fossiliferous clay at Hamilton Creek road cutting consists of clay with finely dispersed carbonate and scattered quartz grains. Fragments of foraminifera, echinoids and molluscs are present.

A lithological comparison can be made between the glauconitic clay at Johanna River and the glauconite rock observed by Dellenbach (1965a) and designated subunit Bc, in Geltwood Beach No. 1 well. The mineralogy is similar in both the surface and subsurface samples. The sandy clay and fossiliferous clay studied have similar characteristics to sediments recorded as subunit Bc_2 from well studies in the Pt. Campbell area.

Castle Cove Limestone

This limestone sequence, referred to as the Castle Cove Limestone by Carter (1958b), is poorly exposed at the Johanna River mouth; at Castle Cove the junction between the limestone and the underlying Brown's Creek Clay is transitional.

General Lithology

The sequence consists of alternating beds of gritty limestone and soft gritty marls.

The sandy limestone is light brown, compact and contains polished and ironstained quartz grains; abundant dark brown limonite pellets are also present; recrystallized calcite, dolomite and ? siderite occur. Abundant fragments of mollusc and bryozoa were observed.

The mineralogy shows some resemblance to that observed in limonitic sandstones referred to as subunit Bc_2 and penetrated by wells in the Port Campbell area.

Angahook Member

This sequence was first defined as the Angahook Member by Raggatt and Crespin (1952), and referred to as the Angahook Formation by Singleton (1967). Good exposures of this succession can be seen at Soapy Rocks, Anglesea, and at Airey's Inlet. At the former locality, coarse-grained pebbly sandstone and clays occur which rest conformably on the Anglesea Sand.

General Lithology

The sandstone is brown, subangular to rounded, bimodal, medium to very coarse-grained and granule to pebble size, and moderately sorted. Important components are: undulose quartz; metaquartzite and quartzite; limonite pellets and rare chlorite grains. Ferriferous chlorite may occur as coatings around grains or as a matrix. Cross-bedding and slumping are present in the sandstone.

At Airey's Inlet a light brown soft bentonitic clay occurs; the brown coloration appears to be due to disseminated iron oxide. Thin dark brown ironstained lenses and laminations are present.

The composition of the sandstone is similar to that observed in the subsurface and called subunit Bc_2 in the Port Campbell area. The lithology shows similarities to the Mepunga Formation (Bock and Glenie 1965).

Clifton Formation

This formation, first defined as the Clifton Formation by Baker (1953), is exposed at Princetown where it rests unconformably on the Dilwyn Clay; however this contact was not observed. According to Taylor (in Singleton 1967) this unconformity, in the subsurface, diminishes westward and disappears at Peterborough.

General Lithology

At Princetown three lithological units can be recognized: Limonitic sandstone at the base; a limonitic and phosphatic conglomerate - 1' thick; and a fossiliferous limestone.

The limonitic sandstone is light brown, angular to rounded, very fine to very coarse-grained and poorly sorted. Important mineral constituents are: undulose quartz and quartzite; abundant limonite pellets and ooliths; and bioclasts of bryozoa, echinoid spines and foraminifera. Finely recrystallized calcite cement predominates.

The conglomeratic section consists of dark brown, subangular to rounded, fine to very coarse-grained, poorly sorted limonitic calcarenite with brown pebbles. Important mineral components are: undulose quartz; relicts of pellets and ooliths; bioclasts of echinoids and bryozoa. The cement is limonite. A phosphate test carried out on the brown limonite cement was negative.

The fossiliferous limestone is medium brown, and contains abundant fossil fragments of bryozoa, foraminifera and echinoids; rare quartz grains are present. Dark brown limonitic pellets and patches also occur. Recrystallization of calcite has taken place, obliterating most of the fossil fragments.

The mineralogy of the limonitic sandstone is comparable to the limonitic sandstone facies observed in the subsurface and called subunit Bc_2; this sandstone also exhibits similar characteristics to the Castle Cove Limestone. The limonitic calcarenite and fossiliferous limestone can be more closely related to subunit Bc_1 recognised in wells. In the subsurface studies subunit Bc_1 has been equated with the Clifton Formation.

Calder River Limestone

This sequence, referred to as the Calder River Limestone by Carter (1958b), is exposed at Spud Point where a calcarenite rests on a phosphatic bed beneath. This phosphatic bed appears to be similar to the one observed in the Clifton Formation at Princetown. Singleton (1967) considers an unconformity to be present at the base of the Calder River Limestone.

General Lithology

At Spud Point two different lithologies can be seen: a thin (1' thick) basal bed containing phosphatic nodules and scattered quartz pebbles; and a calcarenite above.

The calcarenite is medium brown, subangular to subrounded, medium to very coarse-grained and poorly sorted. Important mineral constituents are: abundant (50%) bioclasts of bryozoa and foraminifera; brown limonite pellets and limonitic rock fragments; minor quartz. Recrystallization of the fossil fragments has taken place. This rock possesses a high porosity (20%).

The lithology and mineralogy of this sequence are similar to that of the Clifton Formation observed at Princetown, and show a close association with subunit Bc_1 sediments recognized in the subsurface.

Waurn Ponds Limestone

Exposures of this sequence, referred to as the Waurn Ponds Limestone by Spencer-Jones (1967), are to be found in the valley of Waurn Ponds Creek, where it rests unconformably on the Lower Cretaceous Barrabool Sandstone. The limestone is also exposed in a monoclinal structure with an east-north-east trend, $\frac{1}{2}$ mile north of Waurn Ponds.

General Lithology

The succession consists of fossiliferous limestone, marl and clay.

The sample studied is a medium brown, speckled, subangular to subrounded, very fine to very coarse-grained, poorly sorted calcarenite. Important mineral components are: abundant (50%) bioclasts of bryozoa, molluscs, and rare foraminifera; brown limonite pellets; minor quartz. Calcite is the most important cementing medium. Limonite staining is evident throughout the rock.

In terms of framework and mineralogy this calcarenite is similar to the fossiliferous limestone and calcarenite observed in the Clifton Formation and Calder River Limestone, respectively.

Jan Juc Formation

This sequence, defined as the Jan Juc Formation by Raggatt and Crespin (1955), is referred to as the Jan Juc Marl by Singleton (1967). The succession is well exposed in the coastal section between Rocky Point and Fisherman's Steps, Torquay, where the Point Addis Limestone passes laterally into the Jan Juc Marl (Singleton 1967).

General Lithology

The typical section consists of clay and marl containing comminuted autochthonous fossils, and thinly bedded calcarenite. Shelly glauconitic marl occurs which has been extensively burrowed; the glauconite may be present as pellets or as a replacement in the burrows. Thin (3" thick) hard sideritic bands also occur in the marl section.

The calcarenite is medium brown, friable, subrounded, medium to coarse-grained and moderately sorted. Important constituents include: bioclasts of foraminifera, echinoid fragments, bryozoa and molluscs; abundant green glauconite pellets, some of which show varying degrees of limonitization. Much of the calcareous matrix is stained with limonite.

The framework and mineralogy of this calcarenite are similar to sediments designated as Bc_1 from subsurface studies in the Port Campbell area.

Puebla Formation

The name Puebla Formation was originally proposed and defined by Raggatt and Crespin (1952 and 1955) to include the clay unit and succeeding units of differing lithologies. However Singleton (1967) prefers to use the term Puebla Clay in a restricted sense to include only the clay unit in the sequence. The Puebla Clay is exposed in the upper part of a cliff section between Bird Rock and Fisherman's Steps. This sequence rests conformably on the Jan Juc Formation.

General Lithology

The succession consists of grey clay with thin bands of cemented concretionary limestone. A limestone nodule examined was finely crystalline with silt-size pellets and pyrite clusters. Fragments of molluscs, echinoids and bryozoa were observed.

The lithology of this sequence shows close affinities to the marl observed in the subsurface in the Port Campbell area and referred to as Unit Bb.

Zeally Limestone Member

This calcareous sequence was first referred to as the Zeally Limestone Member by Raggatt and Crespin (1955). Singleton (1967) prefers to use the term Zeally Limestone in a restricted sense, to include only the calcarenite unit which crops out at Jan Juc Point, Torquay, and at Point Danger. It rests conformably on the Cellepora Beds.

General Lithology

The calcarenite is buff, compact, subangular to subrounded, medium to coarse-grained and well sorted. Important constituents are: abundant bioclasts of foraminifera, and calcite grains; rare scattered quartz grains.

This lithology can be closely related to the carbonate sequence (Unit Bb) recognized in the subsurface almost throughout the basin.

Newer Volcanics

The Western District plains are covered with Pliocene to Recent olivine basalt flows. The physiography of the volcanoes and lava field has been described by Ollier and Joyce (1964). The pyroclastics are largely restricted to the volcanic cones. The volcanoes include lava cones, scoria cones and maars. In the Camperdown district the pyroclastics contain ejected blocks and shaped volcanic bombs; these bombs frequently contain olivine diopside cores.

CONCLUSIONS

Observations suggest that some comparisons may be made between those surface sediments investigated in this study and those examined during the Otway Basin Review; however such comparisons are based purely on lithological and mineralogical characteristics.

The Otway Group sediments, particularly the sandstones, can be related to sediments observed in Fergusons Hill No. 1 and Anglesea No. 1, on the basis of similarities in framework and mineralogy. The Eastern View Coal Measures sequence observed at the surface can be compared with sediments exhibiting similar lithological characteristics in Anglesea No. 1. On the basis of framework and mineralogy the Pebble Point Formation could be identified with sediments recognized during subsurface studies.

The upper Tertiary sediments, however, present many more problems; although some samples examined, showed certain mineralogical features which had been recognized in the subsurface, the evidence was such that only tentative comparisons could be made. It is apparent that more detailed petrological studies of these surface sediments are required in order to assess more clearly their stratigraphic relationships.

If any attempt is to be made to reconstruct the depositional history of this area of the Otway Basin then it is vital that systematic and detailed petrological studies of surface type sections be undertaken in conjunction with palaeontological studies; only after this has been achieved can a satisfactory comparative study of the surface and subsurface stratigraphy be carried out.

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TABLE I

List of Field Samples from Otway Region and Barrabool Hills

Sample Reference Map	Sample Reference Sample No	Location	Lithology	Nomenclature	Age	Thin Section
J.54 -	12/18	Mt. Leura Quarry	Olivine core	Newer Volcanics	Pliocene-Recent	
J.55 -	9/1	Jan Juc Point	Calcarenite	Zeally Ls Mbr.	L Miocene	
J.55 -	9/3	Bird Rock	Clay & Ls	Puebla Fm.	L Miocene	
J.55 -	9/2	Bird Rock	Gl. Calcaren.	Jan Juc Fm.	U Oligocene	
J.55 -	9/7	Waurn Ponds	Calcarenite	Waurn Ponds Ls.	Oligocene	1
J.54 -	12/11	Spud Point	Calcarenite	Calder River Ls	U Oligocene	1
J.54 -	12/17	Princetown	Limestone	Clifton Fm.	Oligocene	1
J.54 -	12/16a	Princetown	Lmn. Calcaren.	Clifton Fm.	Oligocene	1
J.54 -	12/16b	Princetown	Lmn. Ss.	Clifton Fm.	Oligocene	1
J.55 -	9/6	Airey's Inlet	Clay	Angahook Mbr.	L Oligocene	
J.55 -	9/4	Soapy Rocks	Pebbly Ss.	Angahook Mbr.	L Oligocene	1
J.54 -	12/12	Castle Cove	Lmn. Calcaren.	Castle Cove Ls.	U. Eocene	
J.54 -	12/10	Hamilton Creek Road cutting	Fos. Clay	Brown's Creek Clay	U Eocene	
J.54 -	12/13	Castle Cove	Fos. Clay	Brown's Ck Clay	U Eocene	
J.54 -	12/14	Johanna River	Gl. Rock	Brown's Ck Clay	U Eocene	1
J.55 -	9/5	Anglesea Coal Mine	Brown Coal	Eastern View C.M.	M Pal-?U Eoc.	
J.54 -	12/15	S.E. of Princetown	Pebbly Ss.	Pebble Pt. Fm.	M Palaeocene	3
J.55 -	9/8	Barrabool Hills Rd.	Lithic Ss.	Barrabool Ss.	L Cretaceous	2
J.54 -	12/9a	Beech Forest	Mudstone	Otway Group	L Cretaceous	1
J.54 -	12/9b	Beech Forest	Lithic Ss.	Otway Group	L Cretaceous	1

APPENDIX I.

Detailed Petrography of Field Samples from Otway Region and Barrabool Hills

Lower Cretaceous

OTWAY GROUP

Sample No.: J54 - 12/9b.

Locality: Beech Forest, Otway Ranges.

Age: Lower Cretaceous.

Macroscopic petrography:

Lithic Sandstone: light grey, compact, angular, very fine-grained and moderately sorted. Dark rock fragments are abundant. Little or no carbonate cement; clay matrix of possibly kaolinite and chlorite. Pyrite occurs as aggregates and individual cubes. Thin dark carbonaceous laminations are present. A phosphate test carried out on the sample yielded a low precipitate. The sandstone breaks with a flat fracture. Porosity is poor.

Thin section petrography:

Lithic Sandstone (Subgreywacke): Grey, angular to subangular, very fine to fine-grained (0.06 - 0.15 mm., main mode - 0.09 mm.), and moderately sorted. Quartz (10%), oligoclase, andesine, and graphic intergrowths of quartz and feldspar (30%); abundant lithics - low grade metamorphic fragments, siliceous aphanitic fragments, chloritic fragments and volcanic flow rock fragments - (45%). Chloritic clay matrix, spots and patches of diagenetic siderite (15%). Minor muscovite, rare garnet and penninite. Many of the lithic grains are coated with chlorite. Much welding of the lithic grains. Spots and lenses of carbonaceous matter. Porosity is slight.

Sample No: J.54 - 12/9a.

Locality: Beech Forest, Otway Ranges.

Age: Lower Cretaceous.

Macroscopic petrography:

Mudstone: Dark grey, dense. Abundant carbonized plant fragments are present.

Thin section petrography:

Mudstone: Grey, with angular to subangular silt-size quartz and minor plagioclase feldspar. Sericite flakes present. Chloritic clay with finely disseminated carbonaceous matter.

BARRABOOL SANDSTONE

Sample No: J.55 - 9/8

Locality: Barrabool Hills Rd., $\frac{3}{4}$ mile west of Ceres.

Age: Lower Cretaceous.

Macroscopic petrography:

Lithic Sandstone: Medium greenish-grey, compact, angular, very fine-grained and moderately sorted. Dark coloured lithics are abundant. Pink coloured spots present - probably decomposed feldspar. No carbonate cement visible; greenish chloritic matrix. Dark carbonaceous clay patches and coaly fragments.

Thin section petrography:

Lithic Sandstone (Subgreywacke): Greenish grey, angular to subangular, very fine to medium-grained (0.06 - 0.30 mm., main mode - 0.12 mm.), and moderately sorted. Quartz (10%), feldspar, - untwinned, oligoclase and andesine - (30%); abundant (45%) lithics of chloritic aphanitic fragments, volcanic flow rock fragments, low grade metamorphic fragments and chalcedonic fragments. Chloritic clay matrix (15%); some chlorite infillings show "chevaux de frise" structures; chlorite coatings around grains. Spots of siderite and haematite. Squeezed muscovite. Much alteration and welding of lithic grains. Thin lenses of carbonaceous matter. Porosity is slight.

Tertiary Sediments

PEBBLE POINT FORMATION

Sample No: J.54 - 12/15

Locality: Coastal section S.E. of Princetown.

Age: Middle Palaeocene.

Macroscopic petrography:

Sandstone: Dark brown, friable to compact, subrounded to rounded, coarse to granule size, with pebbles (4-7 mm.), and poorly sorted. The quartz grains are polished and show overgrowths. The bonding media ranges from a silty clay matrix to a brown sideritic cement. Some green fragments occur in the cemented sandstone. A phosphate test carried out on the sample did not yield a precipitate.

Thin section petrography:

Sandstone: Brown, angular to rounded, bimodal, very fine to granule size (0.06 - 0.45 mm., and 1.26 - 2.76 mm.), and poorly sorted. Quartz (50%) - undulose, composite, and fractured quartz with sericite; feldspar-untwinned - (2%); metaquartzite and chalcedony (3%); chamosite pellets and ooliths and iron oxide pellets (10%); mollusc and echinoid fragments (5%). Cement (30%) consisting of abundant siderite with iron oxide aggregates, and minor calcite. In the friable sandstone chloritic and illitic clay is present. Grain contacts are rare, and only minor corrosion of grains by carbonate occurs. Often pellets are obliterated due to recrystallization of siderite. The formation of siderite appears to have caused redistribution of iron oxide. Porosity is slight.

EASTERN VIEW COAL MEASURES

Sample No.: J.55 - 9/5

Locality: Anglesea Brown Coal Mine.

Age: Middle Palaeocene - ? Upper Eocene.

Macroscopic petrography:

Coal: Brown dull, earthy, with uneven fracture; rare limonite pellets. Plant remains.

BROWN'S CREEK CLAY

Sample No: J.54 - 12/14.

Locality: Johanna River Coastal Section.

Age: Upper Eocene.

Macroscopic petrography:

Glauconitic Clay: Medium green, with abundant brown limonite pellets and iron-coated quartz grains. The pellets are medium to coarse-grained. Abundant fossil fragments of foraminifera and gastropods. The clay possesses a sandy texture.

Thin section petrography:

Glauconite rock: Green, with abundant (60%) glauconite; abundant (30%) pellets, ooliths and limonitic fragments; fossil fragments (10%) of bryozoa, foraminifera, mollusc and echinoid debris. The glauconite contains finely dispersed calcite and shows little evidence of limonitization. The pellets and ooliths are rounded, fine to coarse-grained and poorly to moderately sorted; although pellets and ooliths are limonitic, there is evidence of chlorite-probably chamosite - forming the cores of some of the ooliths. Detrital quartz grains are rare. Limonitization of pellets, ooliths and rock fragments appears to have taken place prior to deposition in the glauconite rock.

Sample No: J.54 - 12/13.

Locality: Castle Cove.

Age: Upper Eocene.

Macroscopic petrography:

Fossiliferous Clay: Buff, with abundant fine-grained fossil debris of mollusc fragments, echinoid spines and foraminifera. Very fine-grained green glauconite pellets occur together with minor quartz grains. This rock has the texture of a calcarenite.

Sample No: J.54 - 12/10

Locality: Hamilton Creek road cutting.

Age: Upper Eocene.

Macroscopic petrography:

Fossiliferous Clay: Light brown, with abundant fossil fragments of foraminifera, echinoids and molluscs. The clay contains finely dispersed carbonate and scattered brown limonitic patches. Scattered quartz grains occur.

CASTLE COVE LIMESTONE

Sample No: J.54 - 12/12

Locality: Castle Cove.

Age: Upper Eocene.

Macroscopic petrography:

Limonitic Calcarenite: Light brown, compact, with subrounded to rounded, coarse to granule size, polished and ironstained quartz. Abundant fossil debris of mollusc and bryozoa fragments. Abundant dark brown, fine to medium-grained limonite pellets. Cement consists of calcite, dolomite and ? siderite. Porosity is poor.

ANGAHOOK MEMBER

Sample No. J.55 - 9/4

Locality: Soapy Rocks.

Age: Lower Oligocene.

Macroscopic petrography:

Pebbly Sandstone: Medium brown, friable, subangular to subrounded, bimodal, coarse-grained, granule to pebble size (5-12 mm). Abundant quartz and minor limonite pellets. Iron staining on the quartz grains is due to the iron oxide present in the clay matrix.

Microscopic petrography:

Pebbly Sandstone: Brown, subangular to rounded, bimodal, medium to very coarse-grained (0.36 - 1.14 mm., main mode - 0.45 mm.), and granule to pebble size (3.60 - 9.90 mm.). Quartz (55%) - undulose and strained, metaquartzite and quartzite; limonite pellets and rare chlorite grains (5%). Minor chloritized mica. Ferriferous chlorite (15%) forms well developed rims around the detrital grains. In some parts ferriferous chlorite fills voids. Little evidence of pressure welding and only minor grain contact. Quartz with overgrowths occurs as well rounded grains suggesting second cycle of deposition. Intergranular porosity may be as high as 25%.

Sample No: J.55 - 9/6

Locality: Airey's Inlet.

Age: Lower Oligocene.

Macroscopic petrography:

Clay: Light brown, soft, bentonitic, with very fine sandy texture. Brown coloration appears to be due to disseminated iron oxide. Scattered fine-grained quartz is present. Thin dark brown iron-stained lenses and laminations occur.

CLIFTON FORMATION

Sample No. J.54 - 12/16b.

Locality: Princetown.

Age: Oligocene.

Macroscopic petrography:

Limonitic Sandstone: Light brown, compact, subrounded to rounded, medium to very coarse-grained and moderately sorted. Abundant polished ironstained quartz grains and limonite pellets. Carbonate cement-chiefly calcite. Fossil debris of molluscs; also limonite moulds. Porosity is moderate.

Thin section petrography:

Limonitic Sandstone: Brown, angular to rounded, very fine to very coarse-grained (qz. 0.12 - 1.35 mm., pellets 0.15 - 0.75 mm.), and poorly sorted. Quartz (30%) - undulose, fractured with iron oxide in fractures, quartz with overgrowths, quartzite; limonite pellets and ooliths (20%); bioclasts (10%) - bryozoa, echinoid spines and foraminifera. Finely recrystallized calcite (30%); selective recrystallization of fossil fragments.

Little grain contact. Iron oxide coats most grains. Well rounded quartz with overgrowths are second cycle products. Calcite cement is an early diagenetic product. Porosity 10%.

Sample No: J. 54 - 12/16a.

Locality: Princetown.

Age: Oligocene.

Macroscopic petrography:

Limonitic Calcarenite: Dark brown, compact, dense, subrounded to rounded, fine to very coarse-grained, and poorly sorted. Fossil casts are present. Polished ironstained quartz grains and limonite pellets. Limonite cement. This lithology represents the bonding medium for the conglomeratic bed present. Phosphate is reported to occur in nodular form in this bed.

Thin section petrography:

Limonitic Calcarenite: Brown, subangular - rounded, fine to very coarse-grained (0.18 - 1.44 mm., main mode 0.30 mm.), and poorly sorted. Quartz (20%) - undulose and fractured; bioclasts (35%) - bryozoa and echinoid fragments; relicts of pellets and ooliths (15%). Abundant (30%) limonite cement. Some quartz grains are rimmed with limonite. Diagenetic limonite has almost obliterated the fossil fragments and altered the matrix material.

Sample No: J.54 - 12/17

Locality: Princetown.

Age: Oligocene.

Macroscopic Petrography:

Limestone: Medium brown, compact with abundant bryozoa fragments. Much of the carbonate appears to be finely recrystallized.

Thin section petrography:

Limestone: Brown, with abundant bryozoa and some foraminifera and echinoid fragments. Angular to subangular, very fine to medium-grained quartz (5%); dark brown limonite as pellets, patches and in disseminated form (15%). Some patches appear to be of ferriferous chlorite composition. The calcite has been recrystallized and has obliterated many of the fossil fragments. Limonitization appears to have taken place after deposition; there may have been two phases - one prior to the recrystallization of the calcite during which alteration of chlorite took place, and the second and main one occurred post recrystallization.

CALDER RIVER LIMESTONE

Sample No: J.54 - 12/11

Locality: Spud Point.

Age: Upper Oligocene.

Macroscopic petrography:

Calcarenite: Medium brown, friable, subrounded, medium to very coarse-grained and moderately sorted. Abundant bioclasts of bryozoa; brown limonite pellets; scattered polished quartz grains. Minor cementing medium. Porosity is good.

Thin section petrography:

Calcarenite: Brown, subangular to subrounded, medium to very coarse-grained (0.27 mm. - 1.74 mm.) and poorly sorted. Limonite pellets and fragments are medium to very coarse-grained (0.36 mm. - 1.74 mm.); fossil fragments are medium to very coarse-grained (0.30 mm. - 1.50 mm.); quartz fine to very coarse-grained (0.24 mm. - 1.65 mm.).

Bioclasts (50%) of bryozoa and foraminifera; brown limonite pellets and limonitic rock fragments (25%); rare quartz (5%) - composite and undulose. Little evidence of cement. Porosity 20%. Recrystallization of fossil fragments. Limonite fragments are reworked material; some of the material was originally ferriferous chlorite. Recrystallization of calcite has replaced some of the limonite.

WAURN PONDS LIMESTONE

Sample No: J.55 - 9/7

Locality: ½ mile north of Waurn Ponds.

Age: Oligocene.

Macroscopic petrography:

Calcarenite: Medium brown, speckled, compact, subrounded, coarse to very coarse-grained and moderately sorted. Abundant bioclasts of bryozoa; brown limonite pellets; well rounded and polished quartz grains occur. Carbonate cement with some disseminated limonite. Intergranular porosity is poor.

Thin section petrography:

Calcarenite: Brown, subangular to rounded, very fine to very coarse-grained (0.09 - 1.2 mm., bioclasts 0.30 - 0.81 mm., quartz 0.09 - 1.2 mm., pellets 0.33 - 1.05 mm.,) and poorly sorted. Quartz and metaquartzite (5%); bioclasts (50%) of bryozoa, molluscs and rare foraminifera; brown limonite pellets (10%); calcite cement (20%). Porosity 15%. Limonite staining around and inside bioclasts and coating detrital grains. Limonitization appears to have taken place during deposition of the calcarenite.

JAN JUC FORMATION

Sample No: J.55 - 9/2

Locality: Bird Rock to Fisherman's Steps.

Age: Upper Oligocene.

Macroscopic petrography:

Calcarenite: Medium brown, friable, subrounded, medium to coarse-grained and moderately sorted. Bioclasts of foraminifera, echinoid fragments, bryozoa and molluscs. Abundant green glauconite pellets; some pellets show varying degrees of limonitization. Much of the calcareous matrix is stained with limonite. Porosity is good.

PUEBLA FORMATION

Sample No: J.55 - 9/3

Locality: Bird Rock to Fisherman's Steps.

Age: Lower Miocene.

Macroscopic petrography:

Limestone: Medium grey, hard, compact, finely crystalline with silt-size pellets and pyrite clusters. Fragments of molluscs, echinoids and bryozoa.

This sample is part of a limestone nodule.

ZEALLY LIMESTONE MEMBER

Sample No: J.55 - 9/1

Locality: Jan Juc Point, Torquay.

Age: Lower Miocene.

Macroscopic petrography:

Calcarenite: Buff, compact, subangular to subrounded, medium to coarse-grained and well sorted. Abundant bioclasts of foraminifera; calcite grains present; rare scattered quartz. Minor cement. Intergranular porosity is fair.

NEWER VOLCANICS

Sample No: J.54 - 12/18

Locality: Mt. Leura Quarry

Age: Pliocene to Recent

Macroscopic petrography:

Green, crystalline fragments containing olivine crystals and dark diopside crystals. This fragment formed the core of an olivine bomb. Olivine bombs are abundant in the volcanic ash which is present in a nested maar near Camperdown.