NOTOCENE STRATIGRAPHY OF THE FLETCHER CREEK AND INANGAHUA JUNCTION AREAS, NORTH WESTLAND.

BY

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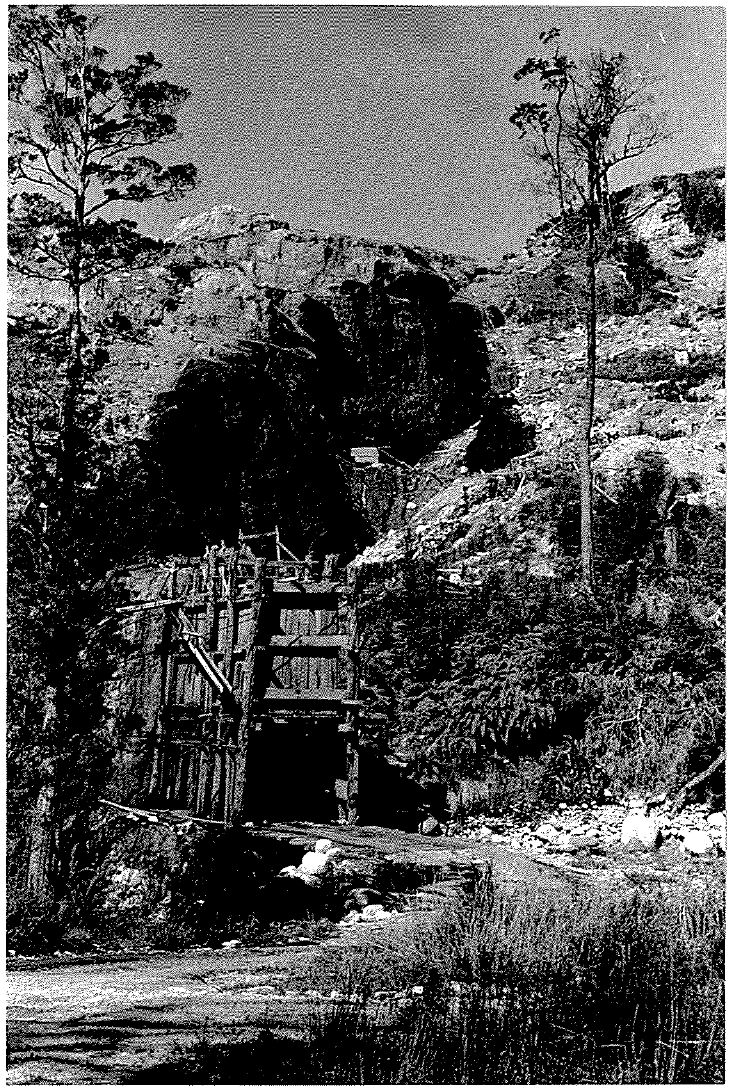

Frontispiece. A vertically dipping coal seam in Fletcher Creek. Rough Creek Coal Measures.

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ABSTRACT.

In the Inangahua and Fletcher Creek areas, North Westland, Greenland Group greywackes and argillites, into which the Tuhua Group granitic rocks have intruded, are unconformably overlain by lower Tertiary to lower Pleistocene transgressive and regressive sediments.

Several reference sections in the Tertiary strata have been measured, of which the thickest totals over 1000 m, and is subdivided into the Brunner Formation (coal measures): Island Formation; sandstone and algal limestone and the Kaiata Formation, mudstone, interpretted as a transgressive sequence. The Cobden formation, unconformably lapping onto the Kaiata Formation is delimited at its base by a breccia, deposited during Whaingaroan basin warping and basement faulting, and at its top by a glauconitic phosphatic richly fossiliferous horizon.

The regressive sequence is represented by the Inangahua Formation of graded bedded foraminiferal limestones, sandstones and silts conformably overlain by coal measures in Fletcher Creek. Overlying the coal measures is a thin sequence of fossiliferous marine strata of possibly Waitotaram age, overlain by Old Man Gravels deposited at the beginning of the Kaikoura Orogeny.

Calcareous Algae and a Teredinid are described in detail.

ACKNOWLEDGEMENTS.

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CHAPTER ONE.

INTRODUCTION:

This project concerns the description and interpretation of the pre Tertiary and Tertiary geology of an area near Inangahua Junction, Fletcher Creek, a tributary of the Inangahua River, North Westland.

Twentyfive days fieldwork was undertaken in February, and continued with a brief visit in April, during which time the author was accompanied by Mr. I. Crooks and Dr. R.M. Carter, and completed with six days work in May.

The areas lie within the National One Mile series, Map S31 and on Sheet 15 of The New Zealand Geological Map (Bowen, 1964). Access to the area north of the Buller River can be gained either by rail bridge at Inangahua or via an aerial cable 5 km to the west, owned by the New Zealand Electricity Department.

Geological observations in the areas mapped were generally confined to the river beds and bluffs. Prominent bluffs of limestone occur in the Buller Gorge, where much of the outcrop has resulted from rockfalls during a major earthquake epicentred near Inangahua in 1968. Many cliff faces are presently unstable; minor rockfalls and shocks were frequently experienced during the period of fieldwork.

The native flora is mixed beech in untouched areas, while large areas that were previously cleared have since been colonized by nettles, gorse and blackberry.

Dairy farming and coalmining are the principal industries in the region.

PREVIOUS WORK:

McKay (1877) mentioned the Inangahua area during a fossil collecting expedition on the West Coast. Subsequently (1888, 1897) he mapped all the Notocene formations from the Hawks Crag Breccia to the Blue Bottom Formation together.

Henderson (1917) mapped the stratigraphically uppermost coal measures in Fletcher Creek with the regional "lower" coal measures later formalized by Suggate and Wellman (1949), and now correlated with the Brunner Formation (Gage, 1952). Both Henderson, and Suggate and Wellman recognised the presence of marine strata within the "Brunner" strata.

Gage (1952, p 45) suggested that algal limestone and sandstone overlying the Brunner Coal Measures in Fletcher Creek could be equivalent to the Island Formation in the Greymouth area.

More recently, Phillips (1963) mapped the area around Inangahua. He proposed several new units, correlating his Buller Mudstone with the Kaiata Formation in the Greymouth area, defining the strata regionally equivalent to the Blue Bottom Formation as the Inangahua Formation and recognising the presence of Cobden Limestone in the area.

Nathan (1970) wrote on the mineral resources of the area around Inangahua and mentioned coal and limestone in the Fletcher Creek area.

Katz (1968), in a discussion of potential oil formations in New Zealand mentioned that near Inangahua Junction, Oligocene strata rests practically on basement, separated from it by only a few feet of Eocene strata, and that both the Eocene and Oligocene rapidly thicken from there to the Westport area, and that at least Oligocene strata thicken to the east also.

Neighbouring areas that have been described include the Reefton area (Suggate, 1957; Gage, 1948), Blackwater River area (Nathan, 1966) and the Heaphy Coal Mine, (Gage and Wellman, 1944).

The most recent geological map of the area is the New Zealand Geological Map 1:250,000 (Bowen, 1964).

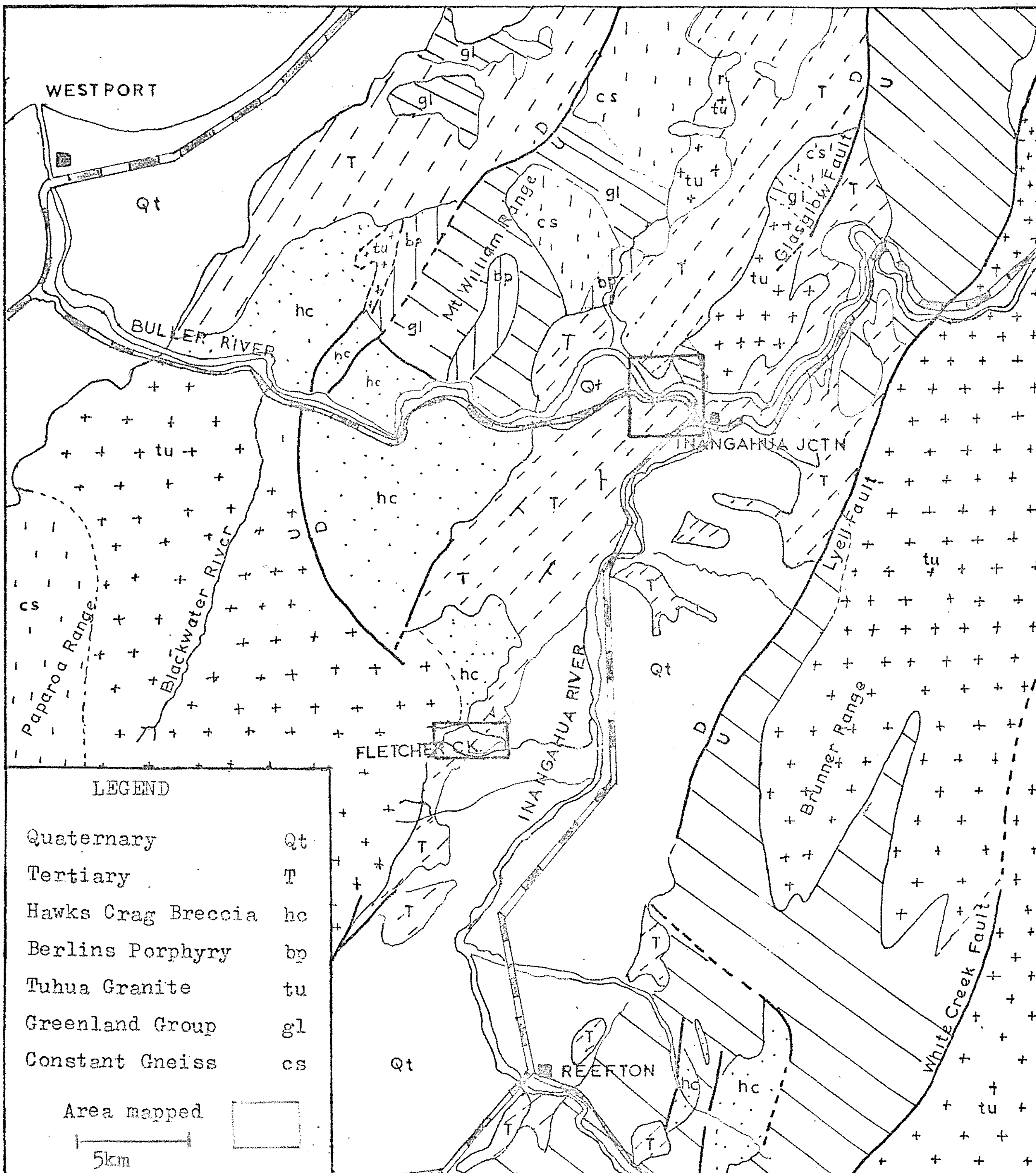


Fig. I. Location map showing the regional geological features. Modified after Bowen (1964).

REGIONAL GEOLOGICAL SETTING:

Regionally the areas investigated lie in a sediment filled topological and stratigraphic depression flanked by the Paparoa and Mount William Range to the west and the Brunner Range to the east (Fig.1)

Among the oldest rocks outcropping in the region are undifferentiated greywackes and argillites of the Greenland (= Waiuta) Groups. The group is unfossiliferous quartzose, and is interpreted by Laird (1972) as a submarine fan turbidite sequence. Formally (e.g. Gage, 1948) the Greenland and Waiuta Groups were distinguished on a basis of regional strike but since the two groups are stratigraphically identical, Laird has combined them into a single unit, the Greenland Group. The sediments are of late ?Pre Cambrian to pre mid Devion age.

The Tuhua Group of calc-alkali and potassic granites, and associated somewhat older intrusives, outcrop over large areas in the ranges. Granitic rocks of the Tuhua Group intrude both the Constant Gneiss and Greenland strata, and give mainly Carboniferous Rb/Sr model ages on micas (Aronson, 1968).

Unconformably overlying the above rocks in the south Paparoa Ranges and near Reefton are the Ohika Beds of lower Cretaceous age, consisting of shale, vitric tuff, conglomerate and greywacke, overlain by the Hawkes Crag Breccia, of middle to late cretaceous age, and correlated with the Jay Formation of the Paparoa Group at Greymouth by Gage (1952).

Coal measures of the Paparoa Group overlie Greenland rocks in the south Paparoa Range, and are considered to be Upper Cretaceous in age. Paparoa rocks are reputed to be unconformably overlain by the Eocene and later transgressive and regressive sediments.

Notocene rocks in North Westland occur in three major parallel belts, possibly partly equivalent to original depositional belts. The western belt is preserved along the coast from Greymouth to north of Westport. A second major area of Tertiary rocks extends along the Grey Inangahua valley and the third belt, with the thickest sequence of sediments, extends from Maruia, north to the headwaters of the Karamea River.

The above three belts have been referred as the Paparoa, Grey-Inangahua, and Murchison geosynclines respectively by Bowen (1964). Dibble & Suggate (1956) suggested that the Paparoa Geosyncline had its axis along the line of the present Paparoa Range and was separated by a rising area from the Murchison Geosyncline to the east. Movements in the Upper Oligocene - Lower Miocene caused the former areas of thick sediment accumulation to rise and the median area between to sink to form the Grey-Inangahua Geosyncline or 'Graben' of Henderson (1917).

Marine and freshwater deposition continued into the early Pleistocene, when deposition of terrestrial sediments of the Old Man Gravels, the stratigraphically highest of the folded rocks began.

CHAPTER TWO - PRE-NOTOCENE GEOLOGY

The Pre-Notocene rocks exposed in the area include Greenland Group sediments, Tuhua Group granites, diorites and associated contact metamorphic rocks, and the Hawkes Crag Breccia.

GREENLAND GROUP.

Name and Type Locality:

The Greenland Group is named by Morgan (1908) who referred to greywacke and argillite at Mount Greenland. Similar rocks have been termed Kanieri Series by Bell & Fraser (1906) a name which was subsequently discarded by Morgan (1908).

Lithology:

The rocks outcropping in the Buller Gorge consist of interbedded fine to medium feldspathic quartz arenites and argillites. A poorly developed slaty cleavage is seen in argillitic beds where jointing is well developed.

Sedimentary Structures:

Well developed sedimentary structures are found in river washed outcrops at the east end of a beach seam 378 625 in the Buller Gorge. Very finely cross laminated ripple and flame structures, and graded beds (Fig.2) from 1 to 3 cm in thickness, are common. Also found at this locality, in thickly bedded greenish grey medium sandstone, are ovate concretionary masses, weathered reddish brown, from 10 to 40 cm in diameter, consisting of dolomite cemented sandstone (Fig.3).

Quartz Veins are common, and are usually one concordant with bedding. An almost pure white quartz reef, 3.4 m in thickness runs parallel to the strike at (398 624) some 300 m downstream from the Inangahua River junction.

Petrography:

Thin sections of several samples of the Greenland rocks have been examined in order to establish the gross petrography.

O.U. 31303 (391 624) (Fig.4): Very hard dark grey sandstone. Seen in thinsection, the rocks consists of abundant quartz,

Fig.2. Laminated and ripple drift structures developed in graded beds.

Fig.3. Dolomite cemented concretions in coarsely bedded arenite.

commonly elongate grains, with minor plagioclase (An 10-40, Michel-Levy method), muscovite, and phyllitic and quartzite rockfragments. Large quartz grains up to 0.8 mm in diameter are commonly well rounded. The matrix consists of very fine grained, slightly recrystallised quartz and sericite, the latter showing a strong orientation parallel to the bedding. Patches of carbonate, showing a good rhombohedral habit typical of dolomite are present. Modal analyse: quartz 50%; plagioclase and rockfragments 5%; Matrix 35%; Dolomite 10%.

O.U. 31304 (387 625): Medium, grey, calcareous arenite, weathers reddish brown. In this section, the detrital mineralogy is similar to that of O.U. 31303. However a drusy mosaic carbonate cement, which constitutes approximately 40% of the rock has been identified as dolomite by x-ray difraction.

O.U. 31305 (391 624): Dark grey argillite with a slaty cleavage parallel to bedding, defined by a single quartz arenite lamina, 2 mm in thickness. In thin section, the rock consists of a dense mixture of quartz and sericite. The quartz lamina has been sheared to form a micro pinch-and-swell structure and is intersected by a quartz vein (Fig.5). A little carbonaceous material is present.

O.U. 31306 (387 625): Sandstone with laminated graded beds. Very fine pale greenish-grey sandstone beds grading up to dark grey argillite. Thin section cut normal to bedding. Above the sharp base of each bed the very fine grained quartz sericite sandstone contains abundunt dolomite aggregates up to 0.2 mm in diameter. An incipient cleavage is developed at an angle of 45^{o} to the bedding, reflected by the orientation of sericite under crossed nicols.

Distribution:

Greenland Group sediments outcrop extensively at water level in the Buller Gorge from 400 m below the Inangahua River junction, downstream for 1.5 km and north for 1 km in the area of Welshman Creek.

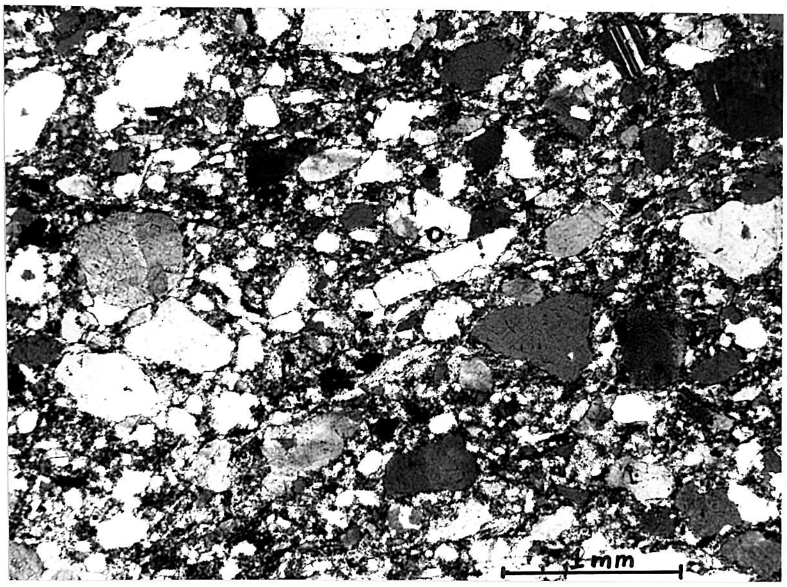


Fig. 4. Unsorted feldspathic lithic quartz arenite. Note trace of bedding. O.U. 31303

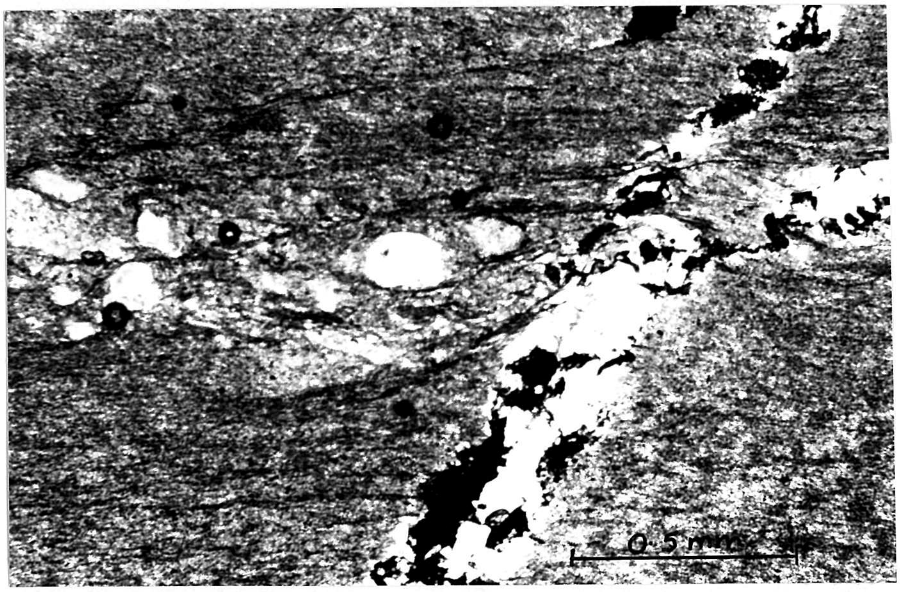


Fig. 5. Sheared quartzose sand laminae in argillite O.U. 31305

Age:

The age is uncertain. Hume (1972, in prep.) has evidence suggestive of a sedimentary contact with the Constant Gneiss in the Central Paparoa Range. U-Pb dates from detrital zirons by Aronson (1968) give a model age of 711 ~~1008~~ my. A few samples of argillitic rocks of the Greenland Group from South Westland yield whole rock K-Ar ages up to 440 my. A late Pre Cambrian to pre Mid Devonian age has been suggested by Laird (1972).

Metamorphism:

A distinction can be drawn between the quartz recrystallisation and sericite formation in the rock matrix, which is a regional phenomenon, and the amphibolite facies metamorphism in the contact aureole of the Tuhua intrusives. Away from the aureole, the development of a widely spaced cleavage and the development of a favoured orientation of micaceous minerals (seen in thin section under crossed nicols) indicates an equivalent grade to mesoscopic textural Zone 2A and the microscopic textural Zone 2 of Bishop (1970).

Structure:

In the Inangahua Gorge the strata are steeply dipping and strongly folded about a steep N.W. plunging axis. (Fig.9) illustrates a sheared fold developed in medium grained greywacke and argillite beds in Welshman Creek (394 632).

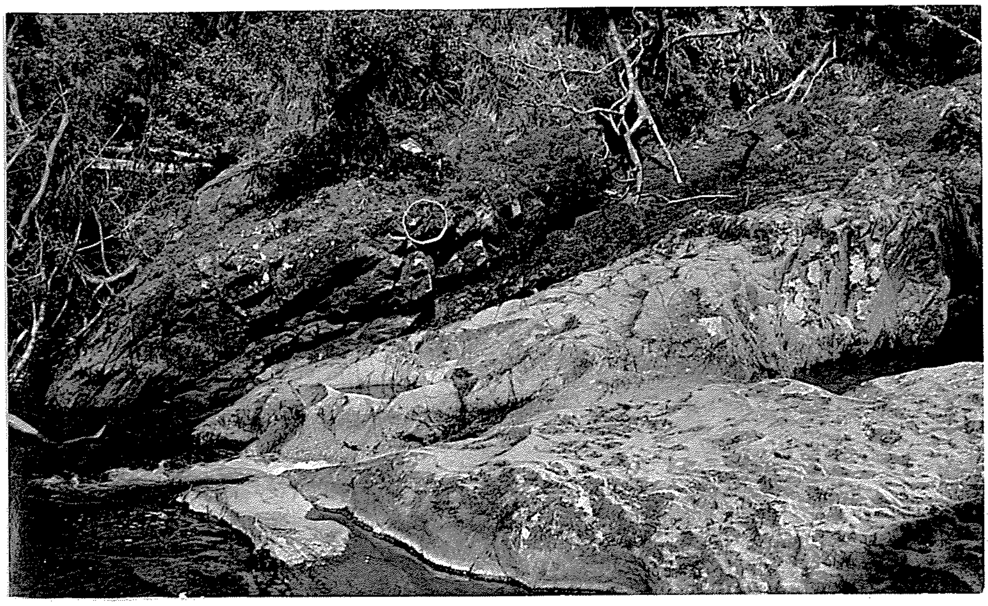


Fig.6. Intrusive contact between Greenland Group sediments and Tuhua quartz diorite.

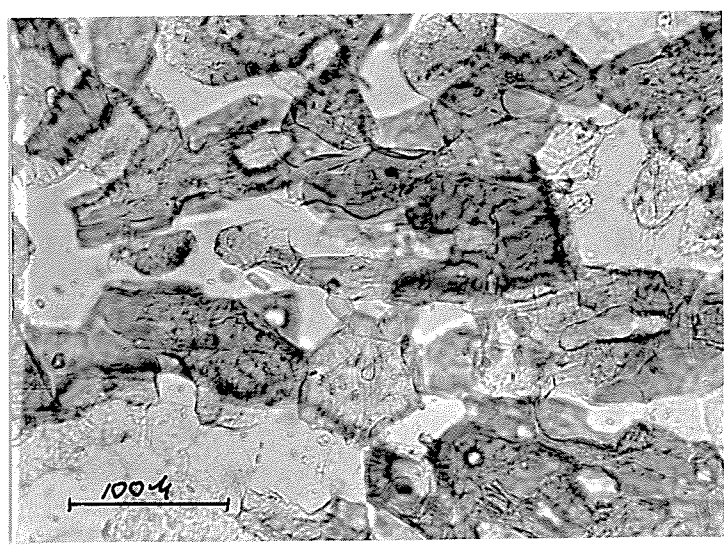


Fig.7. Hornblende hornfels. Mainly hornblende and quartz. O.U.31307.

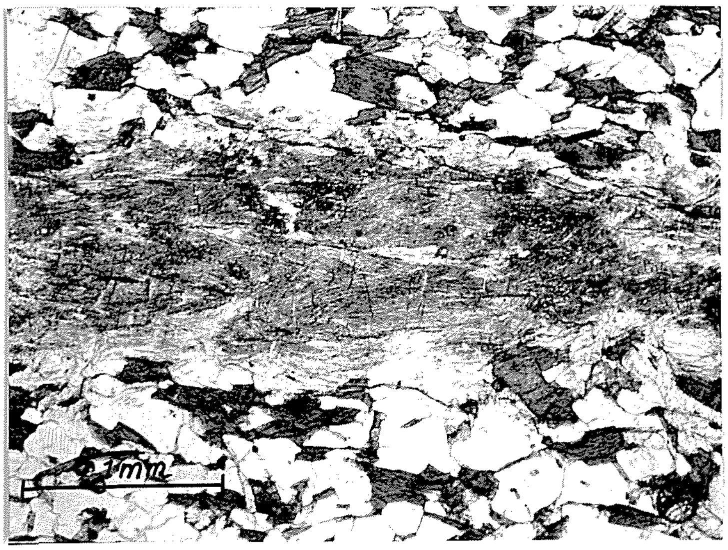


Fig.8. Fibrolite and muscovite intergrowth. Granoblastic matrix of quartz, biotite and plagioclase. Note the cleavage of the fibrolite aggregrate. O.U.31308.

TUHUA GROUP.

Name and Type Locality:

Bell & Fraser (1906) referred to granitic rocks, intrusive into the Greenland Group, at Mount Tuhua, (Sheet 17, Warren).

Distribution:

Diorite and pink orthoclase granite outcrop in the Buller Gorge near the Inangahua River Junction and to the N.E. Microcline granite outcrops in Fletcher Creek, while in Hunt Creek (275,445) an assemblage of muscovitic pegmatite gneisses, orthoclase granites, and fibrolite gneissic hornfels occurs. Dark coloured dykes (possibly lamprophyric), up to 20 cm in thickness, are common. No attempt was made to systematically map the intrusive rocks.

Petrology:

The petrology of representative samples is described below because of its relevance to provenance studies for the Notocene sediments.

Microcline granite O.U. 31310 Fletcher Creek, (275 445): Moderately weathered greenish grey coarse grained granite. In thinsection the rock consists of microcline, 35%; quartz 40% and plagioclase (An 10-20), 15%; weathered biotite 10%. Accessories include apatite and magnetite.

Biotite Diorite O.U. 31309 Section 1 (403 611): In hand speciman, grey quartz and white feldspar phenocrysts up to 10 mm occur in a finer grained groundmass. In thin section the mineralogy is biotite 20%; quartz 38%; and plagioclase AN 20-30 42%. Accessories include chlorite and rutile.

Orthoclase Granite O.U. 31312 Welshman Creek. (396 638): This rock occurs as veins of 10 to 40 mm in thickness in the above diorite, related to a separate intrussive body. In land samples the rock is pink and coarse grained, and in thin section the dominant minerals are orthoclase 50%; quartz 40%; and biotite (altered to chlorite), 10%. Accessories are magnetite, muscovite, and sillimanite.

Contact Relations:

In Welshman Creek, a possible intrusive contact occurs between the Greenland rocks and porphyritic quartz diorite (Fig.6). This contact was mapped by Henderson (1917). In thin section samples taken 1 m from either side of the contact have a similar mineralogy to the diorite described above.

An outcrop of hornfels occur at (399 618). It is uncertain whether this outcrop is part of the contact aureole or whether it is a large raft of stoped sediment. Numerous rounded xenoliths of biotite hornfels up to 1 m in diameter are common.

Petography:

Biotite-Hornblende hornfels - O.U. 31307 (399 618):
A very dark greenish-grey rock with a well developed lamination. Pale yellowish to medium bluish-green hornblende (Fig.7) and brown biotite lepidoblastic segregations separated by granoblastic quartz-rich laminae. Minor prismatic, very pale green diopside is associated with the hornblende.

Fibrolite-Muscovite Hornfels - O.U. 31308 (277 456):
In hand specimen a strong foliation is present which in thin section is reflected by sheaf-like segregations of fibrolite fibres (Fig.8), associated with coarse grained muscovite. Individual fibrolite fibres occur up to 10 u in diameter. Modal Composition: fibrolite 5% and muscovite 5%, quartz 60%, biotite 15%, and plagioclase (An 20) 15%, with accessory magnetite.

Fig. 9. Steeply plunging sheared syncline in Greenland Group strata.

Fig. 10. Fallen block of Hawks Crag Breccia

CHAPTER THREE - NOTOCENE STRATIGRAPHY.

INTRODUCTION:

In the area mapped near Inangahua Junction, and in Fletcher and Hunt Creeks some 20 km south, important Tertiary reference sections occur. The beds are homotaxial equivalents of the classic West Coast Formations long recognised in the Greymouth area. (Morgan, 1911; Gage, 1952). The new Formation names proposed by Phillips (1963) were not completely adhered to, since only slight modification is necessary to enable Greymouth formations to be directly applied in the Inangahua region. Table 1 outlines the classification adopted, including its relation to the schemes of earlier workers.

<table>
<tr><th>Greymouth</th><th>Fletcher Creek</th><th colspan="2">Inangahua</th></tr>
<tr><td>Gage (1952)</td><td>Suggate & Wellman (1949)</td><td>Phillips (1963)</td><td>This Study</td></tr>
<tr><td>Recent Terrace Gravels</td><td></td><td>Recent</td><td>Recent</td></tr>
<tr><td>Old Man Gravels</td><td>Old Man Gravels</td><td>Old Man Gravels</td><td>Old Man Gravels</td></tr>
<tr><td rowspan="3">Upper Tertiary (Blue Bottom Fm.)</td><td>Waitotaran M.Bs.</td><td rowspan="2">Rough Creek C.Ms.</td><td>Waitotaran M.Bs.</td></tr>
<tr><td>Upper C.Ms.</td><td>Rough Creek C.Ms.</td></tr>
<tr><td>Pareora Beds</td><td>Inangahua Fm.</td><td>Inangahua Fm.</td></tr>
<tr><td>Cobden Fm.</td><td rowspan="2">Landon Beds</td><td rowspan="2">Cobden Limestone</td><td rowspan="2">Cobden Fm.</td></tr>
<tr><td>Port Elizabeth Fm.</td></tr>
<tr><td>Omotumotu Fm.</td><td rowspan="3">Arnold Beds</td><td rowspan="3">Buller Mudstone</td><td rowspan="2">Kaiata Fm.</td></tr>
<tr><td>Kaiata Fm.</td></tr>
<tr><td>Island Fm.</td><td>Island Fm.</td></tr>
<tr><td>Brunner Fm.</td><td>Brunner C.Ms.</td><td>Brunner C.Ms.</td><td>Brunner Fm.</td></tr>
<tr><td>Basal Conglomerate - Paparoa Group</td><td>Hawkes Crag Breccia</td><td>Hawks Crag Breccia</td><td>Hawks Crag Breccia</td></tr>
</table>

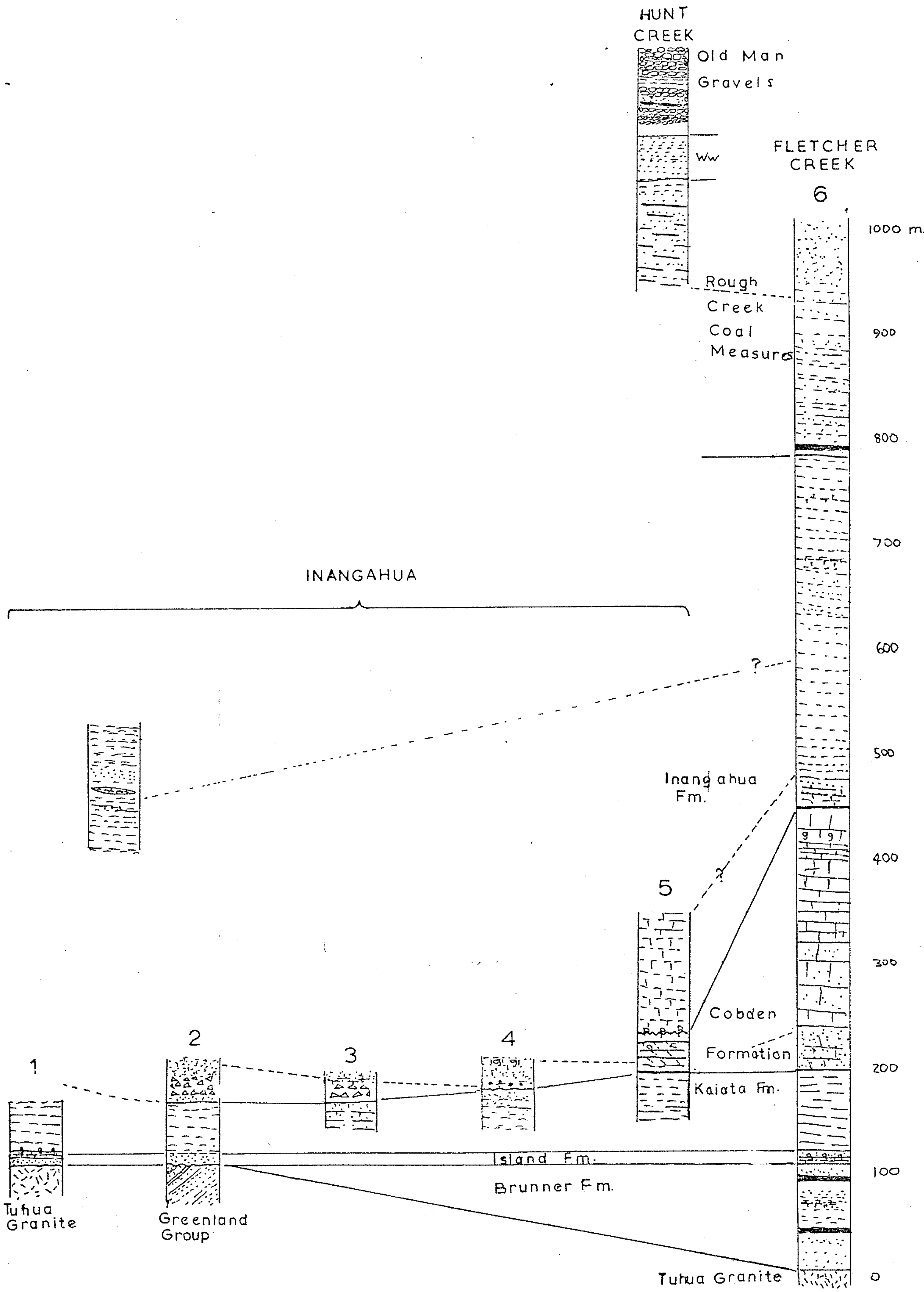
Table 1: History of lithostratigraphy.
Fm = Formation; C.Ms. = Coal Measures; M.Bs. = Marine Beds.

The upper part of the Cobden Formation of Phillips is here treated as basal Inangahua Formation. Phillips mapped no rocks equivalent to the Omotumotu or Port Elizabeth Formation of Gage (1952), in the Inangahua area.

MEASURED SECTIONS:

Stratigraphic sections, measured in both the Inangahua and Fletcher Creek areas are presented along with their location data in Appendix A. Figure 11 is a schematic stratigraphic correlation of the sections measured.

Fig.11. A correlation of the reference sections measured in the Inangahua and Fletcher Creek areas.



HAWKS CRAG BRECCIA:

The Hawks Crag Breccia outcrops in the bed of Hunt Creek (275 455), 15 km S.W. of the type locality, between Hawks Crag and Little Hawks Crag in the Buller Gorge.

Bowen (1964) mapped the Breccia in Hunt Creek as being in unconformable sedimentary contact with the underlying Tuhua rocks, but the lack of suitable outcrop prevented confirmation of his observation.

The Breccia consists of pebbles of granite and greywacke in a dark red muddy-gravel lithified matrix (Fig.10), similar to the rocks described by Morgan and Bartrum (1915, 76-7) from the type locality, and by Gage (1952) from the Greymouth area.

BRUNNER FORMATION:

Name:

The name is derived from the term Brunner Coal Beds, introduced by Hector (1884) for coal bearing strata in the Brunnerton district. (In Fleming, 1958).

Type Section:

Gage (1952) defined the type section as the quartzose coal measures above the Dunollie Formation of the Upper Paparoa Group of coal measures, and capped by the Island Formation, on the south slope of seven Mile Valley, north of Greymouth.

Distribution and Lithology:

Brunner Formation outcrops in Fletcher Creek (Section 6) but is not seen in Hunt Creek. In the Inangahua area, the Brunner Formation is absent, but occurs 5 km to the west of the map area at Burley's where coal mining operations are currently in progress. In Fletcher Creek the uppermost coal seam is being privately mined by open cast methods (Fig.12).

The formation consists of quartzose sandstone, fine granule conglomerate, finely bedded micaceous siltstone and interbedded coal seams. Suggate and Wellman (1949) report that the coal is of low rank and contains about 5% sulphur.

A thin concretionary horizon occurs below the uppermost coal seam, containing unidentified foraminifera, Flabellum and a Teredinid, the latter described 'Appendix B'. The coal measures rest unconformably on leached granite in Fletcher Creek and possibly on Hawks Crag Breccia 1 km to the north, in Hunt Creek.

300 m upstream from the section measured is an infaulted lens of basal Brunner Formation which appears to have been included in a composite section by Suggate and Wellman (1949).

Conditions of Deposition:

The conditions of deposition of the Brunner Formation has been a subject of considerable controversy (e.g. Henderson

(1917, p 86); Suggate (1949); Gage (1949, 1952)).

Two different sets of conditions are thought to have been operative. The first is the accumulation of coal measures in subsiding geosynclinal areas, and the second is the accumulation of coal measures as deposts on a peneplain as a result of the rise of base level during regional Lower Tertiary marine transgression.

Both depositional conditions are favoured for the coal deposits in the area, since an undoubted transgressional sequence can be demonstrated in the succeeding marine sediments, yet rapid variations in thickness of the coal measures can only be accounted for either by local relief in the deposition area or by local subsidence.

Henderson (1917), and Suggate and Wellman (1949) noted the presence of marine fossil in the concretionary horizon, and Suggate and Wellman also noted the presence of marine borings penetrating into the top of the coal seams, which they interpret as the result of local temporary shallow submergence.

Age:

No new age significant data was discovered by the writer. The age is considered to be Kaiatan on regional grounds (Bowen, 1964).

Fig.12. Easterly dipping coal seam near the top of the Brunner Formation currently being mined in Fletcher Creek.

Fig.13. Uppermost algal limestone facies of the Island Formation in Fletcher Creek.

ISLAND FORMATION:

Name:

The term Island Sandstone was first published by Hector (1877), the name coming from a small island in the Grey River near Dobson (in Fleming, 1958).

Type Locality:

Gage (1952) defined the type section as calcareous sandstone overlying coal measures, exposed on the north bank of the Grey River at Brunnerton.

Distribution and Lithology:

In the area investigated, the Island Formation outcrops in Fletcher Creek (Section 6) and downstream from the Inangahua River junction (Section 1 and 2).

Two lithofacies [1] are recognised -

(1) A calcareous fine quartzose sandstone, similar to that outcropping at the type locality, and

(2) A biohermal foraminiferal algal limestone, also known elsewhere in the region (e.g. Webby, 1960).

In section 1, the basal horizon comprises 7 m of coarsely bedded quartzose fine to very fine sandstone with thin granitic pebble conglomerate horizons. From grain mount examination, quartz is the dominant mineral, with minor orthoclase, tourmaline, zircon, biotite, and muscovite present. Above this a sandy algal limestone grades up to 5 m of pale grey limestone containing small algal bioherms (Fig.14) (up to 15 cm in diameter) in a muddy, quartz granule, foraminiferal matrix. Gradationally overlying the algal limestones is a dark grey glauconitic

1. Waage (1968) uses the term lithofacies for the term lithotope of Wells (1947, p 119) - the rock record of a particular environment; for one or more bodies of sedimentary rock distinguished from enclosing deposits by noteworthy lithologic, organic and/or internal structural features. This usage is followed here.

dark grey forminiferal limestone containing abundant Asterigerina Cyclops, and also Halkyordia bortrumi, Hauerina motoensis, Auinqueloculina sp, and Cibicides maculatus (S31.856). Macrofossils present in the sandstone and limestone include Ostrea sp, Serripecten sp, and indeterminable gastropoda. Following Phillips (1963), the algal are referred to the genus Archaeolithamnion.

Fig.15 shows part of thinsection O.U. 31333 with foraminiferal, algal, echinoderm, and molluscan debris cemented by microcrystalline sparry calcite. Pyrite and glauconite are present as bore fillings of foraminiferida and algae, and also as scattered dense patches in the cement. Overlying the limestone on a sharp base is a dark brown carbonaceous mudstone, slightly glauconitic in the lower most 30 cm.

In scattered outcrops downstream from Section 1, the sandstone lithofacies rests unconformably in the Greenland Group.

In Fletcher Creek the sandstones and algal limestone (Fig.13) that overlie the coal measures have been previously correlated with the Island Formation by Gage (1952). In contrast with the Island Formation near Inangahua Junction, the Formation here comprises a repeated sequence of muddy algal limestone overlain by sandstones containing abundant Ophiomorpha-like burrows.

Age:

Suggate and Wellman (1949) placed the Island Formation at Fletcher Creek in the Kaiatan stage.

Conditions of Deposition:

The mode of Formation of the Island Formation is discussed under the Kaiata Formation.

Fig.14. Calcareous algae encrusting shell fragments in a shelly foraminiferal matrix. Limestone lithofacies-Island Formation.

Fig.15. Foraminiferida, and echinoderm and molluscan fragments, partly replaced by phosphate and pyrite, and cemented by fine-grained drusy mosaic calcite.

KAIATA FORMATION:

Name:

The name is based on Kaiata Creek, a branch of the Grey River, and stems from the mapping of Morgan (1910).

Type Section:

The type section is in Soldier Creek, in the Blackball area, where the formation is reduced in thickness and is capped by the Omotumotu Formation.

Distribution and Lithology:

Mudstone and siltstones outcrop in Fletcher Creek and extensively in the Buller Gorge.

The base of the formation is well exposed in Section 1 where the dark brown carbonaceous mudstone is moderately glauconitic at the base, resting on the limestone lithofacies of the Island Formation. The mudstone contains abundant pyritic nodules and burrow casts.

Calcareous nodules and concretions are common, and range in size from 1 to 100 cm in diameter. Three types are present -

(1) Nodules, which commonly occur in bedding planes (Fig.16),
(2) Cylindrical concretions, which occasionally have a pyrite core and appear to have nucleated around burrows (Fig.17), and
(3) Septarian Concretions.

Near 377 618 (Section 4) on the north side of the Buller River, the upper part of the Kaiata Formation is seen to consist of a blue-grey massive marl containing numerous septarian concretions up to 100 cm, but generally 40 to 50 cm in diameter. Fig.18 shows a concretion crossed by a series of cracks that widen toward the centre, filled with brownish yellow sparry calcite.

Overlying the mudstone, and surrounding a layer of large septarian concretions concentrated on the mudstone surface at this locality is a coarsely bedded fossiliferous grit,

Fig. 16. Nodular calcareous concretions orientated parallel tobedding. Section 2.

Fig. 17. Cemented burrow. Section 2.

Fig.18. Septarian concretion with calcite filled radial and concentric fractures . Note the decrease in fracture thickness towards the exterior. Section 4.

the basal bed of the Cobden Formation at this locality. It is apparent that the overlying grit has been deposited on a local erosion surface, littered with residual septarian concretions, cut into the Kaiata Formation. The concretions are identical to those in the mudstone below, therefore it must be concluded that their formation was early diagenetic process, predating deposition of the overlying grit.

In Fletcher Creek the mudstone is more micaceous with fewer concretions. Thinsection O.U. 31336 is part of a barite - carbonate - pyrite concretion which consists of a calcified bored wood nucleus 1.5 cm in diameter. Several generations of radial crystalline calcite bore linings (? Teredinid tubes) are present, filled with drusy mosaic calcite and cemented mud. Barite, identified by X-ray diffraction is present as aggregrates of bladed coarsely crystalline crystal

In the Inangahua area, near (382 620), a sharp but low angle unconformity occurs between the uppermost Kaiata Formation and the overlying limestone. At this locality (lower centre, Fig.19) the Kaiata Formation consists of strongly crossbedded moderately hard micaceous very fine sandy limestone interbedded with more muddy horizons. The overlying yellow-grey glauconitic medium sandy limestone grades up into fine sandy limestone [2]. Phillips (1963) reports that a similar unconformity was visible in new road cuts at (385 624) during his mapping. This locality is now overgrown.

The Kaiata Formation was considered by Gage (1952) to have been deposited unconformably on the Island Formation in the Greymouth area. At Inangahua, the presence of glauconite in the rocks above and below the basal contact perhaps suggests the possibility of a slight disconformity,

2. An alternative interpretation, not favoured by the author is that this surface is in fact a major cross bed or channel feature within the lower part of the Cobden Formation, the unconformity with Kaiata Formation falling below the base of the outcrop.

but no more so than might be expected at the onset of transgressive marine conditions.

Paleontology:

Macrofossils are few and poorly preserved in the Kaiata beds. Phillips (1963) reported *Baryshira morganii*, (Allan), *Proximetra amorica* (Suter), *Dentalium solidum* (Hutton), *Notocyathus pedicellatus* and *Stephanocyathus tatei*, of which *Dentalium* was recollected from outcrops on the north side of the Buller River at 383 623. Foraminifera are abundant. A small poorly preserved fauna from the uppermost Kaiata bed in Section 2, (S31 f857) contains: *Cyclammina incisa* (Stache), *Bathysiphon sp*, *Ammodiscus incestors*, and *Haplophragmoides sp*.

Age:

Of the fossils cited above, *Baryshira morganii* is restricted to the Arnold Series (Fleming 1966). Because common Bortonian genera are not represented, the formation can probably be dated from Kaiatan to Runangan.

Conditions of Deposition:

Gage (1952) considered that because of the fineness and indistinct bedding of the Kaiata Formation in the Greymouth area, deposition took place at least several miles from land. In the Inangahua area a transgressive sequence can be demonstrated which partly alleviates the requirement that the formation was deposited far from shore. A hypothetical transgressive model is presented in Fig.20 which takes into account the sequence as seen at Inangahua (Section 1). The sandstone lithofacies (3) of the Island Formation represents an inshore beach deposit, transgressing over Brunner coal measures (2) and basement (1). The limestone lithofacies represents a transgressing algal reef (4) bounded by a backreef facies (5) of sandy muddy algal detritus and a forereef facies (6) of foraminiferal algal limestone. Offshore from the reef, carbonaceous mud of the Kaiata Formation (7) is being deposited, protected

Footnote: Though barrier sands are known in this stratigraphic position elsewhere on the West Coast (e.g. Cape Foulwind), they do not outcrop unequivocally at Inangahua. They may be partly represented by the slightly sandy facies at the top of the Kaiata Formation at 382,620 or else they have been eroded off along the Oligocene unconformity.

Fig.19. An unconformity between the fine sandy facies of the Kaiata Formation and the overlapping limestone facies of the Cobden Formation. 3 and 4 refer to measured sections.

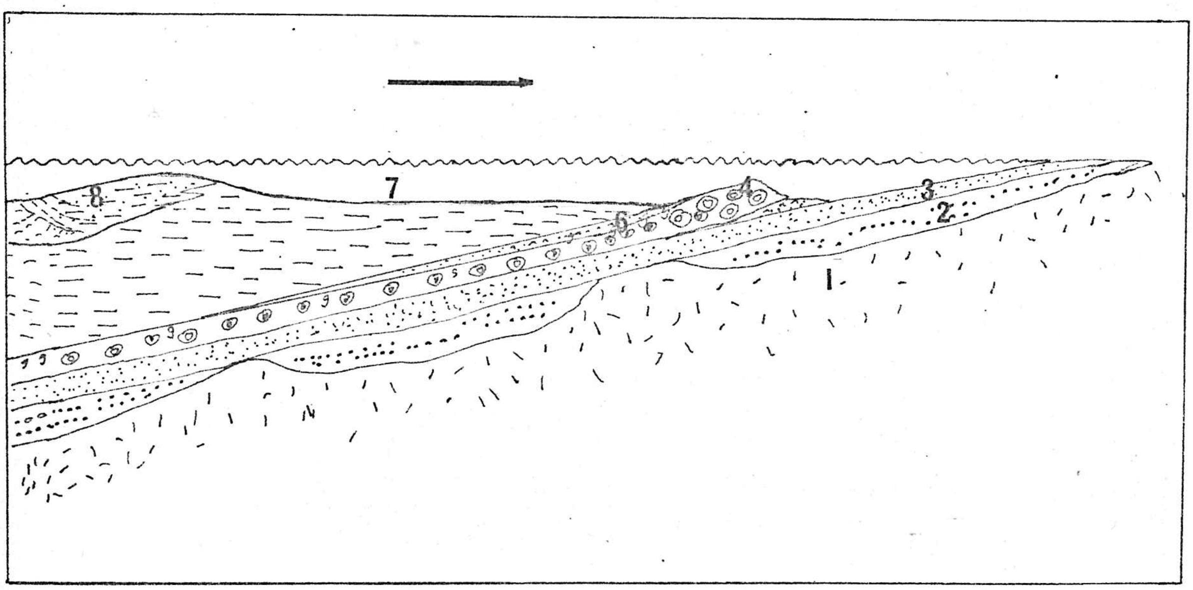


Fig.20. A schematic origin of the transgressive sequence: 1, basement; 2, Brunner Formation; 3, sandstone and 4,5,6, limestone facies of the Island Formation; 7, mudstone, and 8,cross-bedded fine sandy facies of the Kaiata Formation.

by an offshore barrier of very fine sandy silt (8). See footnote, page 28.

COBDEN FORMATION:

Name:

Hector (1880) referred to a limestone near the suburb of Cobden, Greymouth, as part of his Cobden Series.

Type Section:

A type section of the Cobden Formation was defined by Gage (1952) for an arenaceous and argillitic limestone on the north slopes of Tyndales Hill Greymouth.

Lithology and Distribution:

The Cobden Limestone forms a prominent ridge in Fletcher Creek which extends north to the Inangahua Area, across the Buller Gorge. At Inangahua a lower breccia facies, stratigraphically correlated with a coarse quartzose calcarenite in Fletcher Creek, and an upper limestone facies are recognised.

Breccia Lithofacies:

In Section 2, sandstone overlying the Kaiata Formation grades up into thirty metres of hard calcareous breccia, which thins to the west where it laps onto the underlying mudstone. The sandstone is a moderately sorted, finely current bedded spar cemented quartzose calcarenite and overlies a thin granite conglomerate resting on a sharp unconformable contact (Fig.21) with the underlying mudstone. Allochemical grains are rare near the contact (e.g. Thinsection O.U. 31316) and increase in abundance upward into breccia which is composed of many varieties of lithoclasts distributed along vague horizons in a matrix of quartzose spar cemented skeletal debris.

Sedimentary Structures:

Bedding in the breccia is crudely demonstrated by grainsize variation between adjacent beds, and by clasts orientated with their long axes parallel to bedding. Some graded beds are present, but do not have well defined bases and tops. Normal grading occurs in beds up to 20 cm thick (Fig.22), but is not normally seen in natural outcrops where bed relations are not clear.

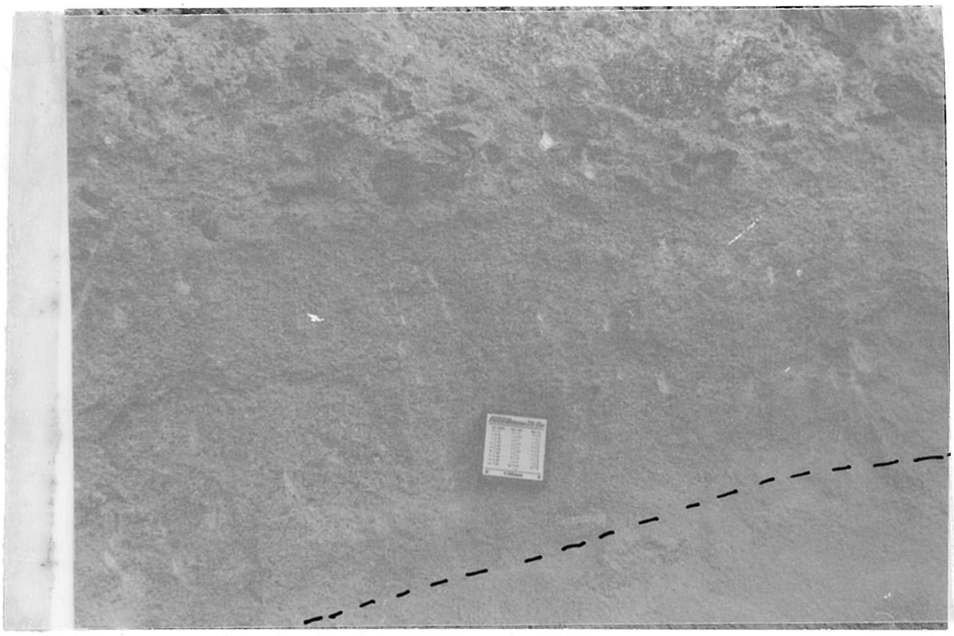


Fig.21. An unconformity between kaiata mudstone and the overlying breccia facies of the Cobden Formation. Section 2.

Fig.22. Development of poorly defined graded bedding, with a disruption of bedding about a hornfels lithoclast. Not insitu. Section 3.

Interbedded with the breccia (Section 3) are a number of thin laminated beds of muscovitic quartzose calcarenite which thin and dissappear over distances of a few metres. Boulder sized clasts up to 20-30 cm in diameter are common, more rarely attaining a size of over 1.5 m (E.g. Section 2, 130 m). In sawn hand specimens, the size of calcareous algal fragements varies sympathetically with lithoclast grain size.

Petrology:

Because the majority of clasts are of greater size than 5 mm they can be studied in detail. Angular to subrounded lithoclasts make up a large part of the breccia. Judged subjectively in outcrop, the most common rock types appear to be hornfelsed greywacke, phyllite, and diorite and quartz pebbles. Quantitative data from clast counts on four 0.25 M^2 bedding plane quadrates is presented in Table 2.

Fig.23, a photograph of a hand specimen of the breccia, illustrates well the diversity of lithoclasts found. The overall colour is pale greenish grey, but the combination of brown, green, and white clasts produces a somewhat mottled appearance. Sutured grain-boundaries and interpenetrating clasts are common, and are interpreted as pressure solution and compaction textures.

Many thinsections of lithoclasts with diameters greater than 15 cm have been examined. They include:-

O.U. 31313 - Greywacke ; a coarse grained quartz arenite of similar mineralogy and texture to that of the Greenland Group.

O.U. 31314 - Medium grained porphyritic albite trachyte.

O.U. 31315 - Biotite muscovite plagioclase (quartz) hornfels

O.U. 31316 - Porphyritic quartz diorite (cf O.U. 31309, Section 1).

O.U. 31317 - Biotite andesine (quartz) hornfels

O.U. 31318 - A mixed contact rock of quartz diorite and orthoclase - muscovite - biotite (quartz) hornfels. (Fig.24).

The matrix of the breccia consists of approximately 10% quartz, trachyte, phyllite, greywacke, and hornfels grains, the remainder being allochemical grains and sparry

Table.2.Field data from counts on four 1/4 m^2 bedding planes.

Rock Type	No. of pebbles over 1cm in diameter.				
	A	B	C	D	Group
Fine grey greywacke	3	7	2	4	Basement Rocks
Coarse greywacke	2	-	1	1	
Phyllite	12	17	12	10	
Laminated hornfels	37	13	10	6	
Spotted hornfels	-	-	4	-	
Gneissic granite	-	-	2	-	
Biotite porphyritic granite (diorite)	-	2	4	6	
Green (?) volcanic rock	11	2	4	1	
Quartz	10	8	4	8	
Kaiata mudstone	-	1	-	-	Lower Tertiary Rocks
Cemented pale grey marl	-	-	5	-	
Algae bearing sandy limestone	3	2	6	-	
Coal	-	-	-	1	
Glauconitic micaceous sandstone	-	5	1	-	
Micaceous sandstone	-	2	-	-	
Fine grained glauconitic limestone	-	-	3	-	

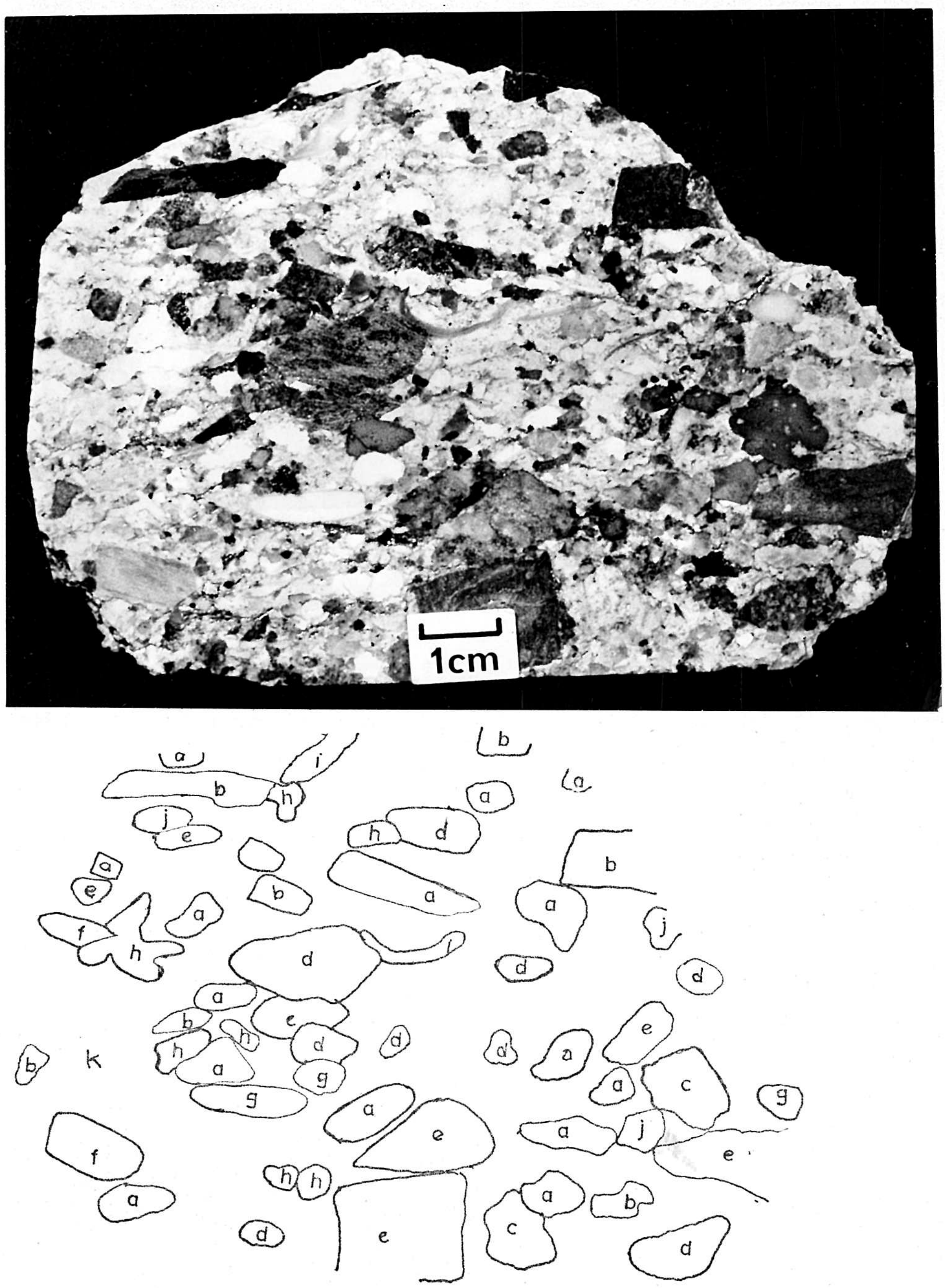


Fig.23. Hand speciman petrology of a sample of the breccia from Section 3: a, biotite diorite; b, biotite hornfels; c, trachyte; d, quartz; e, greywacke; f, phyllite; g, bryozoacolony; h, calcareous algae; i, molluscan fragment; j, glauconitic limestone; k, spar cemented quartzose allochemical matrix.

Fig. 24. A variety of lithoclasts; a, biotite gneiss; b, trachyte; c, composite rock of diorite and K-feldspar, biotite hornfels (O.U. 31318).

Fig. 25. Hornfels and greywacke lithoclasts. Hammer sub-parallel to bedding plane. Section 3. Not in place.

calcite cement. Dusty echinoid test fragments and spines (Fig.26) commonly occur surrounded by overgrowths of clear calcite (Fig.27) which represent the largest continuous spore grains seen in hand speciman. Both calcareous and agglutinating benthonic foraminifera are common, pelagic forms are rare. Molluscan and brachiopod debris is ubiquitous, often showing filamentous algal borings, (Fig. 28).

Bryozoan colonies are abundant, with both spheroidal and branching forms present. Zooecia, which have single liminated walls composed of radial fibrous calcite, are filled principally by drusy mosaic (Fig.27 b). Fragments of calcareous algae are abundant throughout.

In Section 4 (see lower left, Fi.19) the breccia facies is represented by a finer grained fossiliferous quartz feldspathic grit, containing abundant mudstone and glauconitic sandstone pebbles and overlying a sharp contact on dark grey siltstone of the Kaiata Formation (Figs. 29 &30). This contact is better exposed at times of low river level. Because a layer of large septarian concretions (derived from the Kaiata Formation) are concentrated along the surface, an unconformity is again inferred. Thinsections of the grit (e.g. O.U. 31320) reveal abundant quartz, microcline and greywacke, phyllitic, and trachytic rockfragments, with some muscovite and biotite. Cement is coarse grained sparry calcite with euhedral and disseminated dendritic patches of pyrite. The macrofauna at this locality includes: Ostrea sp., Placamen cf morgani (Marwick), Lentipecten sp. and Spissatella sp. together with other unidentified bivalves, Ophiomorpha-like burrows (Fig.29) and a chalky calcareous algae possibly Lithothamnion (S31,f).

Limestone Facies:

The basal grit in Section 4 grades up into a medium grained coarsely bedded glauconitic limestone with a sparse macrofauna of brachiopoda and echinoids including Rhizothyris sp.

Section 5 was measured in approximately the middle of well-exposed continuous cliff outcrops (Fig.30). The contact between the grey bioturbated mudstone of the Kaiata Formation

Fig. 26.Echinoderm spines and bryozoan fragments on a surface weathered parallel to bedding.

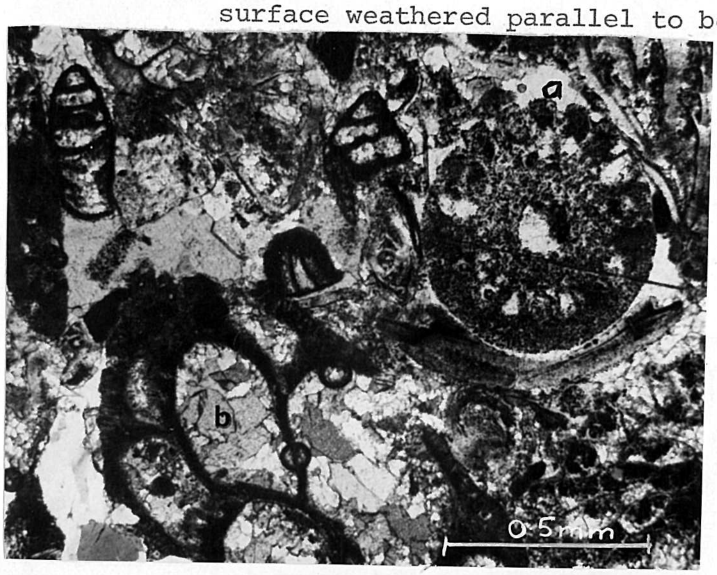


Fig. 27. A photomicrograph of the sparry calcite cemented matrix. Note the syntaxial rim (a) about an echinoderm spine and the drusy mosaic infilling bryozoa zooecia (b).

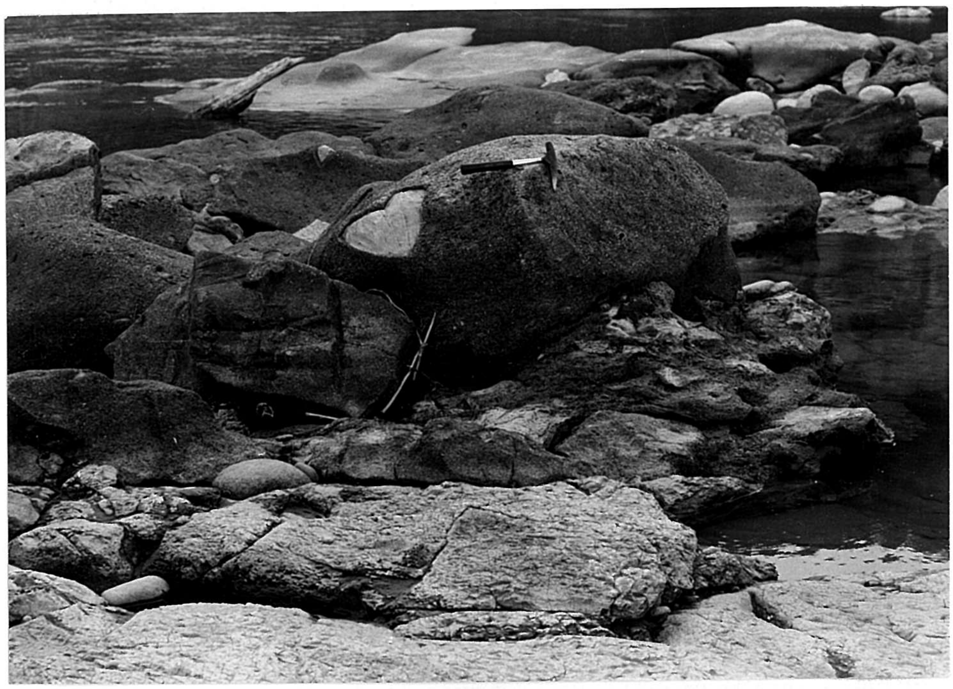
Fig.28.Glauconite filled filamentous algae borings, Molluscan fragment.

and the overlying limestone is not seen. The lowermost lithology exposed is a coarsely crystalline limestone similar in petrography to the limestone near the top of Section 2. Figs.30 B & 31 illustrate massive cross bedding and channel structures which occur throughout the lower part of the limestone, in interbedded hard cemented coarse grained and finer grained quartzose biosparites. A notable feature of the limestone is the abundance of glaucorite pellets, and calcareous algae (Lithophyllum) fragments up to 5 mm in diamter, concentrated in bands from 2 to 10 cm in thickness (O.U. 31321).

Locally abundant algal stromatolites, round in shape and up to 10 cm in diameter, occur in well defined horizons (e.g. Lithophyllum O.U. 31335; 35 m, section 5). Pinkish cream phosphatic nodules up to 4 cm in diameter, consisting of sand grains cemented in a mosaic of birefringent apatite are common throughout the limestone (e.g. O.U. 31322, 65 m, Section 5).

Near the top of the Cobden Formation is Section 5 the lower crossbedded coarse grained limestone grades into a fine sandy dense limestone with abundant molluscan, brachiopod and echinoderm debris. The top 1.5 m of the limestone contains a zone of Ophiomorpha-like burrows filled with coarse phosphatic sediment, which terminate at a 15-20 cm thick phosphatic fossiliferous horizon that here delimits the top of the Cobden Formation, and is marked by a prominent break in slope (Fig.30B). This bed can be traced along the outcrop for at least 200 m, where it is still 20 cm thick at the edge of the outcrop belt, and is also exposed at (361,609), 1 km to the S.W. A more complete discussion and description is presented in Chapter 5.

In the Fletcher Creek area a phosphatic horizon was not seen, however a sparse phosphatized fauna of molluscs and corals was collected from the uppermost limestone in Hunt Creek (451,296). In Fletcher Creek the contact between the Cobden Formation has been drawn above a slightly glauconitic biosparite at the 460 m level.



vv

Fig. 29. A general view of the unconformity between the Kaiata Formation and the overlying Cobden Formation. Hammer rests on a Residual concretion. Section 4.

Fig.30. A close-up of the unconformity in above fig.

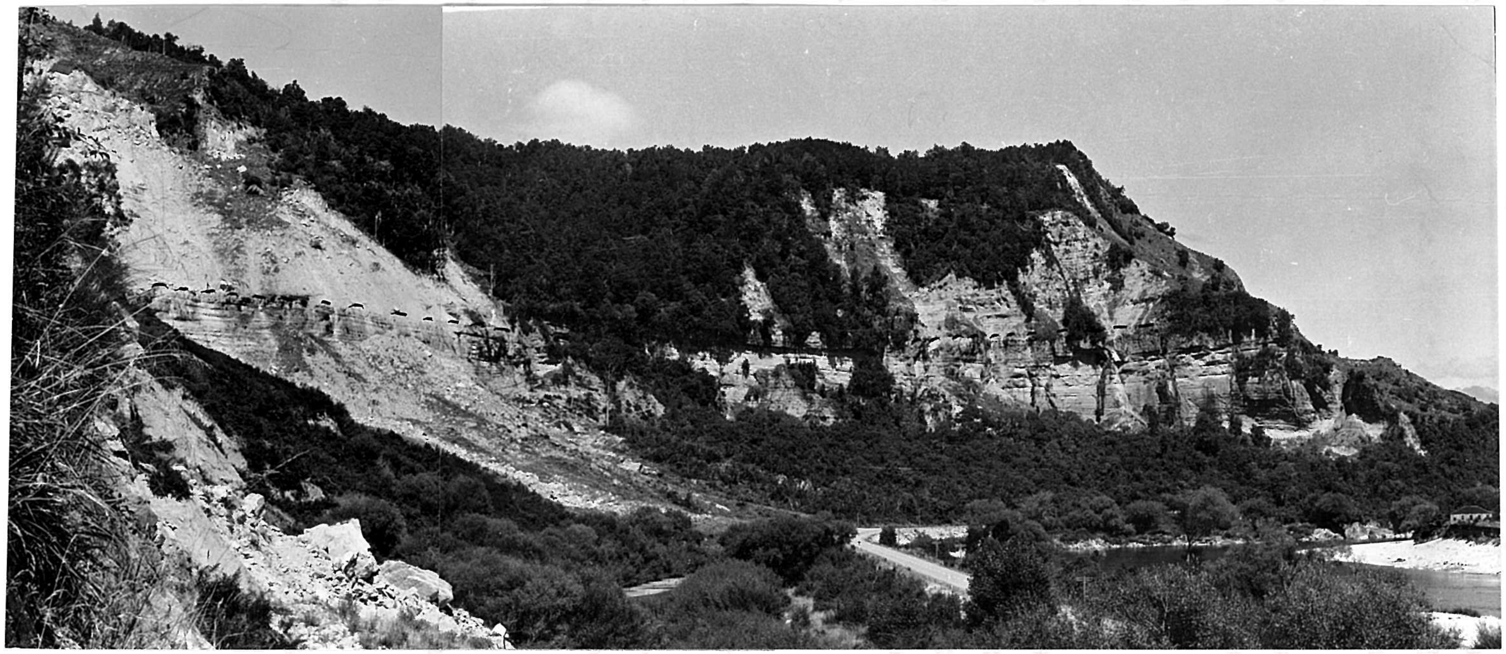


Fig.30B. A general view of Section 5. A contact between the Cobden Formation and the overlying Inangahua Formation (marked by a phosphatic horizon) occurs along the break in slope towards the right. Note the large scale cross bedding, centre left.

Provenance and Conditions of Deposition:

The clastic components of the basal breccia facies were derived from a local source, probably in shallow water. Clasts of igneous and metamorphic rocks and greywacke were derived from a nearby basement source, possibly as a result of local tectonism, and Tertiary sedimentary clasts were derived by reworking of sediment typical of the underlying formations.

Deposition of coarse grained shell debris continued on into the limestone facies, with a reduced proportion of terrigenous grains.

Scanning electron photomicrographs of several quartz sand grains from the breccia were obtained in an effort to gain some knowledge of the transporting agent from surface textures (Krinsley and Margolis, 1968). Analysis of the photographs (from 100 to 1320 x, magnification) suggests that the primary surface features have been overprinted by later diagenetic etch pits.

Age:

No fossils of restricted zonal significance have been found but foraminiferida dates from strata above and below place a range of Ar-Ld on the age of the breccia. Regional considerations suggest it is most likely to be of upper Whaingaroan age (Bowen 1964).

Correlation:

The breccia facies of the Cobden Formation in the Inangahua area is possibly a correlative of breccia facies of the Omotumotu Formation (Gage, 1952) in the Greymouth area and may also be equivalent to the Torea Breccia near Westport. (Laird and Hope, 1968).

Fig.31. A lensoid channel structure in the limestone facies.

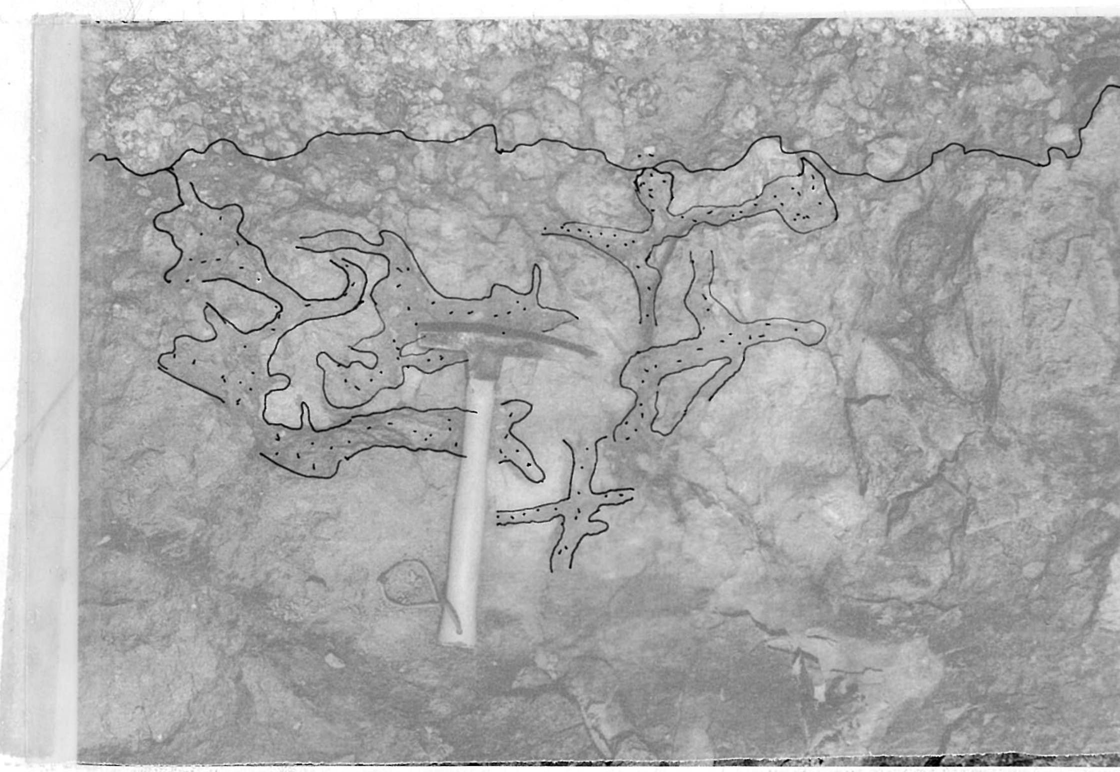


Fig. 32. A general view of the phosphatic horizon and the underlying limestone with a concentration of Ophiomorpha burrows.

INANGAHUA FORMATION:

Type Locality:

The Inangahua Formation was defined by Phillips (1963) as mudstone, siltstone and sandstone lying between the Cobden Limestone in the Inangahua area and the non-marine sequence forming the Rough Creek Coal Measures. The type lower boundary is here redefined as the disconformable contact between blue-grey bedded sandy marls and the underlying phosphatic bed at the top of the Cobden Formation in Section 5.

Lithology and Distribution:

The lower part of the Inangahua Formation (as redefined above, caps the Cobden Formation where it forms high bluffs in the Inangahua area. The lower interbedded very fine sandy limestones and marls (Fig.33) grade up into coarsely bedded fine sandy limestones with abundant 'fucoid' impressions. In the east of the Inangahua map, the Inangahua Formation outcrops along the banks of the Buller River, in a thick sequence of massive blue grey sparsely fossiliferous calcareous silt, with concretionary bands up to 1 m in thickness, and isolated single concretions up to 2 m in diameter. A similar lithology outcrops in the roadside near 398,605. In an exposure on the east bank of the Inangahua River (413,612) a sequence of massive grey mudstone interbedded with brownish grey well sorted fine sandstone outcrops. The lower 10 m mudstone bed contains a body of biotitic muscovitic calcarenite has a maximum thickness of 1.5 m and lenses out to zero thickness over a distance of less than 100 m (Fig.34).

In Fletcher Creek a semi-continuous section is exposed from the Cobden Formation to the overlying coal measures. No obvious evidence for a basal unconformity was seen. The basal contact is placedbetween a very fine sandy marl at the 360 m level, and the underlying slightly glauco itic quartz bearing algal bryozoan limestone (O.U. 31325) of the uppermost Cobden Formation. The sequence seen in both Fletcher and Hunt Creeks consists of very fine sandy marl at the base grading up into finely bedded muddy micaceous sandstone with occasional concretionary horizons. Fig. 35

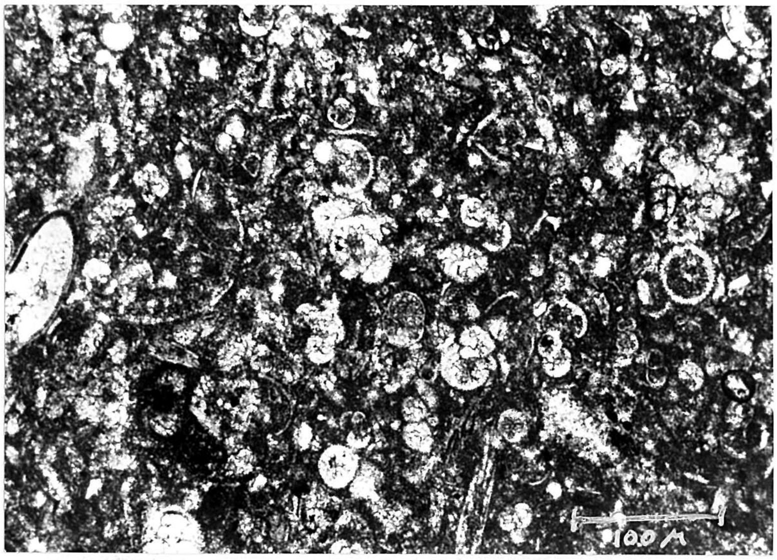


Fig.33. Foraminiferal limestone. Basal Inangahua Formation. Section 5.

Fig.34. A lens of biotite-quartzose calcarenite in massive mudstone, Inangahua Formation.

illustrates flame structures present in graded, laminated micaceous silts and sands in Hunt Creek. (304 455). Near the top of the section the proportion of carbonaceous material increases until finally coal measures are encountered.

Sedimentation:

The basal strata of the Inangahua Formation (Section 5) at Inangahua contain a high proportion of pelagic foraminifera and are considered to have been deposited in deeper water than the underlying coarse grained algal bearing limestones of the Cobden Formation. Turbidite character is seen in outcrops as grain by grain weathering of the sandy bases of individual beds grading up into flaky weathering. This phenonmena is taken as reflecting the qualitative proportions of clay size particles, and hence the normal graded nature of each bed.

Deposition of very fine sandy limestones continued in the Inangahua area until local basin filling and emergence of adjacent land accompanied the deposition of terrigenous silts with offshore sand barriers (e.g. Fig.34). In Fletcher Creek thick sequences of massive siltstones are not seen, their stratigraphic position being taken by finely bedded turbidite-like graded muscovitic sands and muds (Fig.35).

Paleontology and Age:

Suggate and Wellman (1949) indicated an Upper Landon to Upper Pareora Age for the beds in Fletcher Creek, here included in the Inangahua Formation.

Sandy marls from above the basal contact in Section 5 contain an abundant microfauna, identified by Dr. N. de B. Hornibrook as including Cibicides thiora (Stache) and Globoquadrina dehisens (Chapman, Parr and Collins) of Waitakian age (S31/f853).

Macrofossils are not abundant and where found are chalky and poorly preserved. Dentalium solidum (Hutton), Waiparia sp, and Limopsis solidum (Hutton) were collected near (410 611).

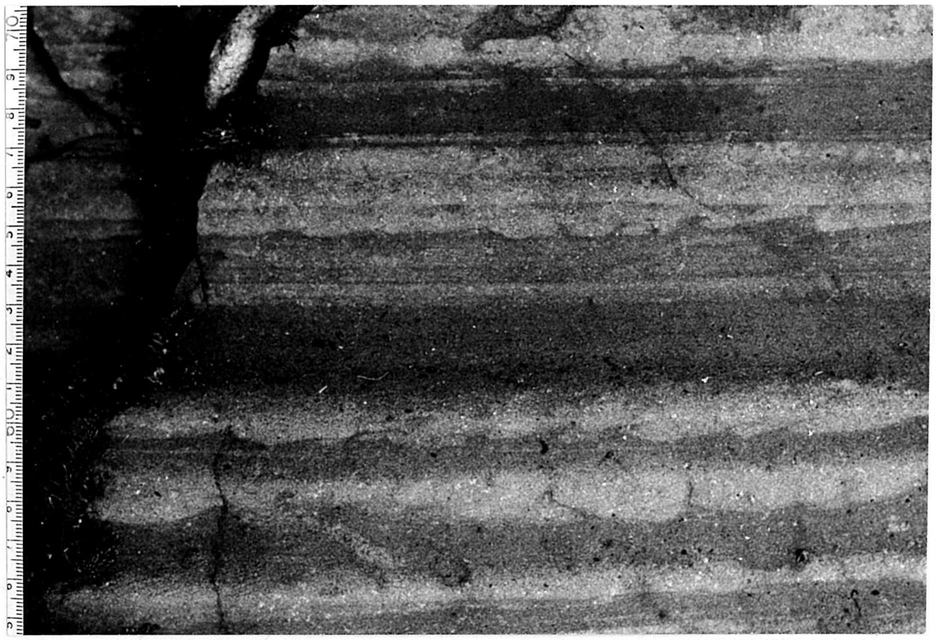


Fig.35. Flame structures in laminated, graded muscovitic sand and siltstone. Hunt Creek.

Fig. 36. A shellbed in the Waitotaran Marine Beds, Hunt Creek. Mainly Maoricrypta

ROUGH CREEK COAL MEASURES:

Name:

The name comes from Rough Creek, 5 km to the SSE of Inangahua Junction.

Type Section:

A discontinuous type section was defined in Rough Creek by Phillips (1963) for a sequence of coal seams, conglomerates, siltstones and sandstones, unconformably overlain by Recent river gravels. The term Rough Creek Coal Measures is equivalent to the Upper Coal Measures of Suggate and Wellman (1949).

Lithology and Distribution:

Rough Creek Coal Measures outcrop in the Fletcher Creek area. Strata exposed in Fletcher Creek include a single thick tectonically deformed vertically dipping coal seam bounded by thinly bedded carbonaceous silts (frontispiece). Above is a sequence of interbedded laminated bioturbated fine quartzose sands and silts. In Hunt Creek coal laminae up to 2 cm thick are seen interbedded with silt and sandstones.

Overlying the coal measures in Hunt Creek are approximately 40 m of interbedded medium sandstones and calcareous grey mudstones with at least five shell beds up to 15 cm thick (Fig.36), referred to as the Waitotaran Marine Beds by Suggate and Wellman (1949). Fossils are chalky and difficult to collect. Macrafossils identified include *Glycymeris Waipipiensis* (Marwick), *Anomia trigonopsis* (Hutton) *Ostrea sp.*, *Maoricrypta sp* and *Perna sp.*

Age:

Wellman and Suggate suggested a Southland to Taranaki Age for the coal measures, and a Waitotaran Age for the overlying marine beds, from macrofossil evidence.

OLD MAN GRAVELS:

Name:

The name comes from an old miner's term for beds underlying the gold bearing late Pleiotocene gravels. No type locality of the Old Man Gravels has been published, the term being restricted to gravels of post-Waitotaran age, forming part of a sedimentary sequence that extends unbroken from Pliocene to early Pleistocene in N. Westland (from Suggate P.276; in Fleming (ed), 1958).

Lithology and Distribution:

The old Man Gravels outcrop in Hunt Creek (310,452) where they apparently conformably overlie the Waitotaran Marine Beds. The steeply dipping strata exposed consist of 30 m of gravel conglomerate overlain by 2 m of moderately hard, noncalcareous grey mudstone with a 10 cm bed of brown woody lignite. The imbricated conglomerate consists of approximately 80% schist, 10% schistose quartz and 10% sandstone, mudstone, granite, and greywacke pebbles in a brown coarse sand matrix. Carbonized leaves and stem fragements are present throughout the mudstone.

Sedimentation:

The Old Man Gravels are of fluviatile origin and appear to have been derived mainly from the Haast Schist Group, east of the Alpine Fault, over 50 km to the east. Their deposition and subsequent deformation together with the underlying Tertiary Sediments can be correlated with the climax of the Kaikoura Orogeny.

CHAPTER FOUR.

ORIGIN OF THE BRECCIA FACIES: COBDEN FORMATION.

It is reasonable to assume that the components of the breccia facies did not reach their site of deposition wholly by traction current processes. Glacial transport or ice rafting, though consistent with some of the features observed, is discredited by the lack of obviously striated pebbles, exotic lithologies, dropped pebbles and the bedding features normally associated with tillites. Primary features within the breccia suggest deposition by mass flow, and in particular by grain flow.

Stauffer (1967) advanced the concept of grainflow as a distinct sedimentary process that separates turbidity current from traction current transport, and is characterised by a distinct set of primary features. Many of these features are present in the breccia facies, including:

(1) Outsize clasts
(2) Thick ungraded sharply bounded beds, commonly massive, but for a diffuse flat lamination.
(3) Direct evidence for mass flow.
(4) Lack of typical turbidite features.
(5) Lack of typical traction current features.

Outsize clasts have already been described. Some beds have sharp and flat bounding planes, and most show a diffuse lamination that may be a structure imported to the interior of a sediment mass during movement. Direct evidence of mass flow is provided by the presence of clasts of soft Kaiata mudstone with diffuse swirled edges, and coal pebbles.

The features described above eliminate turbidity currents and grain by grain deposition. Also, because of the occurence of delicate laminations, the beds involved are not likely to be the result of a chaotic submarine slide. Stauffer (1967) suggested that the presence of a faint flat lamination indicates that the flow moved in laminar fashion, each layer of grains shearing over that below.

Bagnold (1954, 1956) evaluated the effects of grain to grain collisions in the movement of a fluid with dispersed solid particles. If a mass of such fluid is sufficiently dispersed, grain collisions dominate the dynamics of movement. Colliding grains set up dispersive stresses that tend to maintain dispersion and prevent settling. Although Bagnolds experiments involved an imposed shear of a turbulent fluid, Stauffer (1967) proposed that gravity on a slope could also provide the impetus for laminar movement. However, Lindsay (1968) pointed out that clast fabric probably develops in a final short period immediately before the flow comes to rest, envisaging flows which initially travel in a turbulent manner, eventually falling below a critical velocity as the slope decreases, and laminar deposition takes place.

Fisher (1971, p. 924) states that reduction in velocity of a debris flow does not result in the settling out of solids from the water. Rather, the mass 'freezes' in place when the gravity imposed internal shear stress no longer exceeds the yield strength (i.e. as velocity decreases below a certain critical point) and the water eventually separates.

The presence of distinct beds from 10 cm to over 100 cm in thickness, showing an unsupported framework of clasts, indicate that repeated influxes of poorly sorted sediment occurred, possibly separated by short intervals of slight reworking by currents. This mode of transport requires the periodic submarine accumulation of terrigenous and skeletal debris on a slope, followed by flow and subsequent deposition. An obviously suitable site for such an accumulation would be near an active fault scarp able to supply the large volumes of local basement rocks (granite, diorite, hornfels, and greywacke) that are found in the breccia. Older Tertiary limestone mudstones and glauconitic sandstones were also being eroded and redeposited at the same time.

Water depth is likely to have been shallow. The presence of abundant calcareous algae require that the water depth, for the zone of initial accumulation, was within the zone of light penetration (i.e. photosynthesis). Recent calcareous algae are not abundant below 30 m (Monty, 1968), and the breccia may well have accumulated in water considerably shallower than this limit.

Phillips (1963) suggested that the breccia is the product of a single slump movement of material that accumulated elsewhere, possbly as a result of tectonic activity. The possibility of local faulting in the lower Oligocene can be correlated with current theories regarding movement on the New Zealand Alpine Fault and related faults, associated with a widespread paraconformity in the New Zealand region (Carter and Landis, 1972).

CHAPTER FIVE.

PHOSPHATIC HORIZON.

Of particular interest on account of its diagenesis and paleontology, this bed consists of derived pebbles and cobbles, often bored, of fine sandy limestone, in a matrix of phosphatized and glauconitized, quartzose fossiliferous micritic grit. The overlying blue grey sandy marls of the Inangahua Formation penetrate down into the top of the conglomerate and are slightly glauconitic at the base. Aragonitic fossils are only preserved as phosphatized and glauconitized casts, while calcitic brachiopodq and echinoderms remain intact though are generally phosphatized. Fossils occur throughtout the matrix and up into approximately the basal 10 cm of overlying marl. Figure 37 is a close view of the horizon.

The underlying rock is a pale greyish cream fine sandy limestone containing abundant scattered subangular phosphatic nodules up to 4 cm in diameter. In thinsection, the rock is 94% calcite (as foraminiferida, macrofossil skeletal debris, and fine drusy mosaic cement), the remainder being very fine quartz sand with accessory biotite, muscovite, feldspar, and glauconite. The whole rock gives a positive weak test for phosphate (using the ammonium molybdate method suggested by Ber et al 1966, p.508). Cut slabs of the limestone show fine stylolites from 1 to 5 cm apart, orientated sub parallel to the bedding direction, interconnected by vertical sediment filled fissures, up to 1 cm in width.

Autochthonous Pebbles:

Figure 38 is a photograph of a sectioned pebble from near the top of the horizon. This pebble has been exposed to boring organisms, whose borings have subsequently been filled with different sediment types. The pebble itself is a slightly glauconitic fine sandy limestone of similar petrography to the underlying limestone, and therefore interpreted as an insitu residual. Covering the surface is a thin pale grey phosphatic skin, concentrically enveloping

Fig. 37. A close view of the pebble horizon. Note the abundant phosphate pebbles and shell fragments.

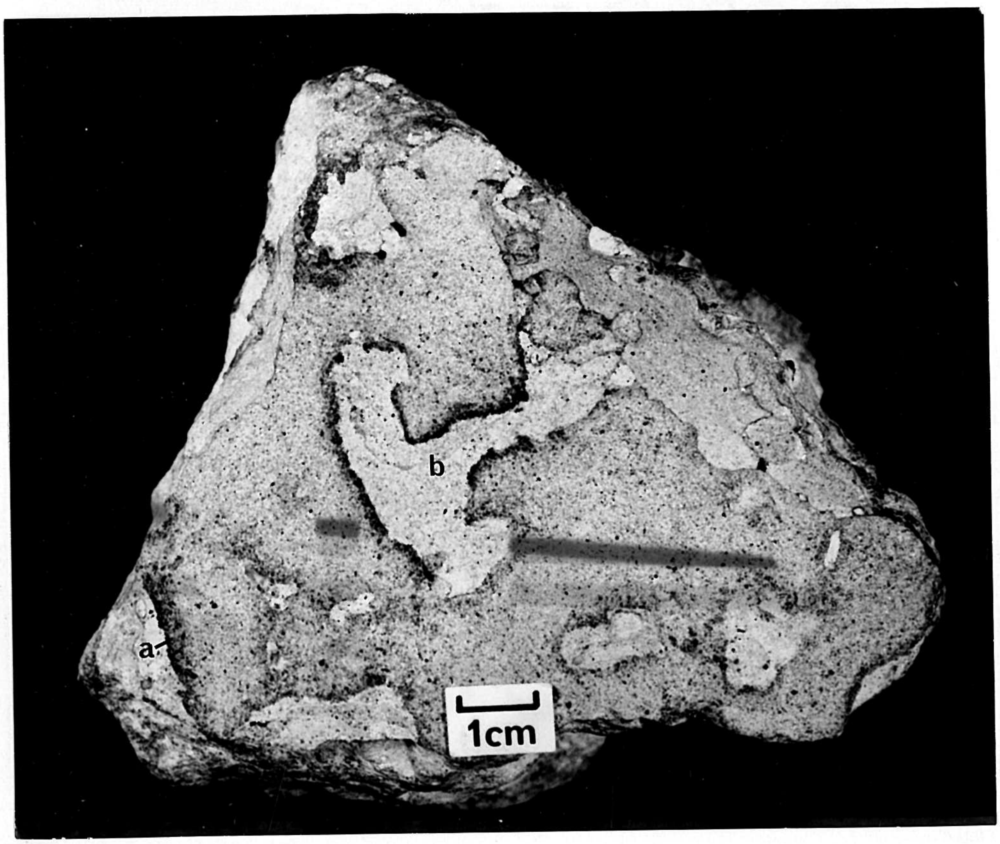


Fig. 38. A bored phosphatized and glauconitized pebble with several generations of infilling sediment.

an inner dark brown phosphatic layer (a) about 1 mm in thickness. This dark phosphate also forms a lining to the boring (b). A green glauconite stain prevades the pebble surface to a depth of 10 to 15 mm. The sediment types in this and similar borings include:-

(1) Nodules of brown phosphatized limestone, themselves with a glauconitic surface (c in Fig.38)

(2) Several generations of shelly phosphatic creamy brown micrite with included quartz pebbles (b, d, and e in Fig.38)

(3) A later stage of calcareous siltstone similar in petrography to the overlying rocks type of the basal Inangahua Formation.

Smaller borings from 1 to 2 mm in diameter rounded in cross section, with smooth walls, probably have a boring pholoslid bivalve or barnacle origin. Bryozoan encrustations occur on pebble surfaces but are uncommon in thinsection.

Pebbles different in petrology to the basal limestone are rare. Only one hornfels pebble, 8 cm in diameter, and not affected by phosphatization, was collected.

The products of diagenesis are not homogeneous throughout the horizon. Commonly, adjacent clasts have been affected by an historically different set of replacement processes. The main types of pre-diagenetic and diagenetic phenomena affecting carbonate clasts, detected in twenty thin sections and hand speciments, are described below:-

(i) Algal borings: Figure 39 is a photomicrograph of a shell fragment in thin section O.U.31328. Numerous tubes interpreted as endolithic algal borings, open to the shell surface. They run at various angles, but are broadly normal to the surface, or parallel to the shell structural elements, and rarely penetrate beyond 30 m. The tubes vary from 4 m to 20 m in diameter and are filled with isotropic glauconite.

Bathurst (1966) described the borings of similar non calcareous endolithic algae from the Bahamas, and noted that they were distinguisable from those made by fungi, arthropods, gastropods and sponges. It is uncertain whether or not micritization followed the death of the alga and vacation of the tube, prior to glauconitization.

(ii) Glauconite: Glauconite is present in the bed as:-

(1) Discrete pellets, usually with radial cracks (E.g. centre left, Fig.40) composed of an aggregrate of randomly orientated crystals
(2) Inside foraminiferidal tests, algal borings, and echinoid stereom, sometimes also as surface replacements
(3) Partial to complete mollusc and branchiopod shell replacements
(4) Pebble surface replacements (Fig.38)

(iii) Phosphate: Phosphate occurs as:-

(1) Diffuse irregular patches of isotropic phosphate in the fine microcrystalline calcite matrix
(2) Isotropic dark brown crusts on pebble surfaces and boring linings (e.g. Fig.38)
(3) Birefringent drusy mosaics and rims around skeletal debris and terrigenous grains, which are in part, cavity filling (Fig.40)
(4) As dispersed birefringent apatite crystals which have nucleated in calcitic shell materials and occassionally coalesce to form a dense framework of local replacement (Fig.43).

X-ray diffraction studies confirmed that all the phosphate varieties seen are the carbonate-fluorapatite, francolite.

Barite:

Coarsely crystalline barite occurs in a single thin-section (O.U.31829, Fig.44), replacing both matrix and originally aragonite shell.

Pyrite:

Pyrite is common on most slides, generally associated with glauconite replacements, and occurs as aggregates of euhedral crystalls.

The above authigenic replacement minerals commonly have

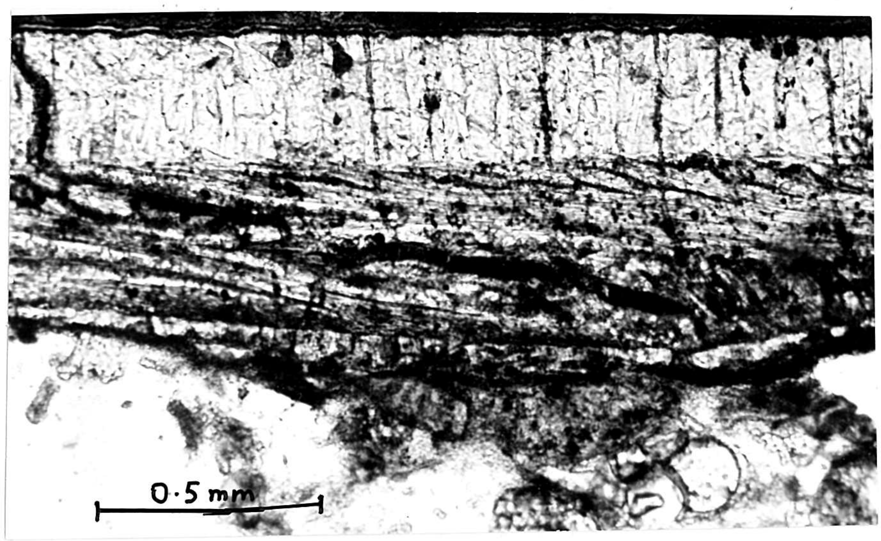


Fig.39. Endolithic algae borings in a brachiopod shell fragment.).O.U.31328.

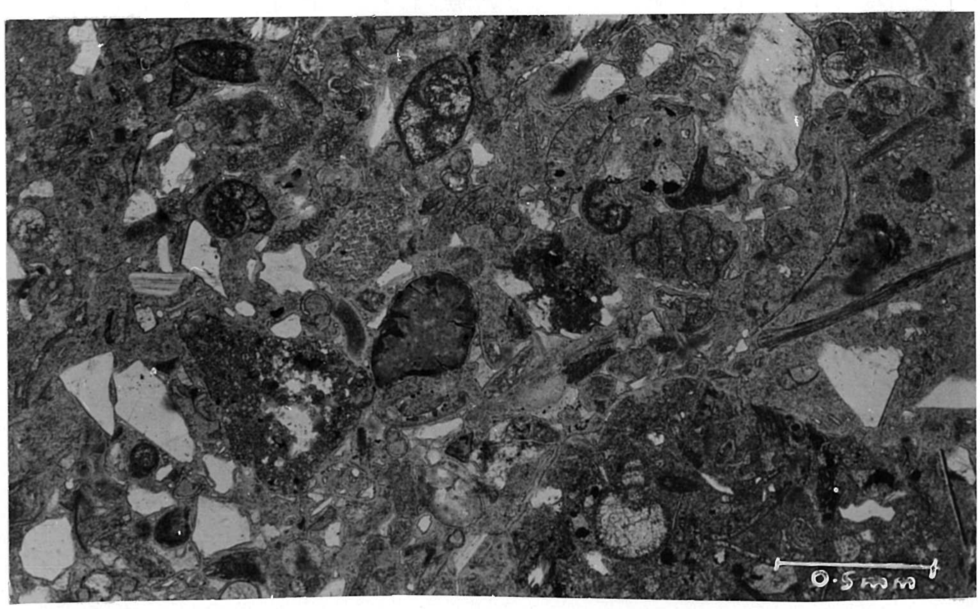


Fig. 40. Phosphate cemented quartzose bioclastic sediment from a pebble boring. Note a glauconite pellet, centre left. O.U.31332.

an intimate paragenetic relationship with each othr, and with the original host minerals, calcite, and aragonite. The following section describes their typical occurence in thin section.

Figure 41 is a photomicrograph of a mollusc shell (probably gastropodan), that shows differential aragonite replacement by glauconite, phosphate, and pyrite. The homogenous layer (a) consists of microcrystalline glauconite with some aggregreates of pyrite. The coarse crossed lamellar layer (b) is composed mainly of pale green strongly pleochroic coarse grained glauconite, with extinction parallel to the original second order lamels, running E.N.E.-W.S.W. and W.N.W.-E.S.E. The fine crossed lamellar layer (c) consists of a framework of birefringement apatite crystals in the lower part of the layer (c'), and crystalline glauconite and pyrite with minor apatite in the upper part of the layer c". Between the first order lamels of this layer is a cloudy phase, brown in colour, which is probably organic material derived from the original conchiolin matrix, and is largely replaced by pyrite in layer c".

A layer of aphanocrystalline phosphate, less than 20 m thick, coats the exterior of the specimen. Figure 42 illustrates the cemented interior matrix of the same mollusc (thin section O.U. 31330). Replacement of a calcareous foraminiferan by successive stages of apatite cementation is evident. Layer (a) is possibly the replaced equivalent of the original calcite test. Layers (b) and (c) represent later (or perhaps earlier) stages of phosphate, involving slightly different conditions reflected by the difference in colour from very pale (b) to dark yellowish brown (c). In each layer the individual crystals are arranged length fast, perpendicular to the surface. The relationship of the sparry calcite (d) to the phosphate is not certain and it might be interpreted as either an earlier or a later phase. A rimmed echinoid spine (e) is also present. Similar zoned phosphates have described by Braithwaite (1968) from a phosphate-carbonate

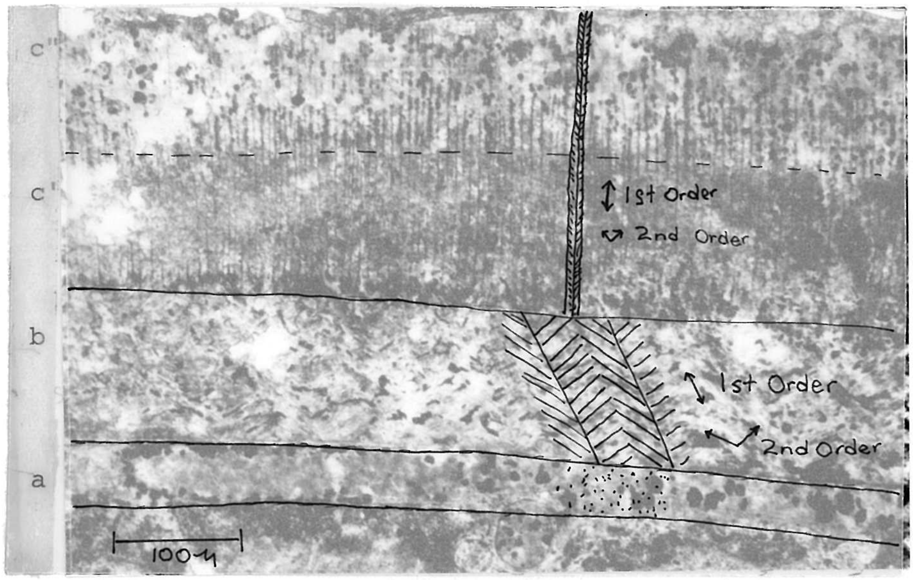


Fig.41. Diferential replacement of a gastropod shell. Layer a, pyrite and glauconite; b, mainly glauconite; c', phosphate; c", glauconite and pyrite. OU 31330.

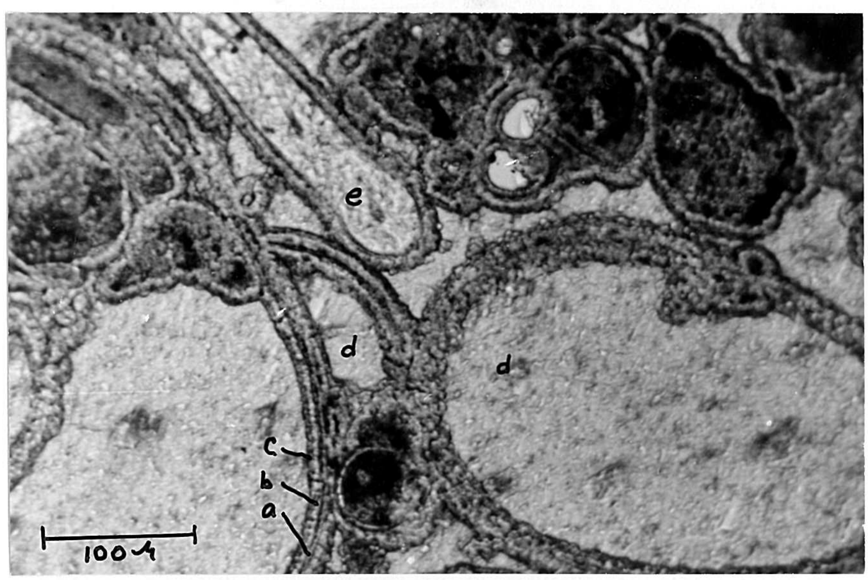


Fig.42. Zoned apatite cement in a bioclastic matrix. OU.31330.

deposit on Remire Island in the Indian Ocean.

Another gastropod (thin section O.U.31329) has been completely replaced by crystalline glauconite in the outer part of the shell, in such a way that the original shell microstructure is again retained. The interior and columellar part of the originally aragonitic shell have been partially replaced by unevenly distributed equidimensional crystals of low birefringent pale brown apatite, in places coalesce to form a close packed crystal mosaic (Fig.43). A thin outer 'skin' of microcrystalline phosphate is again present.

Barite occurs in thin section O.U.31329, a longitudinal section of a gastropod shell. Figure 44 shows a crystalline apatite mosaic (a) and barite (b) replacing the sparry calcite of the gastropod columella. The barite displays good crystal form against calcite. The umbilicus (u) and a wherl (w) are rimmed by apatite and filled by phosphatized shelly micritic matrix. Sparry barite also occurs as a shell cavity infilling in the matrix.

Partial replacement of an echinoderm test is illustrated in O.U. 31331. The original calcite test is largely unaltered. Infilling the inner part of the stereom is a dense mosaic of birefringent apatite crystals, which in places tend to replace the test. The outer test surface has a thin layer of microcrystalline glauconite which in thin section is seen to be associated with pyrite euhedra and intrudes from 0.5 to 1 mm into the stereom.

In thin section, then, the phosphate generally occurs as isotropic particles, or as rim aggregates of birefringent stubby prisms up to 20 m in diameter, from nearly colourless to dark brown. In hand specimens, pebble crusts are dark brown and glassy.

X.R.D. samples were prepared from ground fossil specimens. Selective leaching in dilute acid and in 0.5 M ammonium citrate, the latter method suggested by McConnell (1959), was used with varying success to remove calcite. Apatite peaks (fig.45) compare closely to those given for francolite by Brophy and Nash (1968). The angular distance

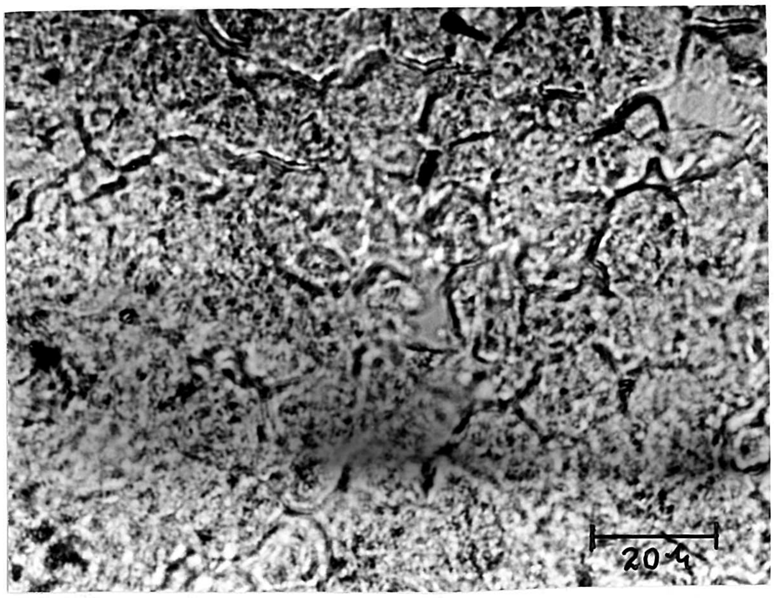


Fig.43. An apatite mosaic replacement of a gastropod Columella. O.U.31328.

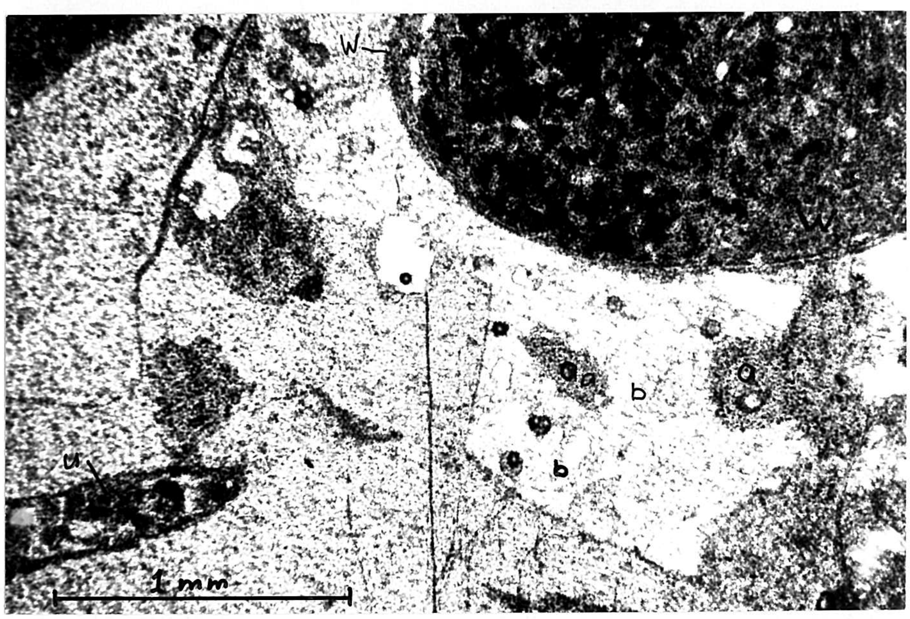


Fig.44. Gastropod columella replaced by barite (b) and dispersed apatite mosaics (a). OU31329.

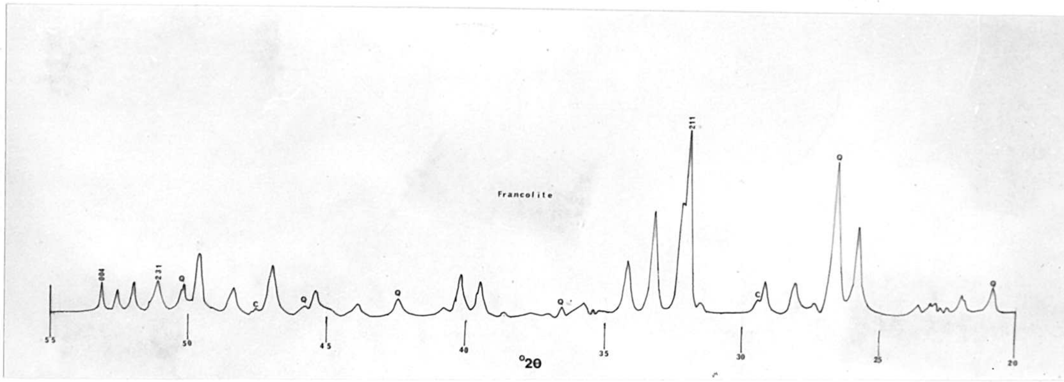


Fig. 45. X-ray diffractograph for francolite. Other peaks are quartz (Q) and calcite (C).

between (004) and (231) has been suggested (Silverman et al, 1952) to be a distinguisable criterion between carbonate fluorapatite (2.3 $2\theta^{o}$) and fluorapatite and hydroxyapatite (2.5 and 2.7 $2\theta^{o}$ respectively). Various samples from the phosphate bed give an angular (004) $\wedge$ (231) distance of 2.1 to 2.22 $^{o}2\theta$ for $Cu_{K_{\alpha}}$ radiation.

INTERPRETATION.

(1) Origin of Glauconite and Phosphate:

It is generally believed that glauconite and phosphates grow as authigenic minerals in the marine environment when the rate of sedimentation is slow. A reducing enviroment (or microenviroment) favours glauconite and pyrite growth, and this was probably provided in the conglomerate bed by the shelly calcareous ooze, rich in organic mucilage on exposed limestone pebbles and shell material, may have maintained the enviroment needed for the formation of glauconite in contact with free ocean water as a constant volume replacement of calcite and aragonite, and perhaps also by the alteration of clay minerals.

Experimentally, apatite has been formed in a variety of ways, summarized in Krauskopf (1967), and including:-

(1) By slow precipation, from seawater, with careful control of pH in the range 8 to 9 by addition of NaOH. This method, researched by Gulbrandsen et al. 1970, resulted in the co precipation of 0.064% P_2O_5 with aragonite.

(2) By replacement of calcium carbonate. This process involves the phosphatization of calcium carbonate by a solution that falls in an area in which apatite is stable, and is a viable mechanism for the formation of the phosphates discussed in this thesis.

The co-precipitation of apatite and aragonite from seawater, suggested by Gulbrandson to account for the P_2O_5 content of normal limestones, does not appear to be applicable in this case, unless such a primary process has been obscured by later redeposition of the phases involved.

(2) Depositional Process:

Data obtained from field observations and laboratory work are consistent with the following inferred history (Fig.46).

The phosphatic horizon appears to have been a hard-ground developed during a hiatus in sedimentation during the Upper Oligocene, with the uppermost tens of centimeters of the limestone becoming cemented on the sea floor. Bathurst (1971) has described a similar case of recent carbonate cementation within the uppermost few centimeters of lime sand in the Persian Gulf. Alternatively hardening may have been affected by the cementation of phosphate crusts. Clearly, early cementation is a prerequisite for the development of semicontinuous areas of hardened sea floor, since the lithified carbonate sand so formed was exhumed, bored and abraded into pebbles.

Burrowing organisms may have been able to colonize transiet areas of soft sediment and therefore do not necessarily pre-date local hardening. Biogenic debris, possibly including infauna, accumulated throughout the life of the surface, in sediment filled pockets and among and on the pebbles. The formation of phosphate and glauconite shell casts appears to have been a continuing process taking place on the sea floor rather than post depositionally in the sediment.

The complexity of processes that a number of fossils have been subjected to is demonstrated by considering fossils described in the previous section, and on the following page.

(a) Gastropod Fragment (Fig.41. O.U. 31330):

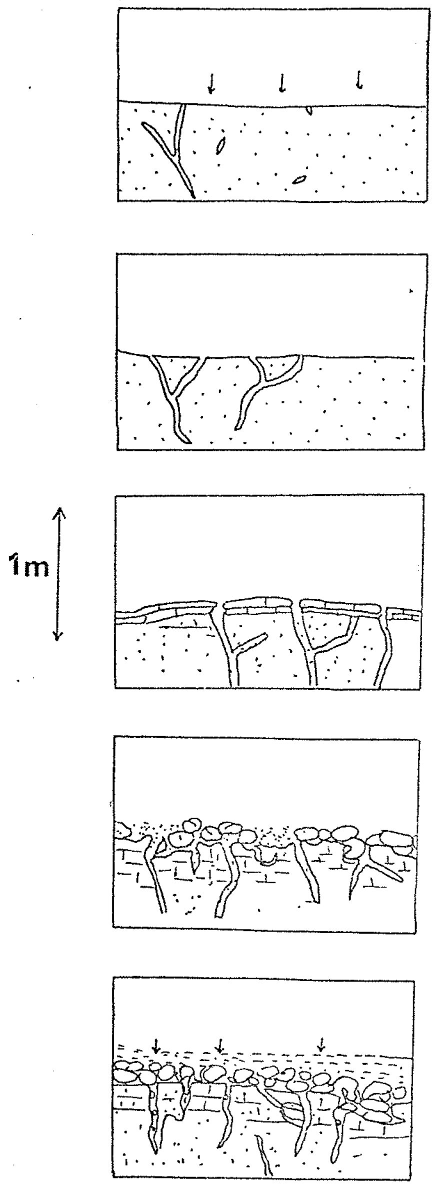
(1) After the death of the animal, the shell remained empty on the sea floor, becoming encrusted by annelid tubes, and possibly bored by algae.

(2) The outer surfaces of the shell, together with the encrusting epifauna were replaced by glauconite with some pyrite.

(3) The shell was buried in the sediment and filled with micritic phosphatic skeletal debris with minor glauconite as pellets and foraminiferida test fillings.

(4) In the sediment the middle shell layer, which had not been previously glauconitized, was replaced by apatite. Originally siliceous sponge spicules in the matrix were later dissolved and replaced by sparry calcite.

(b) Gastropod shell (O.U. 31328): This shell suffered



1.Deposition of fine sandy slightly glauconitic limestone, with mild burrowing activity. Sparse fossils and phosphatic nodules.

2.Cessation of sedimentation, development of an erosion surface with related burrow systems.

3.Local and irregular hardening of the top few cms of burrowed sediment.

4.Hardened surface bored by molluscs and encrusted by surpulids and bryozoa, and colonized by epifaunal invertebrates. Phosphatization and glauconitization, possibly preceded by algal boring and micrite precipitation onexposed surfaces. Accumulation of skeletal debris, and insitu clasts of hardened limestone.

5.Resumed sedimentation activity, with deposition of sandy marls of the Inangahua Formation.

Fig.46.A schematic development of the phosphatic horizon.

a similar initial sequence of changes.

(1) As above.

(2) The outer part of the shell whorl was completely replaced by glauconite without pyrite.

(3) As above.

(4) Following burial the unaltered columella was in places slightly phosphatized.

(5) Transformation of the remaining unaltered aragonite to calcite.

(c) Echinoderm Test. (O.U. 31329):

(1) Following the death of the animal, possibly attributed to predation by a tonnacean gastropod such as Austrosassia (Beu, et al, 1972) the test remained empty on the sea floor.

(2) The inner and outer surfaces of the test were covered by a thin skin of glauconite, with some pyrite, both minerals possbly replacing previously deposited micrite in the stereom.

(3) Buried

(4) Finally, centripetal growth of a phosphate mosaic in the stereom, with slight replacement of calcite.

PALAEOECOLOGY:

A rich fauna collected from the horizon consists primarily of bivalves, gastropods and echinoids, with brachiopods, bryozoa and corals as minor components. A faunal list is presented in Table 3, together with an inferred depth and substrate distribution. This analysis is based on the known distribution of Recent analogous taxa in the New Zealand area, and in the Australian and Western Pacific, with data derived from Morton and Millee (1966), Macpherson and Gabriel (1962), Habe (1964) and Fleming (1969). Much of the shell detail is preserved and the majority of brachiopoda and bivalvia (in particular, Procardia) are articulated double valves, and hence are not derived.

Because the fauna comprises species that lived either on a soft sand substrate or on a hard substrate, both bottom types were closely associated during the life of the horizon. With some exceptions, the fauna is consistent with water depths of about 20 m, However, the absence of stromatolitic algae (abundant in the lime stone below) and the occurrence of the genus Euciroa, which is now characteristic of the bathyal zone, (Fleming 1969), may suggest that the horizon was formed at somewhat greater outer shelf depths. Alternatively the conflicts of data may reflect changing autocology of the species concerned, or variation in some other parameter besides depth.

Table 3. Fauna From the Horizon.

	Substrate		Bathymetric Distribution
	Hard	Soft	
Bivalvia:			
Limopsis zealandica (Hutton)		x	5-100 m
Parvamussium zitteli (Hutton)			Inner Shelf
Lamatula cf. trulla (Marwick)		x	
? Hedecardium sp.		x	Shelf
Longimactra leda (Finlay)		x	To outer Shelf
? Teredo heaphi (Zittel)			
Procardia dolicha (Suter)		x	? Near - offshore
Euciroa cf. ulrichi (Fleming)		x	Outer Shelf - Bathyal
? Cuspidaria sp.		x	Mid Shelf
Gastropoda:			
Astrea bicarinata (Suter)	x		Lowtide - 30 m
Turritella sp.		x	Lowtide - Offshore
Pyrazus sutherlandi (Marwick)		x	Lowtide
Serpulorbis Ophiodes (Marshall & Murdock)	x		Nearshore
Cirsotrema Sp		x	Intertidal to Outer Shelf
Capulus sp	x		Offshore
Cypraea trelissickensis (Suter)	x		Near - Offshore
Willungia fracta (Tomlin)		x	
Magnatica sp		x	
Polinices blaeasa (Marwick)		x	
Mayena sculpturatum (Finlay)	x		Intertidal - few meter
Austrosassia procera		x	Lowtide - offshore
Ficus parvus (Suter)	x		Offshore
? Austrofusus			Nearshore
Conus sp.			Nearshore
Cephalopoda:			
Aturia sp.			Neritic

Table 3 continued:

Brachiopoda:			
Liothyrella concentrica (Hutton)	x		
Campages sp	x		
Terebratulina seussi (Hutton)	x		
Tegulorhynchia squamosa (Hutton)	x		
Waiparia sp	x		
Echinoidea:			
Opissaster rotundatus (Zittel)	x		
Duncaniaster sp.	x		
Coelentrata:			
Flabellum pavoninum distinctum (Edwardsand Maine)	x		
Stephanocyathus (Odontocyathus) mantelli (Edwards and Maine)	x		
Keratesis sp.	x		
Parisis sp	x		
also			
Bryozoa	x		Near to Offshore
Annelida (faecal trails)	x	x	Near to Offshore
Ophiomorpha ?		x	Intertidal to 10 m
Boring algae	x		Photic Zone (to ~ 50 m)
cetacean bone fragments			

CHAPTER SIX.

STRUCTURE

In Fletcher Creek the strata form a monoclinal structure with dips generally increasing up the sequence from 20°-30° in the Brunner Formation to 60°-90° in upper strata of the Inangahua Formation, Rough Creek Coal Measures and Old Man Gravels. A displaced fault sliver of Brunner strata is preserved along a north east trending fault, downthrown side to the west, near 280,446.

At Inangahua the most conspicuous structural feature is the gently folded Mount Courtney Sycline, plunging at a low angle to the North-West. The Inangahua Fault, downthrown side to the east, is not exactly located in the area mapped. Little evidence for the fault is seen in aerial photographs. However, strata immediately to the west of the fault were observed to dip at a high angle to the east in a drag folded anticlinal structure.

CHAPTER SEVEN.

GEOLOGICAL HISTORY.

Carter and Landis (1972) suggested the presence of a widespread Oligocene unconformity in New Zealand and southern Australia which, in southern New Zealand, truncates the later Cretaceous to early Oligocene transgressive shallow shelf sequence and is usually associated with erosion of the underlying rocks, and/or hard ground conditions and condensed strata. The surface is believed to be genetically associated with bottom oceanic currents generated during the separation of the Australian and Antarctic continents in the Oligocene.

Dr. R.M. Carter (Pers. Comm.) has suggested a reinterpretation of the Greymouth geological sequence (Gage 1952). Gage interpreted the eastern breccia facies of the Omotumotu Formation at Greymouth as of Kaiatan age, though at least locally it unconformably overlies an erosion surface on the Kaiata Formation. The breccia contains an abundance of mudstone clasts, and hence the Kaiatan dates from the microfauna in the Omotumotu breccias may well have been based on derived fauna. Gage considered the western sandstone facies of the Omotumotu Formation to be conformable upon the Kaiata Formation. However, these sandstones can be reinterpreted as a genetically different unit, possibly a long shore barrier facies (as seen at Cape Foulwind, Westport) and hence part of the transgressive lower Tertiary sequence.

An analogous situation is envisaged for the stratigraphic sequence at Inangahua (Fig.47). Following deposition of the transgressive sequence of Brunner coal measures, Island sandstone and algal limestone, and Kaiata mudstone with a very fine sand facies at the top, a change in the sedimentation conditions caused erosion of the mudstone and deposition of numerous rock types as breccia clasts in a bioclastic detrital matrix. Erosion of the mudstone, with local concentration of previously formed concretions, occured both as a response to high energy sedimentary conditions (i.e. high current

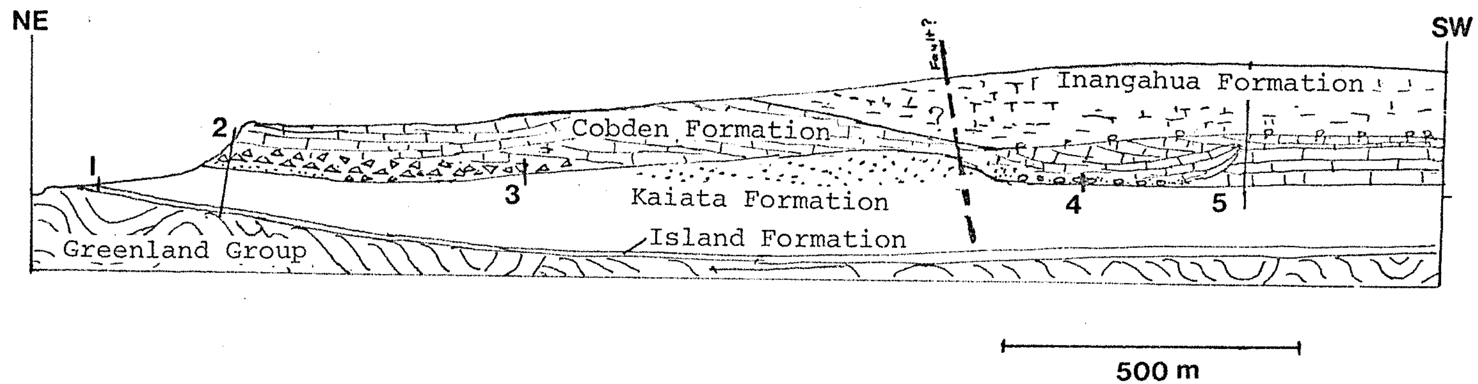


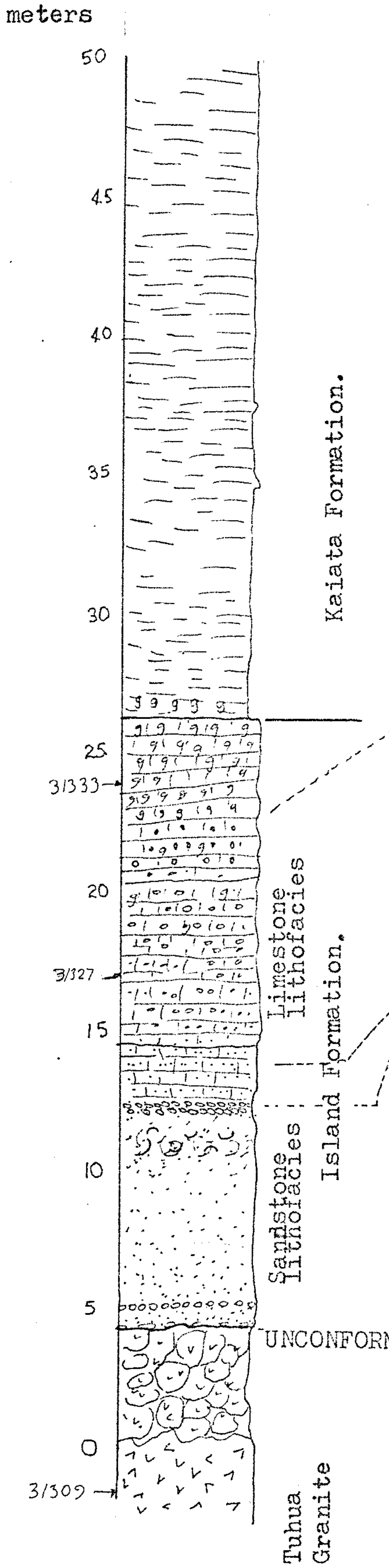
Fig.47. A diagramatic cross-sectuon through the Buller Gorge projected on to a line from 370610 to 392622. Numbers refer to the stratigraphic position of the measured sections.

velocities), and to local faulting related to Oligocene movements on nearby faults, and possibly also the Alpine fault. Deposition of coarse grained, abraded bioclastic detritus with some phosphate continued until a phosphatic hard ground developed on the sediment surface.

In the early Mocene more normal regressive sedimentary conditions were resumed with turbidite deposition of the Inangahua Formation and, with increasing terrestrial influence, deposition of terrestrial coal measures occurred. A thin sequence of strata was deposited during a minor marine incursion during the Waitotaran, followed by a thick sequence of Pleistocene terrestrial alluvium (Old Man Gravels) - the deposition of the alluvium being accompanied and preceded by progressive basin subsidence, and laying down of recent Gravels.

APPENDIX A: MEASURED SECTIONS.

Measured Section 1. (404 611).



Pyrite nodules and carbonate cemented burrows and concretions common.

Dark brown massive carbonaceous mudstone, glauconitic near the sharply defined base.

Darker grey foraminiferida rich limestone with more glauconite and fewer algae.

grades up to

Muddy slightly quartzose algal limestone. Alga occur as stromatolitic sphereical masses up to 10cm in diameter, scattered in a medium grey foraminiferal shelly, muddy, cemented matrix

Dark grey quartzose algal bearing limestone.

Limonite cemented quartzose sandy gravel. Greywacke with a few granitic pebbles

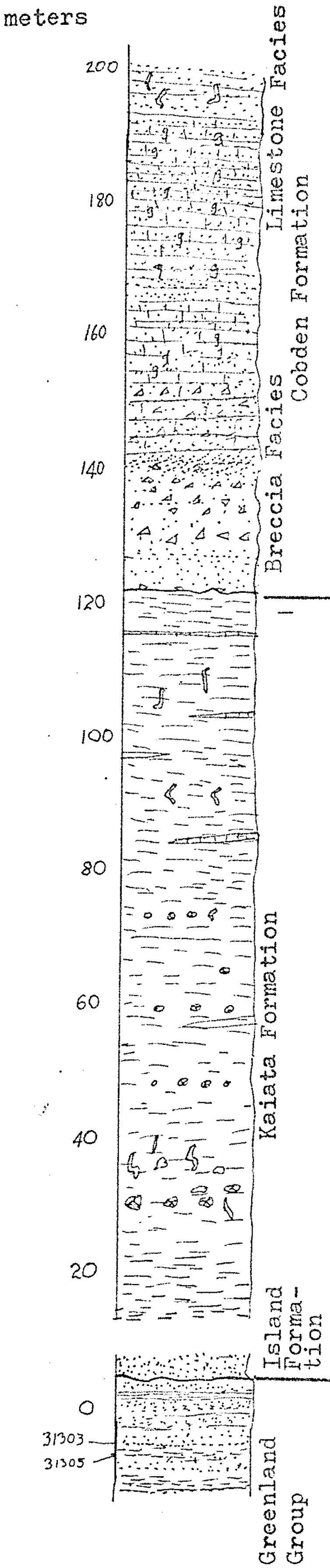
Yellow-brown slightly muscovitic quartz-calcanenite. Wellsorted fine to medium sand. Biohermal groups of <u>Ostrea</u> withscattered <u>Sectipecten</u> . Rare leaf impressions in lower strata.

Quartzose grit overlain by a thin layer of granite pebbles up to 6 cm in diameter.

Zone of leached weathered granite. May be tectonically brecciated.

Coarse grained dark grey porphoritic biotite diorite. Contains abundant hornfelsed greywacke(?) xenoliths and cross-cutting veins of pink orthoclase granite.

Measured Section 2. (391623) to(389621).



Greyish cream sandy limestone with scattered phosphatic nodul nodules up to 3 cm in diameter. bedding fro 20 to 60 cm in thickness. Fragment of calcareous algae and Ostrea .

grades up to

Sandy quartz granule glauconitic calcarenite. Bedding thickness variable; some graded beds defined by size sorting of algal fragments up to 5 mm in diameter.

grades up to

Breccia; unsupported framework of lithoclasts aligned in a coarse grained biogenic limestone matrix.

Incipiently cross bedded coarse grained quartzose sandy limestone. Calcareous algae abundant.

Gritty calcarenite with granitic and greywacke boulders to1m.

Finely bedded quartzose medium grained calcarenite.Scattered weathered granite pebbles along basalcontact.

Unconformity.

Browish-black carbonaceous micaceous mudstone Septarian concretions up to 50 cm in diameter and calcite cemented burrows common. muddy carbonate nodules from 1 to 40 mm in diameter ocassionally occur in distinct horizons. Rare discontinuous cemented concretionary horizons up to 10 cm in thickness.

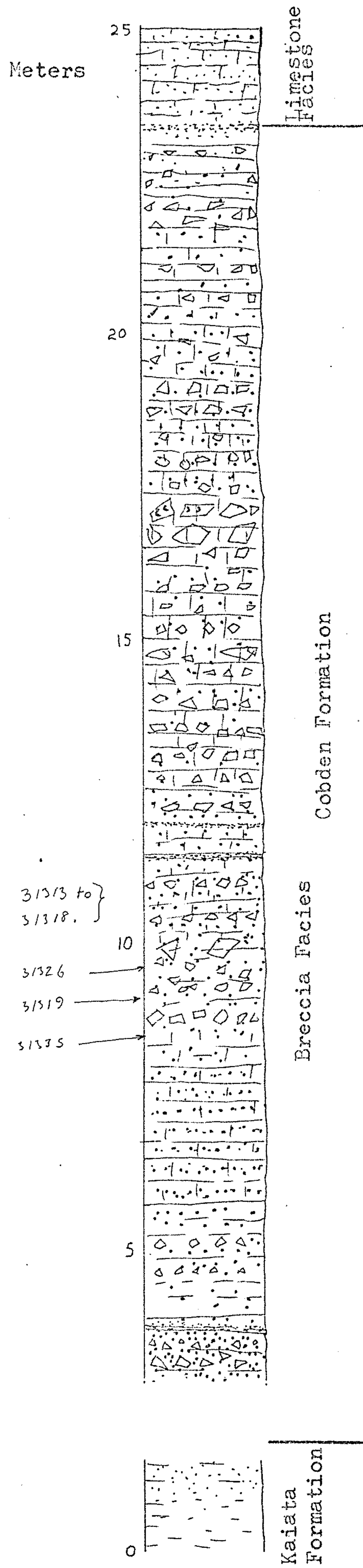
6m obscured.

Yellow brown wellsorted medium quartzose sand .

Unconformity.

Dark greenish grey greywacke and argillite. Bedding defined by sharp margins between coarse and fine grained beds. Slaty cleavage developed in argillites, where micro bedding is common.

Measured Section 3. (385624)



Yellow-grey fine sandy limestone. Slightly glauconitic

Micaceous calcarenite bed

Breccia with common granitic blocks up to 50cm and rarely exceeding 100cm in diameter dispersed in indistinct horizons. Quartzose shell-fragmant matrix.

Thin lens of laminated micaceous sand.
Fine grained breccia.
10cm. Laminated micaceous sand.

Breccia. Granite, greywacke, and hornfels boulders up 40 cm in diameter, but generally 15 to 20 cm. Quartzos shell fragment matrix.

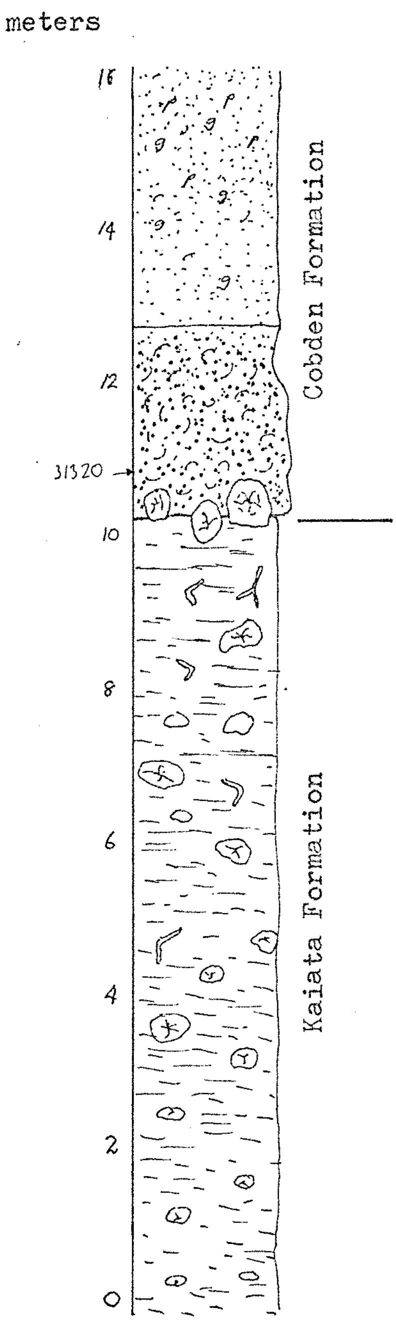
Calcareous shelly grit. Bedding defined by orientation of lithoclasts up to 3cm in diameter. Shell fragments and calcareous algae common.

2cm. Fine silty sand, thinly bedded and laterally disco tinuous.
Pale coarse sandy quartzose limestone with an unsupport framework of lithoclasts.
Gap of 2m.

Inferred Unconformity

Medium grey very fine sandy, muscovitic calcarenite.

Measured Section 4. (377618)



Pale yellow-brown slightly glauconitic medium quartzose sandy limestone; with scattered phosphatic nodules up to 5 cm in diameter. Echinoderms and brachiopods including ?Rhizothyris.

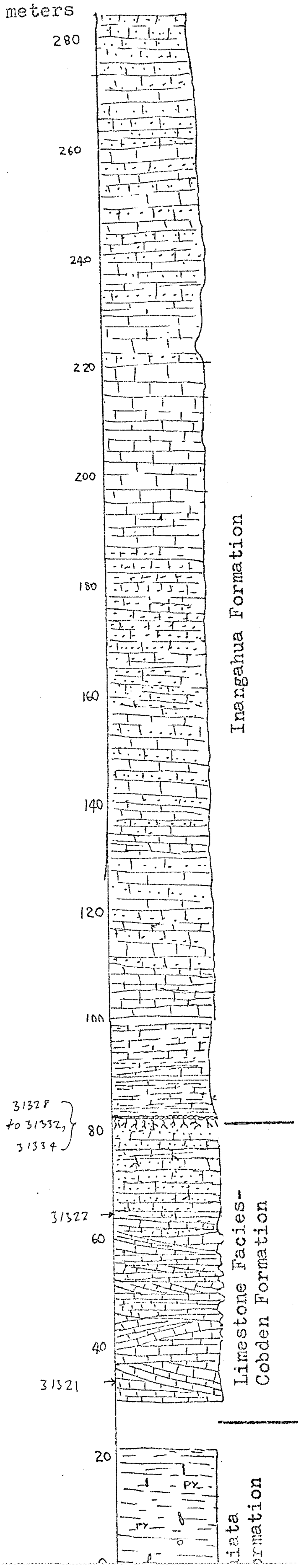
grades up to

Dark grey fossiliferous calcite cemented quartzo-feldspathic grit. Basal contact irregular and sharp with concentrated septarian concretions similar in appearance to those in the mudstone below but with an outer 5 cm layer of cemented grit.

Unconformity

Blue-grey calcareous micaceous marl. Abundant septarian concretions up to 1m in diameter with radial and concentric fractures- filled with yellow brown sparry calcite. Dentalium and Ophiomorpha.

Measured Section 5. (377 615)to(378 610)



As below, but with individual beds from 40 to 140 cm in thickness.

Blue-grey very fine sandy limestone. Graded beds from 10 to 30 cm in thickness, sparse macrofauna.

Fossiliferous Conglomerate. Greenish to brown on weathere surfaces. Bored phosphatised limestone pebbles to 20cm dia Abundant Brachiopoda, mollusca and echinoids, commonly as phosphatic or glauconitic casts.

limestone. Sparsely fossiliferous. Burrowed top 2 m, fine grained and quartzose.

Local abundance of sphereical calcareous algae up to 10 c in diameter.

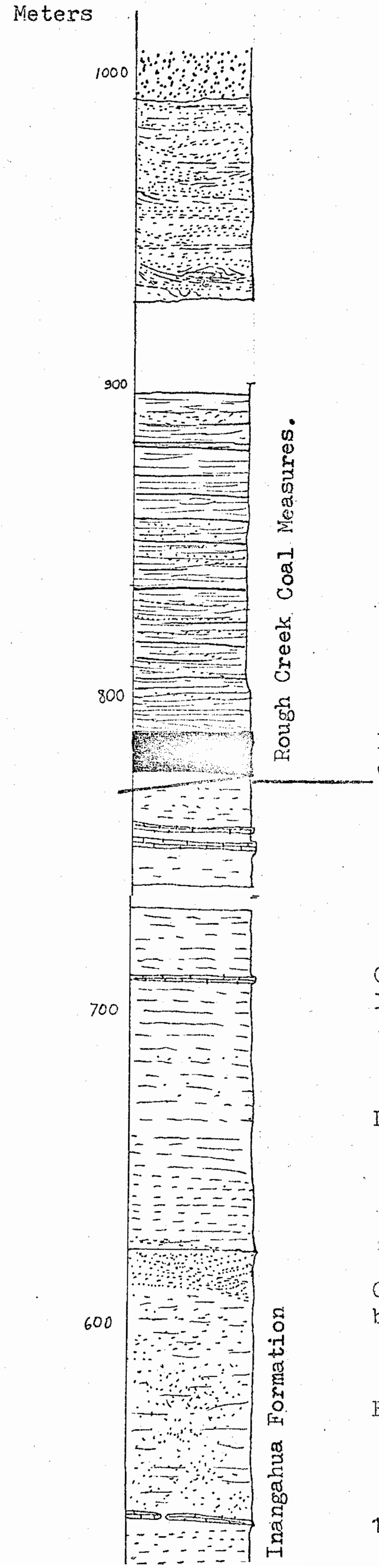
As below, but with massive crossbedding and channel structures.

Algal bearing coarse grained quartzose limestone. Fine to coarse bedding with concentrations of glauconite pellets and algal fragments. Interbedded coarse and fine grain beds. Phosphate nodules common. Rare greywacke pebbles

Inferred Unconformity

Blue-grey micaceous siltstone. Bedding defined by mica flake orientation. Pyrite concretions and calcareous cemented burrows commonly with a sparry calcite core.

Measured Section 6. Fletcher Creek (279446)to (298441).



Yellow-brown massive quartzose sandstone.

Interbedded compact, medium sand and silts,commonly with deformed bedding and scour and fill structures . Burrows from 10-15 mm in diameter in bioturbated beds.

Laminated fine-medium quartzose sand and carbonaceous siltstone with thin coal laminae.

Fault involved hard, black coal seam with interbedded quartzose sand laminae from 5 to 10 cm thick.

Concretionary horizons of carbonaceous medium sandstone.

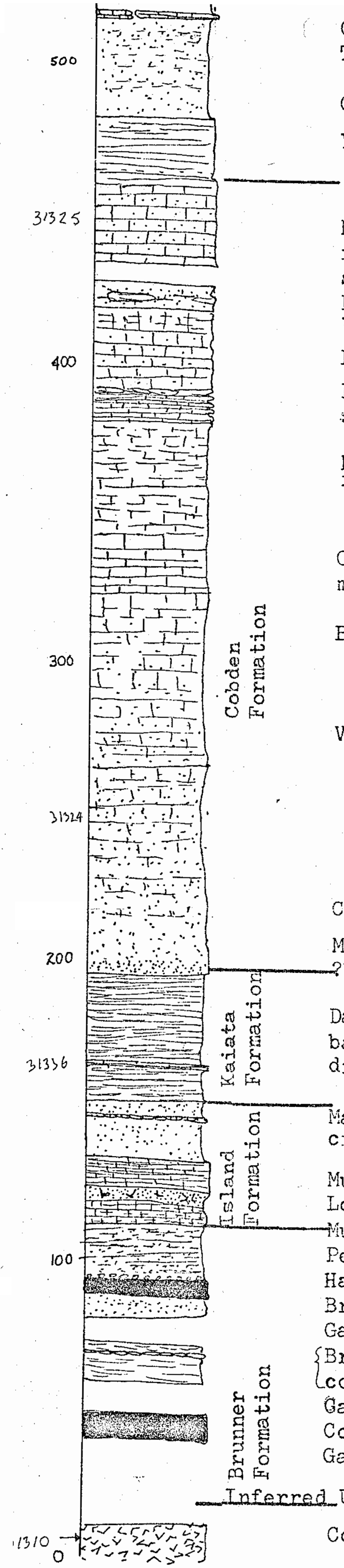
Concretionary limestone band with abundant carbonised leaf impressions

Dark grey muddy fine sandstone, finely bedded

Cross bedded muddy carbonaceous fine sandstone. Uncemented but compact, with sparse chalky macrofossils.

Fine sandy carbonaceous siltstone.

10 cm concretionary band



Concretionary band.
Thinly bedded fine sandstone with carbonaceous laminae.
grades up to
Grey fine quartzose massive noncalcareous sandstone.
Yellow grey very fine sandy marl. Coarse bedding.

Massive coarsely crystalline limestone. common algae fragments and glauconite pellets. Pinkish on weathered surfaces. Basal contact obscured.
Pale grey marl with lensoid cemented bands.20 to 80 cm thick.Sandy at the top.
Flaggy spar cemented shell fragment biosparite.
Pale grey banded very fine grained limestone with hard and soft alternating bands from 20 to 50 cm apart.

Massive pale grey marly limestone,burrowed,with a sparse fauna of small brachiopods and rare echinoderm plates.
grades up to
Crystalline coarsegrained biosparite with little terrigenous material. Flaggy.

Biotitic sandy limestone,coarse grained.

Very coarse granular calcarenite.

grades up to

Calcareous quartz arenite, coarse granule sand.
Muddy granule sand.
?Unconformity.

Dark brown micaceous mudstone, burrowed, with scattered barite bearing carbonate concretions up to 5 cm in diameter.Mica flakes up to 2mm accross. Rare chalky coral
Massive sandstone, burrowed (Ophiomorpha), with a thin concretionary horizon.
Muddy algal bearing quartzose, glauconitic limestone
Loose fine -medium sandstone. Ophiomorpha common.
Muddy algal bearing limestone with abundant quartz pebble Ostrea.
Pebbly quartzose sandstone.
Hard black coal seam with quartzose sand laminae.
Brownish black quartzose granule sand. Finely bedded.
Gap.
Brownish black fine muddy sandstone with a carbonate concretionary layer contain foraminiferida and Teredo, Flabellum.
Gap
Coal outcrops in stream bed.
Gap
Inferred Unconformity.
Coarse grained deeply weathered microline granite

Appendix B:

SYSTEMATIC PALEONTOLOGY:

(1) Calcareous Algae:

Calcareous algae occur throughout the limestone lithofacies of the Island Formation and are also abundant in the Cobden Formation:

RHODOPHYTA (Red Algae)

Family CORALLINACEAE (Coralline Algae)

Sub Family MELOBESIOIDEAE (Crustose corallines).

Archeolithamnion sp:

Occurence - Island Formation (Sections 1 and 6).

Material - Thinsection O.U.31327 and hard specimens.

Description - Thallus thick and crustose, encrusting bryozoa fragments and foraminifera. Tissue mainly regular in texture with areas of well developed growth zones. Hypothallus well developed, variable in thickness, consisting of horizontal to curved rows to cells 10-14 μ in length 6-10 μ in height occasionally arranged coaxially (Fig.I b). Perithalus tissue, (Fig.I a) thick, regular, with pronounced vertical and horizontal rows of cells 6-8 μ in width, 8-10 μ in length, Side walls thin but cross partitions distinct. Sporangia, rare, ovate, in closely spaced groups, 26 m in thickness 40 μ in height.

Dermatolithon sp:

Occurrence - Island Formation (Sections 1 and 6).

Material - Thinsection O.U.31327

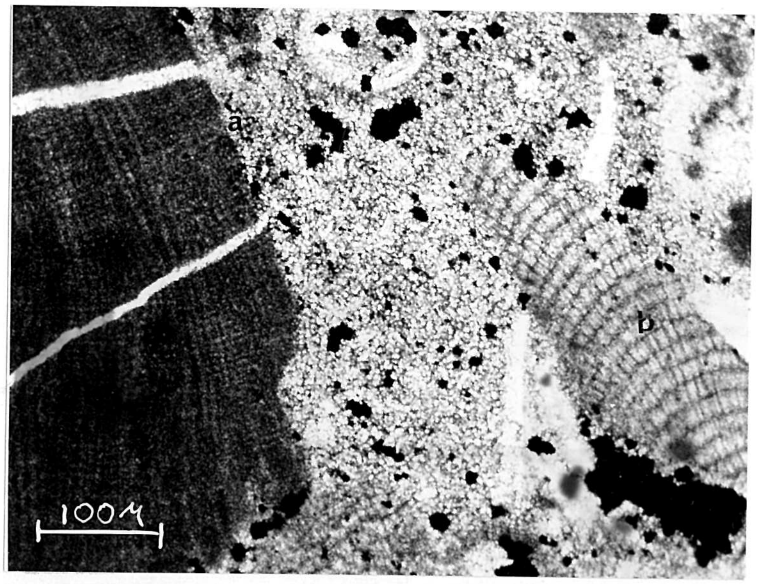
Description:- Associated with Archeolithamnion. Occurs as rare thalli with a single layer of cells 25 μ in width, 20 μ in height, rarely associated with flask shaped conceptacles 250 μ and 200 μ in diameter, with a well defined single aperture.

Remarks - Both Archeolithamnion and Dermatolithon are common Eocene genera (Johnson, 1957).

Lithothamnion sp:

Occurrence - Cobden Formation (Section 3).

Material - Thinsection O.U.31335, and hand specimens.



Fig, I. Archiolithamnion. Perithalus, p, and hypothalus, b.

Fig.II. A general view of lithothamnion encrusting a bryozoa fragment.

Description - Pale creamish white in colour, occuring as crustose nodules and irregular blebs up to 80 mm in diameter, and as encrustations around rocks and shell fragments. Thallus thick, regular. Hypothalus thin, of curved rows of cells. Perithalus thick and well developed. Cells hexagonal in cross section with longest dimension (8-10 μ) normal to layering. Growth zones variable. occassionally well developed. Rare lensoid sporangia filled conceptacles, 280u in diameter, 180 u in height, around which the perithalus cells regularly curve.

Lithophyllum sp:

Occurrence - Cobden Formation (Sections 3 and 5).

Material - Thin section O.U.31335, peel O.U.31326, and hand specimens.

Descriptions: Individual thalli in well defined growth zones from 10 to 20 cells in thickness. Hypothalus well developed, consisting of curved irregular rows of cells (Fig.III, h), terminating at a thin to moderately thick perithalus with vertical rows of cells. (Fig.III, p). Hypothalus cells of irregular shape, 20 μ to 26 μ in length, 14 μ to 22 μ in width. Conceptacles well defined, 500 μ in diameter. 200 μ in height (Fig.IV a).

Remarks: Lithophyllum is uncommon in the breccia facies of the becoming more abundant in the overlying limestone. Lithothamnion is of greater abundance in the breccia.

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2 Teredinid tubes, described below, occur in a concretionary horizon in the Brunner Formation (Section 6, 64 m). Teredo-like borings and tubes are also found above in the Kaiata Formation, where they associated with calcified wood fragment.

Mollusca.

Class BIVALVIA

Order MYOIDA

Family TEREDINIDAE

Teredora or Nototeredo sp (Fig.V) S31/f 861

Description - Tube pale grey, calcareous. 3 mm in diameter, converging to 2 mm in diameter at apeture (a). Tube wall 0.18 mm thick, composed of a single calcitic lamellar layer with lammels normal to the tube surface. Cross section

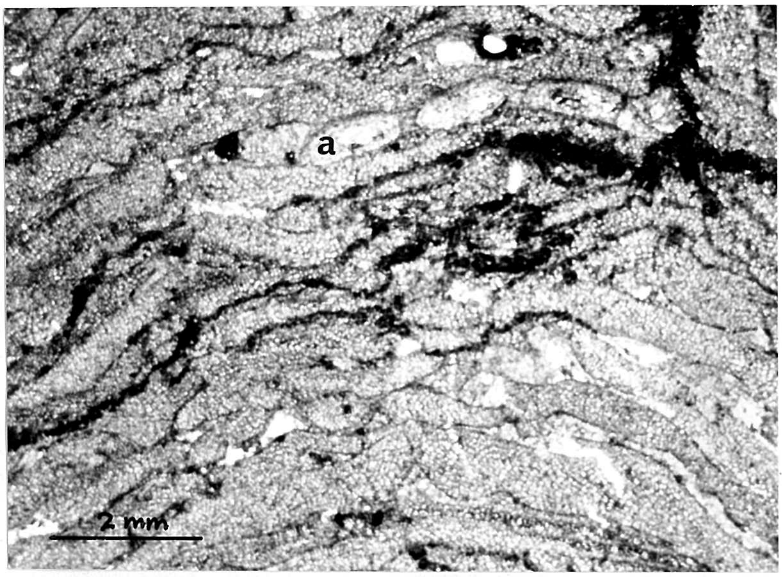

Fig.III.
Lithophyllum.
Note conceptacle with
a single apeture. Peel.

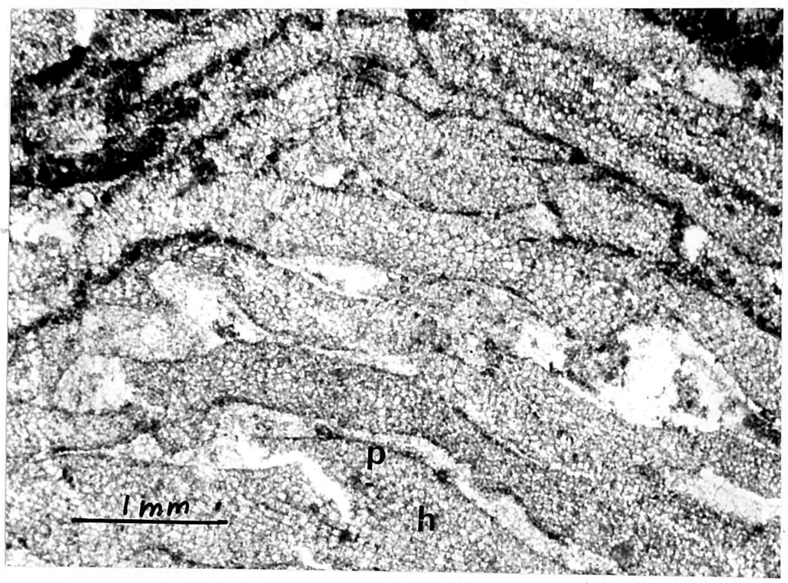

Fig.IV.

Lithophyllum.
Hypothalus,h;
perithalus, P.

Fig.V. Teredo.

circular. Open cup-like calcareous concamerations (c) directed toward posterior end, attached to the tube interior. Enclosed by, but free of, the concamerae is an inner, sediment filled, thin calcareous tube (s), oval in cross section, situated near the posterior end of the tube. Concamerae are reduced anterially, where a narrow groove traverses the tube axis.

Remarks: Tubes from 3 to 16 mm in diameter, 10 cm in length are common and occur orientated parallel to each other and parallel to the bedding plane. Carbonized wood impression are associated with the tubes. No shell has been collected.

The inner calcareous tube can be interpreted as a calcareous lining of the inhalent and exhalent syphons. Yonge (1927) described a recent Teredinid that lives vertically embedded in mud of mangroove swamps of the Pacific, and normally has its syphons encased in a calcareous deposit, thereby suppressing the danger of suffocation by accumulating deposits. Turner (1966) discussed the function of concamerae, which allow the animal to shut off its tube with the help of anteriorly positioned flattened pellets (not preserved in the material at hand).

Teredinids have been recorded from the Island Formation near Greymouth by Gage (1952) and several species have been described from the Pareora in New Zealand (Fleming 1966).

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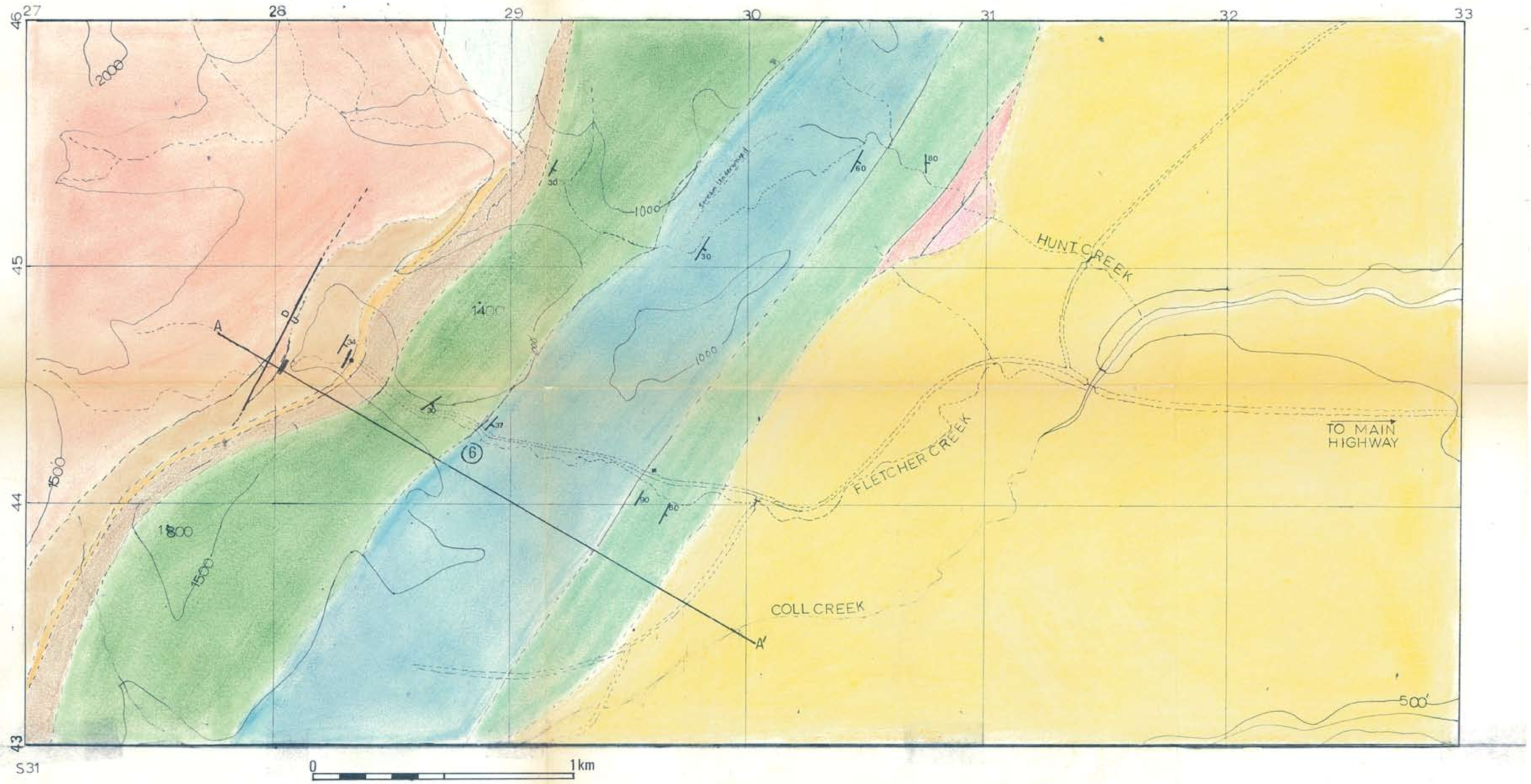
GEOLOGICAL MAP, FLETCHER CREEK AREA

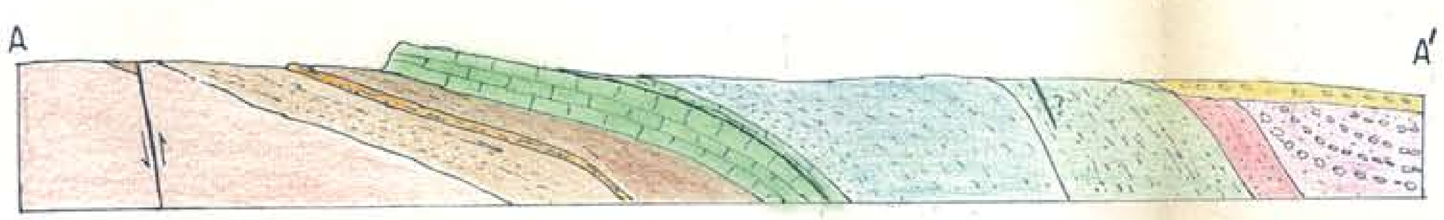


LEGEND

SYMBOLS

Road
Stream
Contact
Dip and Strike

FORMATION	AGE
ALLUVIUM	H
UNCONFORMITY	
OLD MAN GRAVELS	Wn ?
MARINE BEDS	Ww
ROUGH CREEK COAL MEASURES	T S
INANGAHUA	P ↕ Lw
COBDEN	↕ Lwh
UNCONFORMITY	
KAIATA	Ar
ISLAND	↕
BRUNNER	Ak
UNCONFORMITY	
HAWKS CRAG BRECCIA	Cretaceous
UNCONFORMITY	
TUHUA GRANITE	Carboniferous ?



CROSS SECTION (After Suggate and Wellman)

LINDQVIST 1972

GEOLOGICAL MAP, INANGAHUA AREA