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Middle Triassic deltaic deposits in Long Gully, near Otematata, north Otago, New Zealand

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The Corbies Creek Group is additional evidence of shallow marine and terrestrial deposition of some Torlesse rocks during the Middle Triassic. The upper portion of the Corbies Creek Group exposed in Long Gully, 5 km southwest of Otematata, is here interpreted as the remains of a large marine delta, similar to that of the modern Mississippi River. At the base of the deltaic sequence offshore marine siltstones are overlain gradationally by sandstones of barrier bars, probably formed by marine erosion of older delta lobes. These sandstones in turn are overlain by intertidal and lagoonal siltstone and shale and then by a unit of sandstone, siltstone and shale which includes several subunits probably deposited in various subenvironments of a digitate delta. Marine regression effected by the local progradation of the delta lobe finally resulted in the accumulation of coal, shale, siltstone and sandstone on a freshwater delta plain. These terrestrial sediments at the top of the exposed sequence contain megafossil plants similar to other Middle Triassic coastal floras of New Zealand. The lithostratigraphy of the Corbies Creek Group is discussed in an appendix, and several new names are proposed.

INTRODUCTION

Like the Mt Potts Group (Retallack, 1979, 1980), the Corbies Creek Grou shallow marine and terrestrial Middle Triassic rock unit within the deformed Me quartzofeldspathic sandstones which form much of the spectacular mountain scen New Zealand. The Corbies Creek Group also furnishes critical evidence f palaeogeographic and tectonic interpretation of these widespread Mesozoic sands here non-committally termed "Torlesse rocks" (for reasons outlined by Retallack,. These rocks have long been regarded as "eugeosynclinal", deposited in a deep basin adjacent to the shallow marine shelf deposits of the Murihiku Supergroup far west and south (Fleming, 1970). Such an interpretation is difficult to reconcile wi existence of shallow marine and terrestrial Triassic deposits, such as the Mt Pot Corbies Creek Groups, within Torlesse rocks. The nature and location of these s marine rocks are in better accord with the idea advanced by increasing numb geologists (e.g. Coombs *et al.*, 1976; Andrews *et al.*, 1977), that the Torlesse rocks completely different Mesozoic provenance and history to the volcaniclastic Mu Supergroup and allied rocks.

The Mt Potts and Corbies Creek Groups are also among the few Gondwanan T rock units in which terrestrial plant and marine fossils are closely associated. Thu are critical for correlation of a plant-based terrestrial ecostratigraphy and biostratig of Gondwana (as proposed by Retallack, 1977) with the standard geological time which is based largely on the biostratigraphy of marine fossils.

Only the fossil-plant-bearing unit and related marine rocks of the upper Corbies Group are considered in detail here, as evidence for a reconstruction of the vege palaeoenvironment and palaeogeography of Long Gully for a time within the late M

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Triassic (Kaihikuan local stage, roughly equivalent to the Ladinian international The lower Corbies Creek Group and other aspects of its geology are discussed by *al.* (1962), Campbell and Warren (1965), Ryburn (1967) and Force (1974).

Fossil locality numbers cited in this paper (for example, S117/f755) are registe the New Zealand Fossil Record File. Most marine fossils from Long Gully are hou the Geology Department, Otago University, Dunedin and most plant fossils are collections of the New Zealand Geological Survey, Lower Hutt. Formal definit lithostratigraphic units of the Corbies Creek Group is detailed in an appendix paper.

CORBIES CREEK GROUP

This Middle Triassic sequence, largely of sandstone and siltstone, contains abu shallow marine fossils and, in the uppermost portion of the group, palaeosols, co fossil land plants (Fig. 1). These rocks have been metamorphosed to the pre pumpellyite metagreywacke facies of Coombs (1960) and are tightly folded abou plunging moderately to the southwest. Deformation and metamorphism of this de comparable to that of the Mt Potts Group (Retallack, 1979) and other areas of T rocks in the central eastern South Island (regarded as Permian by Gair, 1964). Ho all these rocks are less severely deformed and metamorphosed than the bulk of T rocks exposed to the west and north (Andrews *et al.,* 1977).

The Corbies Creek Group crops out in a 2 km wide fault-bounded strip southv Otematata, north Otago. These rocks are best exposed in the area around the saddl the headwaters of Long Gully, a tributary of the Otematata River, 5 km southv Otematata township, accessible by an unsealed road through "Backyards Homeste Otematata Station (Fig. 2). The Otematata Fault, forming the southwestern bounc the Corbies Creek Group, is a high angle reverse fault dipping 45° to 75° sout The Middle Range Fault to the northeast, also evident from aligned scarp-like slo less well exposed, but may be a similar fault dipping northeast.

MATAGOURI SILTSTONE

This is a massive, fine-grained marine siltstone at the base and grades up-sectic coarse siltstone (Fig. 1). Sandstone interbeds in this formation increase in thickn the section so that the upper boundary with Putakitaki Sandstone is arbitrarily above the last substantial siltstone bed. The lower 10 m of the formation cont diverse brachiopod assemblage with some bivalves (including *Daonella*), gastropo crinoid columnals (S117/f638). The upper section of the formation is ge unfossiliferous, but contains more abundant wood fragments (Force, 1974) and a assemblage of bivalves including *Bakevelloides, Praegonia* and a cardiid, wit brachiopod *Alipunctifera kaihikuana* and crinoid columnals S117/f694). These c up-section probably reflect deposition in shallower water.

PUTAKITAKI SANDSTONE

This is a ridge-forming, coarse-grained sandstone, with some interbedded r sandstone and siltstone towards the base. Grains in the sandstone have a greater de rounding and a higher proportion of rock fragments than is usual in the Corbies Group. The Putakitaki Sandstone has yielded no fossils except for some unident plant fragments. The presence of low-angle cross-bedding (Force, 1974) indicates was deposited in an offshore bar or barrier beach (as defined by Shepard, 1952). T no evidence of mudflat sediments, like those of the Umu Siltstone, underlyi Putakitaki Sandstone. As this is a regressive sequence, these underlying rocks woul been seaward of the bar. Thus this bar is unlikely to have been a chenier (as unde by Reineck and Singh, 1973).

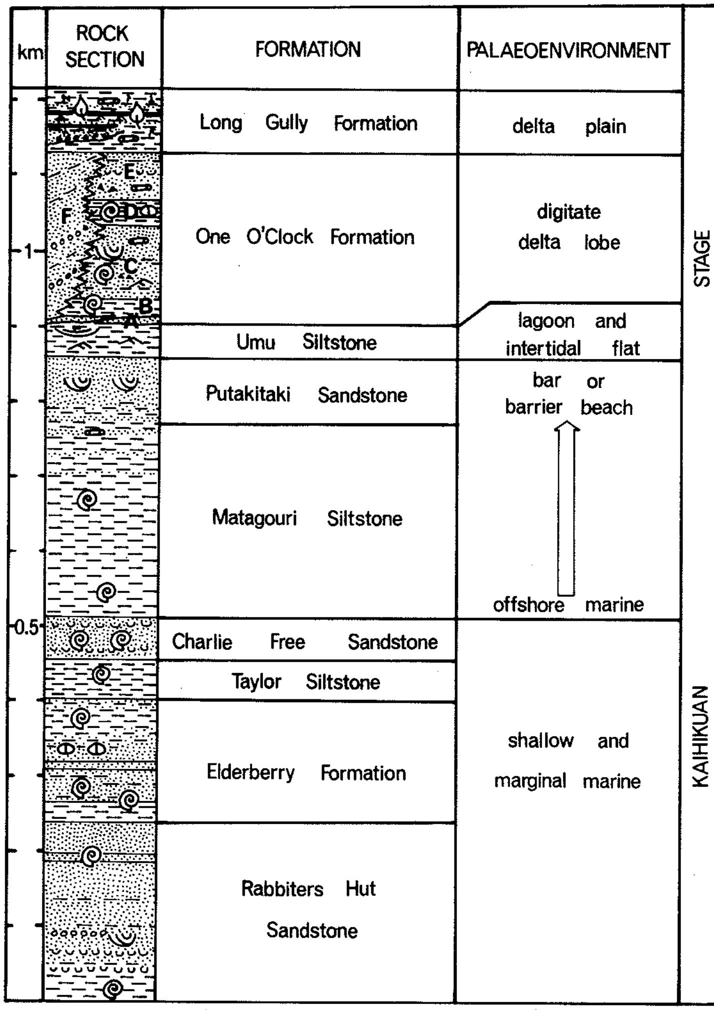


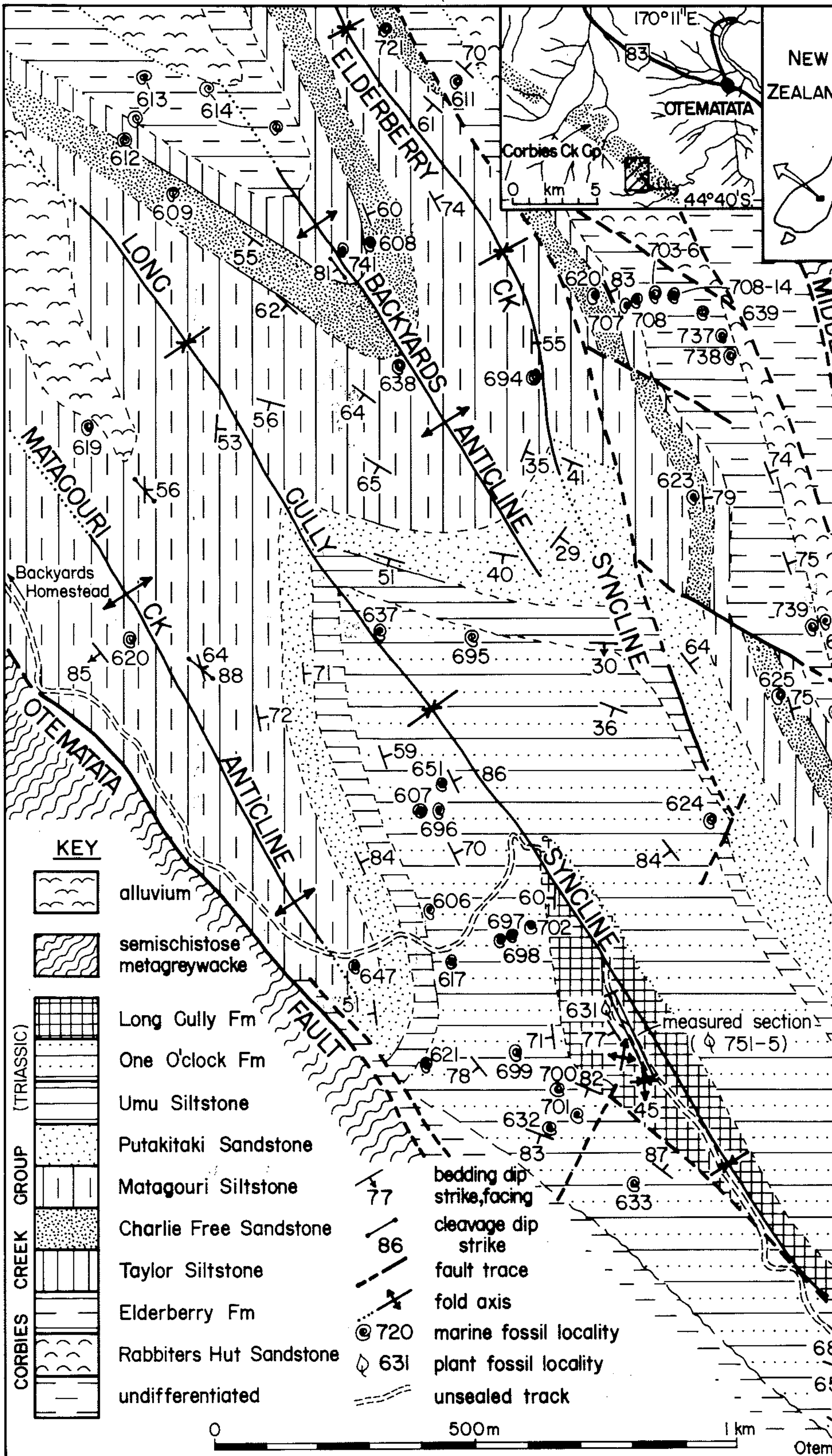
Fig. 1—Geological relationships of formations of the Corbies Creek Group. Lithological k
Figure 4.

UMU SILTSTONE

This formation is largely dark siltstone containing interbeds of shale and sandst 30 cm thick. Ripple-drift cross-lamination, in both lenticular and flaser beds co shows bimodal current directions (Ryburn, 1967, photo 12). There are also local l shale breccia and shallow scour-and-fill structures, filled with interbedded sandst shale. From these various features, we suggest that the Umu Siltstone was deposi tidal flat or shallow lagoon.

ONE O'CLOCK FORMATION

The One O'Clock Formation consists largely of fine to medium grained cal sandstone. There are some units of interbedded muddy sandstone, siltstone an Marine fossils are only found in the lower two-thirds of the formation. Unide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MATAGOURI CK
Backyards Homestead
OTEMATATA FAULT
SYNCLINE
SYNCLINE
MIDD
measured section
(751-5)
KEY
alluvium
semischistose metagreywacke
Long Gully Fm
One O'clock Fm
Umu Siltstone
Putakitaki Sandstone
Matagouri Siltstone
Charlie Free Sandstone
Taylor Siltstone
Elderberry Fm
Rabbiters Hut Sandstone
undifferentiated
(TRIASSIC)
CORBIES CREEK GROUP
bedding dip strike, facing
cleavage dip strike
fault trace
fold axis
720 marine fossil locality
631 plant fossil locality
unsealed track
0
500m
1 km
Otem

wood fragments become much more common in the upper portion of the formatio overlain conformably by the terrestrial Long Gully Formation.

The formation was most likely deposited as an active delta-front sand sheet. Th thickness of the formation (231 m) and its relative mineralogical immaturity (up t feldspar) indicate rapid erosion and deposition with little reworking. In addition s the impersistent normal and thrust faults within the larger isoclinal fold limbs app displace units of different thickness on either side of the fault trace (Fig. 2). Superf these are similar to growth faults, which form concurrently with deposition in r prograding delta wedges (Curtis, 1970). However, considering the structural comp of Torlesse rocks here and elsewhere, such an interpretation must be viewed caution.

Three alternative depositional models of less strongly regressive clastic shoreli not satisfactorily explain the observed features of the One O'Clock Formation. First sandy units (A, C and E in Fig. 1) could be explained as barrier beaches protecting lagoons (Units B and D) from the sea. However, stenohaline spiriferid brachiopo ophiurid starfish have been found in both supposed lagoonal deposits. Furthermo sandy units are quite unlike barrier, beach or bar deposits, such as the Puta Sandstone.

Secondly, the One O'Clock Formation is unlikely to have been deposited in a ridge or chenier plain, like the modern Nayarit Coast (Curray *et al.,* 1969). Once the high occurrence of stenohaline organisms and the nature of the sandstones di this interpretation. Moreover, abundant roots and root casts, and swale peats wo found evenly distributed through a chenier plain deposit, whereas in the One O Formation plant material is rare, fragmentary and increasingly abundant higher the formation. A further objection to this model is that conglomerates intraformational breccias are widespread in the One O'Clock Formation.

Thirdly, the One O'Clock Formation is unlikely to have been deposited in an e or tidal inlet, as described by Allen (1970) and Oertel (1973). If this were the case plant fragments should be more evenly distributed within the formation an sandstones would be more mineralogically mature and thinly bedded, with horiz bioturbation (Reineck and Singh, 1973). Estuarine sands commonly lie on an e older surface and are capped by tidal flat deposits, not seen in the case of th O'Clock Formation. Finally, fossils in the lower two-thirds of the One O'Clock Forn indicate fully marine salinities, unusual for estuaries.

Modern deltas may be classified according to the depositional processes domin their formation (Elliott, 1978). Tide-dominated deltas have an arcuate coastal outli distributary mouths which widen seawards. Tidal flat silt, stabilized by mang generally overlies the thick delta-front sand. Examples are the Klang Langat (Cole *al.,* 1970), Ganges-Brahmaputra and Mekong Deltas (Morgan, 1970). Sea dominated deltas have arcuate to lobate coastal outlines and distributary mout narrow and constricted by spits and shoals. They characteristically develop b beaches and beach ridge plains overlying the delta-front sand, as in the modern G Delta (Elliott, 1978). River-dominated deltas have lobate to digitate coastal outline their distributary mouths are flanked by narrow subaerial and subaqueous levees delta-front sheet or bar-finger sands are overlain by channel sands, freshwater peats, levee silts and interdistributary bay muds. The best known example is the m Mississippi Delta (Shepard, 1956).

Of these three alternatives, the One O'Clock Formation was evidently deposite digitate, river-dominated delta. Strong wave and tidal influence can be rejected same grounds as a beach ridge or estuarine depositional model. Thus the One O' Formation was probably deposited by a digitate delta during what Scruton (1960) its constructional phase. It is likely that the Umu Siltstone and the Putakitaki San represent the destructional reorganization of an earlier delta lobe by waves and t

Each of the units (A to F of Fig. 1) within the One O'Clock Formation c interpreted as a subenvironment of a digitate delta, as has been described for the m

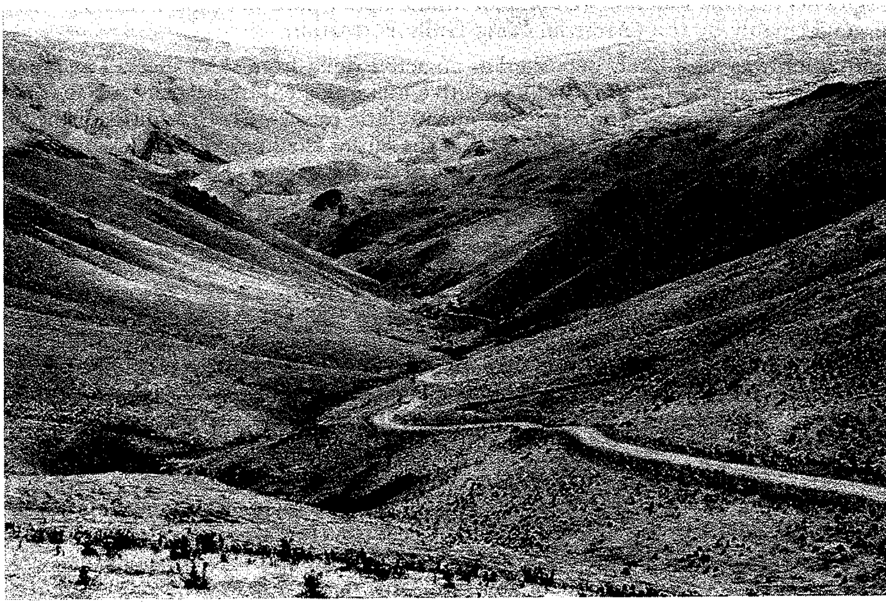

Fig. 3—Looking down Long Gully towards the Otematata River, from the saddle
Backyards homestead. St Mary Range forms the skyline to the left. Asterisk marks
S117/f755 and H35/f3.

Mississippi Delta by Coleman and Gagliano (1965). Units A to E are best expose
segment of the Long Gully Syncline south of the road from Backyards Homest
these units pass laterally into Unit F, which forms the whole thickness of One
Formation south of fossil locality S117/f633 (Figs. 2,3).

Unit A is 6 m of interfingering lenticular outcrops of trough cross-bedded sa
probably best explained as crevasse channels in the subaqueous levee.

Unit B is 21 m of interbedded, dark, micaceous siltstone and medium to
grained sandstone, containing a diverse assemblage of brachiopods, bivalves, ga
and crinoid columnals (S117/f695). It was probably deposited as a distal bar,
from a major distributary mouth.

Unit C is 102 m of fine to medium-grained, blue-grey, strongly (40%) ca
sandstone, commonly trough cross-bedded and ripple marked. This unit also
siltstone, coarse sandstone and intraformational shale breccia in normally gra
from 15 cm to 1 m thick. A poor assemblage of brachiopods has been collected fr
the base of Unit C (S117/f631) and bivalves, with an ophiurid starfish and a sca
near the middle and top (S117/f696 and f617). Unit C contains increasingly cons
plant fragments up-section. It probably formed a distributary mouth ba
accumulation of carbonate aggregates and nodules in the distributary mouth bar
been reported from both the Fraser (Johnston, 1921) and Mississippi deltas (S
1956). This evidently results from the local mixing of water masses of different
and temperature.

Unit D is 29 m of interbedded muddy, micaceous siltstone and calcareous sa
The siltstone contains large ovoid calcareous concretions and nodules (in the stri
of Brewer, 1964). Towards the top of the unit there are several lenses of
conglomerate with conspicuous angular shell fragments. Plant fragments
common. In some places (S117/f702) Unit D contains brachiopod coquinas, la
Alipunctifera, with some bivalves. In other places (S117/f697) only bivalves (
Nuculana, Balantioselena, Praegonia, Daonella and cardiids), scaphopods and

columnals are found. Siltstone is commonly riddled with carbonaceous burrows. are curvilinear, arranged at random low angles to the bedding planes and between 5 mm wide. Unit D was probably a largely-subaqueous levee and interdistributa deposit. This is especially suggested by the laterally variable fossil assemblages a shoreline conglomerates and coquinas. Calcareous nodules are also common i levees of modern digitate deltas (Coleman *et al.*, 1964; Donaldson *et al.*, 1970).

Unit E is 73 m of light coloured sandstone, with some sandy siltston intraformational breccia. Trough cross-bedding is widespread in the sandston several epsilon cross-sets (in the sense of Allen, 1963) were observed in the siltstor shale sequences. Plant fragments and vermicular carbonaceous burrows ar common. Unit E was probably deposited by a distributary channel, flanked by sub levees.

Unit F is the lateral equivalent of all the foregoing units in the southwestern limb Long Gully Syncline, where it embraces the whole of the One O'Clock Format consists largely of medium to coarse grained, massive sandstones, separated by spaced siltstone partings. Pebble conglomerate lenses, up to 30 cm thick, are cor Fossil localities within Unit F (S117/f633, f652, f650, f649, and f648) have y faunas similar to those elsewhere in the One O'Clock Formation, but wit brachiopod and bivalve elements apparently mixed. Unit F was probably a rec location for major distributary channels of the delta.

Unit F overlies undifferentiated, sheared and indurated siltstone, containing brachiopod fauna (S117/f653 further south along strike than shown in Fig. 2). were probably prodelta silts, which were locally eroded by the overlying unit F ch sandstone.

LONG GULLY FORMATION

Only 76 m have been preserved of this terrestrial formation which confor overlies the One O'Clock Formation and completes the regressive cycle of the Corbies Creek Group. Abundant and well-preserved fossil plants, coal and roots in it was deposited as a succession of freshwater coastal plains. A lenticular p conglomerate bed in the formation is probably the channel lag deposit of a Generally the formation crops out poorly from under modern colluvium and alluvi Long Gully, and the soft shales and coal are deeply weathered (Fig. 3). The mea section along the road (Fig. 4) revealed a small isoclinal anticline parallel to the isoclinal syncline mapped by Ryburn (1967). These folds probably formed by mov of incompetent shales and coals into the core of the Long Gully Syncline. This i indicated by the severe shearing and tectonic thickness variation observed in these (Fig. 4). Analysis of the coal (number CS9263 of the Chemistry and Geological S Divisions, DSIR, New Zealand) indicates that it is very weathered and medium v bituminous (R. P. Suggate, pers. comm., 1975). It is a lower rank coal than those Tank Gully Coal Measures (Retallack, 1979), but is also compatible wit metamorphic grade of the enclosing rocks low in the prehnite-pump metagreywacke facies of Coombs (1960). These features, together with the incre abundance of plant fragments in the higher underlying marine formations an structural concordance of these formations with the Long Gully Formation, m unlikely that the Long Gully Formation is an infaulted outlier of Jurassic coal mea as suggested by Mutch (1963).

The sediments of the measured section (Fig. 4) are very similar to river flood deposits of the Tank Gully Coal Measures (see Retallack, 1979). Thin units of sand siltstone and shale often fine upwards and are of a thickness and type comparabl modern crevasse splay (Coleman, 1969) and flood deposits (McKee *et al.*, Palaeosols preserved in the Long Gully Formation appear to have been more weat in the present outcrop than those in the Tank Gully Coal Measures, but are othe similar. These were poorly-differentiated alluvial soils or fluvents, and so indicat

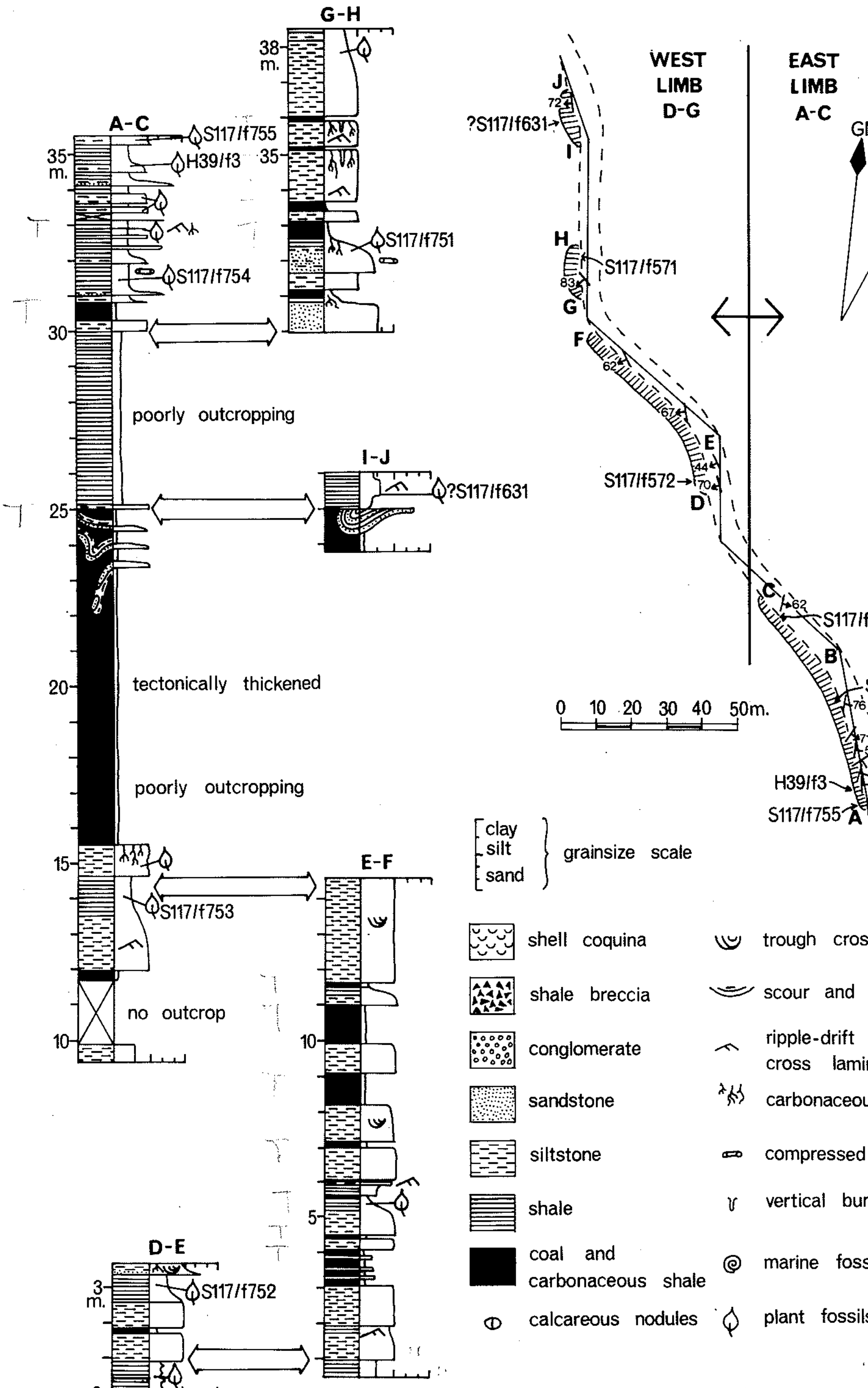

Fig. 4—Plan (upper right) and composite stratigraphic section (left) of part of the Lo
Formation exposed in cuttings along the Backyards road (see Figure 1).

soil formation was constantly interrupted by episodic sedimentation at intervals of than one hundred years. This implies a subsidence rate of at least one metre every years.

Several fossil plant collections were made by Retallack from a measured section o Long Gully Formation in 1975 (Fig. 5) and represent two associations, the Linguifoli and Pachydermophylletum of Retallack (1977).

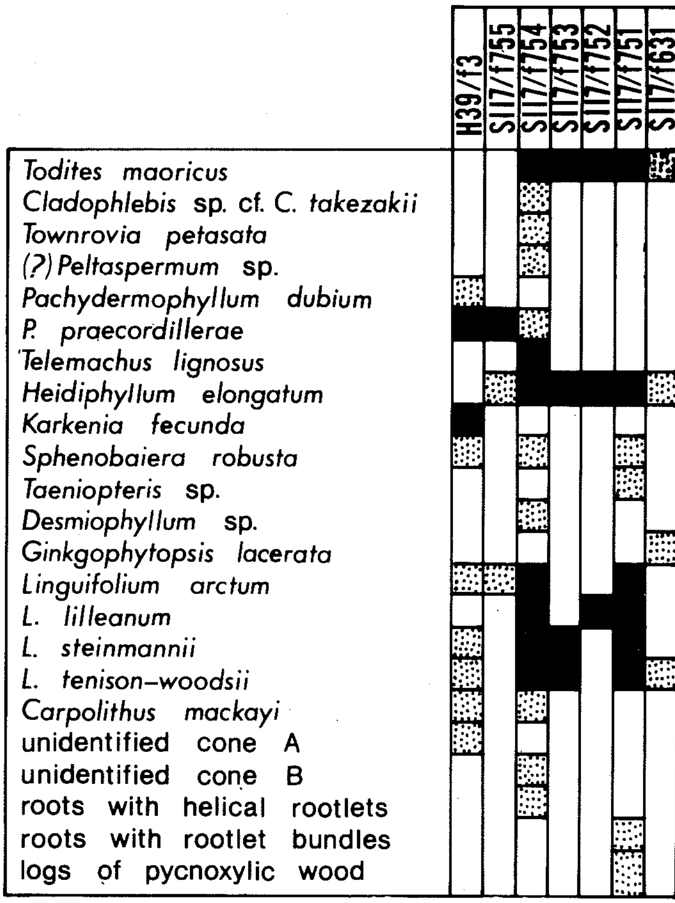

Fig. 5—Plant megafossils and their localities in the Long Gully Formation (from Retallack, 1 Black boxes indicate more abundant species. Localities (specimen numbers) are S117/ (OU14205), S117/f751 (B1090.1-16), S117/f752 (B1089.1-4), S117/f753 (B1088.1-7), S117/ (B1087.1-52), S117/f755 (B1086.1-2), H39/f3 (OU14229-36).

The Linguifolietum appears to have been a swamp woodland, as in the Tank C Coal Measures (Retallack, 1979). Here also, coal, compressed and ferruginized f logs, some with growth rings preserved, and autumnal accumulations of fossil leave common. This association is relatively impoverished and poorly preserved in the l portion of the measured section (S117/f753 and f752) but quite diverse with comm preserved fructifications in the upper portion of the section (S117/f754 and f751). T differences could record the gradation from heath or scrub, growing on distribu levees, passing into the woodland climax further inland.

The two highest localities (S117/f755 and H39/f3) contain conspicuous ar *Pachydermophyllum* (Fig. 5). Associations characterized by these fossil leaves understood near Benmore Dam, where they seem to have been a mangrove v (Retallack, 1977). Because of the complex configuration of digitate deltas, nothi argued from the high position of this association in the regressive Long Gully F These plants may have grown in an interdistributary bay or lagoon.

RECONSTRUCTED TRIASSIC ENVIRONMENT OF THE CORBIES CREEK GROUP

The reconstruction (Fig. 6) summarizes conclusions for each of the precedin for a time within the Ladinian when the upper One O'Clock Formation wa distributary bed of a digitate delta. The faunal assemblages are reconstruc observations of our own collections, from illustrations of Trechmann (1918), (1927), Marwick (1953), Fleming (1962, 1963, 1964), Ryburn (1967), and Sp Gair *et al.,* 1962) and from comparable interpretations of Stanley (1970), Steven

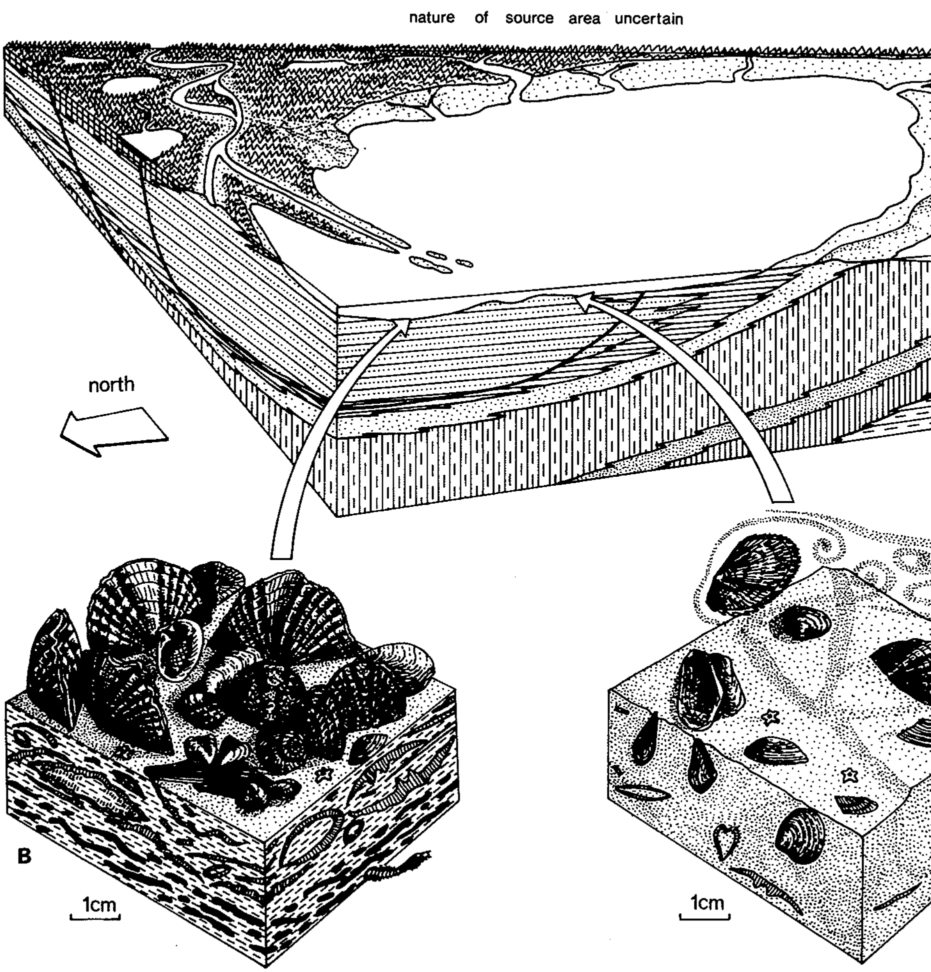

Fig. 6—Reconstructed Triassic environment of the upper Corbies Creek Group.

Freneix and Avias (1977) and Retallack (1979). The following account describes likely panorama, processes and climate.

The source area has been omitted from the reconstruction because no definite id its morphology can be gained from rocks of the Corbies Creek Group. The lack of t coarse conglomerates could indicate a more subdued topography, compared to which supplied the Mt Potts Group, but as Garner (1959) indicates, most of the An mountain chain only delivers fine detritus to the sea. The relative mineralo immaturity of the Corbies Creek Group could be due to cold climate with little chen weathering, active subsidence or a source land of considerable relief. On petrogra grounds, the source terrain probably included a high proportion of granitoid (Ryburn, 1967). Conglomerate clasts in the Corbies Creek Group include chert, qu felsitic rhyolites and dacites, fine-grained quartzose sandstones and quartzite, with l amounts of intermediate volcanics, granitoids, slates and greywackes. None of t features excludes a mountainous source, like that postulated for the Mt Potts G (Retallack, 1979).

During Ladinian time, about 1200 m of marine sediment accumulated to build deltaic coastal plain. The barrier bar (Putakitaki Sandstone) and landward tidal (Umu Siltstone) probably formed from the destruction of an older delta lobe by o waves and tides. Imperceptably building out into the sea nearby is a digitate delta (One O'Clock Formation). Each distributary is flanked by narrow, mounded l which continue offshore into a series of arcuate mouth bar shoals. In times of flood t levees may be breached, and crevasse splays of sandier sediment spread over wider a of the distributary flanks. As in the Fraser Delta (Johnston, 1921), these massive infl of fresh water probably killed large numbers of marine organisms. Burrowing biv faunas near the sandy distributaries were probably better adapted to shifting s periodic shallowing and exposure, and lower salinities, than brachiopod-domin faunas of offshore silts. In this area of salt and fresh water mixing calcium carbona commonly precipitated as concretions and nodules in levees and as widespread s carbonate aggregates, later consolidated into the hard calcareous matrix of sandston the One O'Clock Formation. Interdistributary bays are floored by finer shales sandstones, somewhat protected from river flow and ocean swell by elongate distrib fingers. Richer faunas including stenohaline forms, such as the spiriferinid brachi *Alipunctifera kaihikuana* and the pteriid bivalve *Daonella*, flourished here. These bay fringed by beaches of sand, granules and shell fragments in more seaward areas o delta.

The immaturity of soils on the delta plain indicates aggradation at a rate of at least metre every 500 years. The more exposed younger levees of the distributaries supp relatively impoverished *Linguifolium* scrub. Further inland more diverse *Linguifo* woodlands cover the peaty delta plain. At the seaward margin of these woodl *Pachydermophyllum* mangroves fringe interdistributary bays and lagoons.

A cool temperate climate during deposition of the Corbies Creek Group is indicate its mineralogical immaturity, by prominent growth rings in both fossil wood and ma shellfish and by the low specific diversity and morphological conservatism of its f flora and fauna. Fossil logs in the Corbies Creek Group are no larger than those foun the coeval Mt Potts Group (up to 27 cm in original diameter (Retallack, 1979)) indicate that coastal climate was not too frigid for the growth of trees.

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NOTE ADDED IN PROOF:

Fossil Record File numbers cited in this paper and appendix were recorded b
conversion to metric files. Revised numbers are listed below:

S117/f509	H40/f7509	7878 1762*	S117/f653	H40/f7653	8
S117/f510	H40/f7510	7824 1715	S117/f694	H40/f7694	8
S117/f617	H40/f7617	8168 1401	S117/f695	H40/f7695	8
S117/f620	H40/f7620	8075 1491	S117/f696	H40/f7696	8
S117/f631	H40/f7631	8214 1366	S117/f697	H40/f7697	8
S117/f633	H40/f7633	8205 1365	S117/f702	H40/f7702	8
S117/f638	H40/f7638	8147 1529	S117/f751	H40/f7751	8
S117/f648	H40/f7648	8417 1232	S117/f752	H40/f7752	8
S117/f649	H40/f7649	8409 1214	S117/f753	H40/f7753	8
S117/f650	H40/f7650	8344 1267	S117/f754	H40/f7754	8
S117/f652	H40/f7652	8242 1329	S117/f755	H40/f7755	8

* = estimated only

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Appendix: Lithostratigraphy of the Corbies Creek Group

R. J. Ryburn*

Geological interest in the fossiliferous Kaihikuan rocks near Otematata, of Force (1974) and others, has resulted in the unfortunate publication of several lithostratigraphic names from my unpublished master's thesis (Ryburn, 1967) before their formal definition in print. This appendix is meant to correct this technical deficiency and is abstracted from my thesis, to which the reader is referred for a detailed geological map (including areas beyond Long Gully), stratigraphic sections, palaeontological notes and discussions of the structure and petrography of the Corbies Creek Group.

CORBIES CREEK GROUP Ryburn, new name

This approximately 1.2 km thick sequence of fossiliferous shallow-marine terrestrial sedimentary rocks, crops out in a narrow fault-bounded strip, extending 1 through Backyards homestead from the Otematata River to the flanks of Mount Hor near Otematata, north Otago. Sedimentary rocks of the group include sandstone, silt and mudstone, with minor thin beds of conglomerate and coal. Sandstones of the Co Creek Group are quartzofeldspathic, consisting largely of quartz, K-feldspar, plagio and rock fragments. Occasional thin veins and shatter-fillings containing pre indicate that they belong to the prehnite-pumpellyite metagreywacke facies of reg metamorphism. The Corbies Creek Group is tightly folded about at least four roughly coaxial with its faulted margins: respectively from southwest to northeas Matagouri Creek Anticline, Long Gully Syncline, Backyards Anticline and Elderl Creek Syncline. The group includes nine formations, discussed below in their ord superposition.

RABBITERS HUT SANDSTONE Ryburn, new name

Mappable features: Bluff-forming, massive sandstones, characteristically indur medium to coarse grained, moderately well-sorted and noticeably micaceous.

Type locality: Bluffs along the east side of Corbies Creek 100 m south of the rabb hut from which the formation takes its name (grid reference 773246 on 1:63 topographic map sheet S117).

Thickness: A maximum of 244 m for the formation at the type locality.

Contacts: The base of the Rabbiters Hut Sandstone is obscured by Quaternary allu and appears to have been disrupted by the boundary faults of the Corbies Creek Gr Its upper contact with the overlying Elderberry Formation is a gradational litholo change, mapped as the top of the highest sandstone bed of appreciable thickness.

Lithology: At the type locality, the lowest 61 m of the Rabbiters Hut Sandstone co of micaceous, moderately well-bedded sandstone, which is finer grained and more m than that higher in the formation. From 61 to 122 m above the observed base o formation, it consists of bluff-forming, medium to coarse grained, moderately well s micaceous sandstone. At this level mudstone partings are spaced at intervals of 1 to Cross-bedding, oscillation ripples, pebble conglomerate horizons and shellbeds are One pebble conglomerate 88 m above the base of the formation consisted of well rou

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siliceous pebbles averaging 6 mm in diameter. A shellbed exclusively of gas (*Kamupena greggi*) was found at 67 m above the exposed base of the formatio another of disarticulated trigoniid (*Agonisca corbiensis*) valves, mostly convex up, a In the upper 122 m of the Rabbiters Hut Sandstone at the type locality, mud resistant sandstones in beds up to 24 m thick are interbedded with resistan sandstones of comparable thickness.

Distribution: Folding and faulting in the area between Corbies Creek and Ba homestead has resulted in the repetition of the Rabbiters Hut Sandstone in parallel outcrop to the south of the type locality, exposing only the upper 60-90 formation. At least a 183 m thickness of Rabbiters Hut Sandstone crops out in a against the Middle Range Fault in the headwaters of Elderberry Creek.

Palaeontology: The first fossil collections from this area, reported by Gair *et al.* localities S117/f509 and 510) were from bluffs of the type locality. The sandstones of the middle part of the formation contain few fossils or almost mono shellbed accumulations, particularly of the gastropod *Kamupena greggi* and the t bivalve *Agonisca corbiensis.* More diverse marine assemblages were found in the n sandstones of the upper and lower portions of the formation. For example, the bivalve *Daonella* and terebratulid brachiopods were found in the lower part formation in the type area, and these, as well as lingulid and rhynchonellid brach *Balantioselena* and other bivalves, *Kamupena* and scaphopods in the upper part formation in the same area.

ELDERBERRY FORMATION Ryburn, new name

Mappable features: Siltstones, mainly dark grey and micaceous, interbedded wit medium grained, muddy sandstones.

Type locality: A type section was measured through a steeply dipping sequen spur at the foot of Middle Range (g.r. 806224), between two branches of Eld Creek, after which the formation is named. The stratigraphic succession apparently conformable, but may be dislocated by faults at a low angle to bedding are recognized a short distance along strike.

Thickness: The Elderberry Formation is only 162 m thick at the type locality more than 195 m thick near the road north of Backyards homestead (g.r. 78 784228).

Contacts: As already noted, the contact of the Elderberry Formation with the un Rabbiters Hut Sandstone is gradational. It is possibly also interfingering, as th 91 m thick lentil of medium to coarse grained quartzofeldspathic sandstone, erosional base, some 70 m statigraphically above the top of the Rabbiters Hut Sa near its type locality along Corbies Creek. Connection of this sandstone, pro channel fill, with the main body of the Rabbiters Hut Sandstone was not seen, a formally mapped as an anomalous lentil within the Elderberry Formation.

The upper contact of the Elderberry Formation with the Taylor Siltstone conformable and placed at the top of the highest muddy sandstone bed with a thic a metre or more.

Lithology: Micaceous siltstone and muddy sandstone occur in roughly proportions within the Elderberry Formation, in beds ranging from a few centim several metres thick. Contacts between beds are commonly gradational or obsc mottling from organic burrowing. These dark grey rocks weather brown and disi into small angular chips. Occasional less muddy sandstone beds characteristica weather-resistant ledges. In the type section, medium to coarse grained sandston up to 15 cm thick are prominent from 125 to 140 m above the base of the formati there is a distinctive horizon of brachiopod-bearing concretions about 128 m ab base.

Distribution: The Elderberry Formation can be traced southeast from the type through numerous minor faults into Putakitaki Creek as far as its junction wit Gully. It also crops out in the core of the Backyards Anticline (g.r. 795228), whe is a conspicuous horizon of calcareous sandstone with abundant brachiopods. No of Backyards Homestead to Corbies Creek two parallel exposures of Eld Formation overlie the fault-disrupted Rabbiters Hut Sandstone. Along Corbies C the southwestern exposure belt (g.r. 770237), a brachiopod shellbed in a cal concretionary horizon is similar to that in the core of the Backyards Anticline. Tw outcrop areas isolated by alluvium and solifluxion debris north (g.r. 78722 southeast (g.r. 791223) of Backyards homestead are correlated with the Eld Formation along strike to the northwest.

Palaeontology: Fossils are very common in the Elderberry Formation and form th diverse assemblages known from formations of the Corbies Creek Group. Bival brachiopods are found as scattered individuals and in modest shellbeds. Many bivalves are thin-shelled infaunal forms, found with valves still joined or close to evidently little transported. Brachiopods of the Elderberry Formation include lin terebratulids, and rhynchonellids, as well as common spirifers *Alipunctifera kaihiku Mentzeliopsis spinosa.* Bivalves include the pteriid *Daonella,* the astartid *Balantiosele* and the trigonid *Praegonia coombsi.*

TAYLOR SILTSTONE Ryburn, new name

Mappable features: Recessive-weathering, massive, muddy, micaceous siltstone.

Type locality: The type area is the same as for the Elderberry Formation, w overlies between two branches of Elderberry Creek (g.r. 806224). The forma named to honour the hospitality of Mr and Mrs Taylor of Backyards homestead

Thickness: The Taylor Siltstone is 56 m thick in the type section, and is of comp thickness (61 m) in the southwest limb of the nearby Backyards Anticline. (thickness of the Taylor Siltstone in the nose of this fold is probably due to defor To the northwest along Corbies Creek the Taylor Siltstone is at least 122 m thick w overlies the Elderberry Formation. Deformation here too, up against a fault, is in by an irregularly flexed and cross-faulted sandstone bed, 1 m thick, some 61 m ab Elderberry Formation. However, there is no clear evidence of structural repetitio formation here, and it may have been originally thicker in this direction.

Contacts: The lower contact with the Elderberry Formation is conformable and at the top of the highest muddy sandstone with a thickness of a metre or more. siltstones of the Elderberry Formation, those of the Taylor Siltstone lack consp bedding.

The upper contact of the Taylor Siltstone with the coarse-grained Charli Sandstone is extremely abrupt, probably erosional, and has proven a useful horizon for estimating the displacement along minor faults.

Lithology: At the type locality the Taylor Siltstone is dark grey, muddy, micaceo lacks conspicuous bedding. It is moderately indurated with a crude fracture cl usually subparallel to bedding, and on weathering, breaks down into sharp a fragments. Thin sandstone layers are scattered throughout the lower 18 m formation.

Distribution: Within the Backyards Anticline and to the northwest along C Creek, the Taylor Siltstone is quite constant in its lithology, apart from a 1 m sandstone about 61 m above the Elderberry Formation in the northwestern expo

Palaeontology: The most common and widespread fossil of the Taylor Siltstone pteriid bivalve *Daonella,* usually fragmentary. Coarse siltstone and sandstone beds lower part of the formation are occasionally associated with local concentrati bivalves and brachiopods like those of the Elderberry Formation.

CHARLIE FREE SANDSTONE Ryburn, new name

Mappable features: Ridge-forming, medium to coarse grained, massive, moderate sorted sandstone, characteristically with shellbeds of brachiopods preserved as r and casts.

Type locality: This is in the southwest limb of the Backyards Anticline be Elderberry and Matagouri Creeks (g.r. 796226), near a field referred to as the "U Charlie Free paddock". Charlie Free is reputed to have been an early fence builc the word "free" in the formation name has no textural connotations.

Contacts: The lower contact of the Charlie Free Sandstone with the Taylor Siltst abrupt and probably erosional. Its upper contact with the dark grey Matagouri Sil is placed at the top of a 1.5 m thick bed of massive, medium grained sandstone, a apparently conformable.

Lithology: The characteristic lithology of the Charlie Free Sandstone, best develop the lower 30 m of its type section, is medium to coarse grained, massive, moderatel sorted sandstone, bluish grey in colour and weathering light brown. The sandst slightly calcareous in places, especially near shellbeds. One of these, 15 to 30 cm occurs 8 m above the base of the formation. Mudstone partings are few. In the 24 m of the type section, the sandstones are less massive, generally finer grained, c in colour and include some interbedded muddy sandstones.

Distribution: Away from the type area, the Charlie Free Sandstone can be trace crescentic strike ridge around the nose of the Backyards Anticline. Several disrupted blocks of Charlie Free Sandstone crop out in a linear belt extending fro headwaters of Elderberry Creek to near the junction of Putakitaki Creek and Long A small area of Charlie Free Sandstone has also been mapped in an exposure comp surrounded by alluvium north of Backyards Homestead (g.r. 789231). This is prob continuation of the southwest limb of the Backyards Anticline faulted against a outcrop of Elderberry Formation.

Palaeontology: Brachiopods are found scattered and in shellbeds in the Charlie Sandstone and include terebratulids, rhynchonellids and the spirifers *Alipur kaihikuana* and *Mentzeliopsis spinosa.* Fragments of the pteriid bivalve *Daonella* ar common.

MATAGOURI SILTSTONE Ryburn, new name

Mappable features: A recessive-weathering unit, mainly of micaceous siltstone base, but with increasingly prominent muddy sandstone interbeds towards the to

Type locality: The type section is across the southwest limb of the Backyards Ant (from g.r. 800233 to 779219), on the slope overlooking Elderberry Creek, be Elderberry and Matagouri Creeks. Exposures are poor, even here, and con southwest around a spur into the headwaters of Matagouri Creek, after whic formation is named.

Thickness: 259 m in the type section.

Contacts: The lower contact of the Matagouri Siltstone with the Charlie Sandstone, at the top of a 1.5 m thick bed of massive medium-grained sandstone, is and apparently conformable.

The top of the Matagouri Siltsone is arbitrarily separated from the overlying Puta Sandstone at the top of the highest siltstone bed no thicker than 60 cm. Fron Matagouri Siltstone up section into the Putakitaki Sandstone, sandstone beds incre number and thickness (up to 1.5 m) as interbedded siltstones decrease in thickne

Lithology: The lower half of the Matagouri Siltstone is mainly dark micaceous silt moderately well bedded, with interbeds of mudstone at 8-16 cm intervals and some coloured laminae. Sandstone interbeds a few centimetres thick, are rare. Sanc interbeds are increasingly numerous and thick (up to 1.5 m) higher within the form These sandstones are more or less muddy, ungraded, and have diffuse boundarie

Distribution: The Matagouri Siltstone extends throughout the headwaters of Elder and Matagouri Creeks, through a series of folds (the Elderberry Creek Syn Backyards Anticline, Long Gully Syncline and Matagouri Creek Syncline respec from northeast to southwest). Other fault-disrupted exposures of the Matagouri Sil extend southward along the ridge between Long Gully and Putakitaki Creek.

Palaeontology: The Matagouri Siltstone is relatively devoid of fossils, compared formations of the Corbies Creek Group. A few localities near the base of the fo have yielded a moderately diverse fossil fauna largely of brachiopods, as well as e of burrowing and plant fragments. An exceptional locality in the centre of the fo along Matagouri Creek (S117/f620) is a 46 cm thick, coarse-grained sa containing numerous *Alipunctifera kaihikuana.*

PUTAKITAKI SANDSTONE Ryburn, new name

Mappable features: Massive, jointed, indurated, coarse grained sandstone, fo prominent weather-resistant strike ridge.

Type locality: This is 120 m east of the axis of the Long Gully Syncline (indica prominent change of direction of the strike ridge of Putakitaki Sandstone), on t separating Elderberry and Matagouri Creeks from Long Gully and Putakitak (g.r. 800218). This latter creek and formation name is from the Maori word for Duck.

Thickness: 93 m in the type section.

Contacts: As discussed above, the Putakitaki Sandstone passes gradationall section into the Matagouri Siltstone.

The contact of the Putakitaki Sandstone and the overlying Umu Siltstone is exposed in the type area, but is sharp and conformable elsewhere.

Lithology: Although this formation is mostly massive, indurated light grey, me coarse grained sandstone, some fine grained, darker sandstone and thin siltsto transitional into the underlying Matagouri Siltstone are present in the basa Granule and pebble horizons are also found in places.

Distribution: Along the ridge separating Elderberry and Matagouri Cree Putakitaki Creek and Long Gully, the well-exposed strike ridge of Putakitaki Sa provides a clear trace of the Backyards Anticline, Long Gully Syncline and M Creek Anticline (from northeast to southwest). The Putakitaki Sandstone also some distance along the ridge separating Long Gully from Putakitaki Creek, wh terminated by faulting at a low angle to bedding.

Palaeontology: Only rare and indeterminable plant fragments have been foun Putakitaki Sandstone.

UMU SILTSTONE Ryburn, new name

Mappable features: Finely laminated, dark, micaceous siltstone, with numer interbeds of sandstone and shale, cropping out poorly.

Type locality: In Umu Saddle, from which the formation name is derived, wh road from Backyards homestead crosses from the headwaters of Matagouri Cr Long Gully (g.r. 801211).

Thickness: The Umu Siltstone is 44 m thick at the type locality but varies cons elsewhere from 3 to 60 m due to deformation and also erosion at the base of the o One O'Clock Formation.

Contacts: The Umu Siltstone conformably overlies the Putakitaki Sandstone moderately sharp contact. Its contact with the overlying One O'Clock Formatio sharp and, near the type locality, is partly eroded by channel-like sandstones form base of the One O'Clock Formation.

Lithology: Most of the Umu Siltstone is laminated, dark micaceous siltstone, i muddy and with numerous light-coloured sandy laminae. Sandstone interbeds fr 30 cm thick are common near the top of the formation. Ripple-drift cross-laminat shallow scour-and-fill structures are also common.

Distribution: The recessive-weathering Umu Siltstone occurs everywhere w underlying Putakitaki Sandstone, both units outlining the southeasterly-plungin Gully Syncline.

Palaeontology: No body fossils were found in the Umu Siltstone, although t
present at the very base of the overlying One O'Clock Formation.

ONE O'CLOCK FORMATION Ryburn, new name

Mappable features: Massive, fine to medium grained calcareous sandstone,
thick, well bedded units, with intervening sequences of interbedded sandstone, s
and shale.

Type locality: The southwest limb of the Long Gully Syncline from near Umu
(g.r. 800210) to the head of Long Gully (g.r. 803321).

Thickness: 231 m in the type section.

Contacts: The base of the One O'Clock Formation in the type area consists of le
channel-like sandstone bodies, with erosive bases. The contact is generally more
conformable and is mapped at the base of the first sandstone above the Umu S
with a thickness of more than 50 cm.

The upper contact of the One O'Clock Formation and the Long Gully Format
gradational change in the kind of sedimentary rocks, difficult to place within 15
poorly exposed. It is mapped below the lowest occurrence of brownish or ye
rootlet-bearing sandstones and carbonaceous siltstones characteristic of the Lon
Formation.

Lithology: The base of the One O'Clock Formation in the type section is
partially-coalesced channel-like bodies of cross-bedded sandstone. This is over
21 m of alternating dark micaceous siltstone and medium to coarse grained sands
beds 20-40 cm thick. The lithology which typifies the One O'Clock Formation
developed from 27 to 129 m above the base of the type section. This is a v
resistant, moderately well bedded, fine to medium grained sandstone.
characteristically hard and bluish in colour, because of calcareous cement (as
40% of the rock in places), and it weathers spheroidally. Beds are defined by fine p
and occasional thin beds of muddy siltstone, the latter supplying clasts for
observed in a few places. Overlying this unit in the type section is 29 m of inter
calcareous shale, muddy micaceous siltstone and calcareous sandstone. The s
contains large ovoid calcareous nodules and concretions up to 50 cm long. The ren
73 m of the uppermost One O'Clock Formation is poorly exposed, consisting m
light-coloured sandstone with some sandy siltstone and intraformational breccia

Distribution: Continuing southeast from the type area to the Otematata River, s
and shale interbeds become rare in the One O'Clock Formation. Most of the form
this direction consists of medium to coarse grained massive sandstone, with
spaced siltstone partings. Pebble conglomerates, up to 30 cm thick, are also con

The One O'Clock Formation crops out poorly in the eastern limb of the Lon
Syncline, where it appears to have a greater proportion of silty and muddy interbe
in the type section.

Palaeontology: The One O'Clock Formation is moderately fossiliferous with a f
limited diversity. Siltstones and shales may contain brachiopod shellbeds, lar
Alipunctifera kaihikuana, and (at other localities) bivalves such as *Nuculana, Balant*
Praegonia and *Daonella* and cardiids, as well as scaphopods and crinoid columna
sandy facies of the southwestern limb of the Long Gully Syncline is fossiliferous in
usually with brachiopods and bivalves in mixed and transported assem
Carbonaceous plant debris is common, especially in the upper part of the One C
Formation.

LONG GULLY FORMATION Ryburn, new name

Mappable features: Orange, yellow or brown, mottled sandstone with fossil root tr
well as dark carbonaceous shale, coal and abundant fossil logs and leaves.

Type locality: Cuttings along the road from Backyards homestead to the Ote
River, in upper Long Gully (g.r. 804209).

Thickness: Considering the poor exposure and complex and uncertain structure
Long Gully Formation, deformed in the core of the Long Gully Syncline, the
thickness of the formation is uncertain. It is probably in the order of 100 m or n

Contacts: As already discussed, the basal contact of the Long Gully Formation w
underlying One O'Clock Formation is gradational and poorly exposed.

No units were seen to overlie the Long Gully Formation, as it forms the core
Long Gully Syncline. The uppermost portion of the formation is concealed by alluv
the bottom of Long Gully.

Lithology: The Long Gully Formation is very heterogeneous lithologically, wi
same lithology seldom forming units more than 1.3 m thick. Sandstones are
micaceous, medium grained, and may range from grey and indurated to yell
mottled and friable. Some of this weathering is probably due to continuing wate
down the Long Gully Syncline and Long Gully watershed. Judging from several ho
of fossil root traces in place, some of this weathering is probably also of Triassi
Siltstones and shales are generally grey and more or less carbonaceous. Also prese
thin coal seams (up to 30 cm thick) and pebble conglomerates (up to 25 cm).

Distribution: The Long Gully Formation has only been found in the core of the
Gully Syncline, a position virtually eliminating the possibility that it is infault
mapped by Mutch (1963).

Palaeontology: As described by Retallack (1981) and in this paper, the Long
Formation contains abundant fossil logs and leaves of land plants. Prominent among
are osmundalean fern fronds (*Todites maoricus*), peltasperm pteridosperm
(*Pachydermophyllum* spp.), voltziacean conifer leaves (*Heidiphyllum elongatum*)
gymnospermous leaves of uncertain affinity (*Linguifolium* spp.).