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

G. J. Retallack* and R. J. Ryburn**

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

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

Only the fossil-plant-bearing unit and related marine rocks of the upper Corbies Creek Group are considered in detail here, as evidence for a reconstruction of the vegetational palaeoenvironment and palaeogeography of Long Gully for a time within the late Middle Triassic.
Triassic (Kaihikuan local stage, roughly equivalent to the Ladinian international stage). The lower Corbies Creek Group and other aspects of its geology are discussed by (et al. 1962), Campbell and Warren (1965), Ryburn (1967) and Force (1974).

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

CORBIES CREEK GROUP

This Middle Triassic sequence, largely of sandstone and siltstone, contains abundant shallow marine fossils and, in the uppermost portion of the group, palaeosols, coal, and fossil land plants (Fig. 1). These rocks have been metamorphosed to the pre-pumpellyite metagreywacke facies of Coombs (1960) and are tightly folded about plunging moderately to the southwest. Deformation and metamorphism of this degree is comparable to that of the Mt Potts Group (Rettallack, 1979) and other areas of Tertiary rocks in the central eastern South Island (regarded as Permian by Gair, 1964). However, all these rocks are less severely deformed and metamorphosed than the bulk of Tertiary 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 south of Otematata, north Otago. These rocks are best exposed in the area around the saddles of the headwaters of Long Gully, a tributary of the Otematata River, 5 km south of Otematata township, accessible by an unsealed road through “Backyards Homestead” (Otematata Station (Fig. 2). The Otematata Fault, forming the southwestern boundary of the Corbies Creek Group, is a high angle reverse fault dipping 45° to 75° southeast. The Middle Range Fault to the northeast, also evident from aligned scarp-like slopes, is 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-section into coarse siltstone (Fig. 1). Sandstone interbeds in this formation increase in thickness from the section so that the upper boundary with Putakitaki Sandstone is arbitrarily placed above the last substantial siltstone bed. The lower 10 m of the formation contains a diverse brachiopod assemblage with some bivalves (including Donella), gastropods, and crinoid columnals (S117/f638). The upper section of the formation is generally unfossiliferous, but contains more abundant wood fragments (Force, 1974) and an assemblage of bivalves including Bakevelliidae, Praegonia and a cardiid, with brachiopod Alitupunctifera kaihihuna and crinoid columnals S117/f694). These clasts in the upper section probably reflect deposition in shallower water.

PUTAKITAKI SANDSTONE

This is a ridge-forming, coarse-grained sandstone, with some interbedded mudstone and siltstone towards the base. Grains in the sandstone have a greater degree of rounding and a higher proportion of rock fragments than is usual in the Corbies Creek Group. The Putakitaki Sandstone has yielded no fossils except for some unidentified plant fragments. The presence of low-angle cross-bedding (Force, 1974) indicates that it was deposited in an offshore bar or barrier beach (as defined by Shepard, 1952). There is no evidence of mudflat sediments, like those of the Umu Siltstone, underlying the Putakitaki Sandstone. As this is a regressive sequence, these underlying rocks would have been seaward of the bar. Thus this bar is unlikely to have been a chenier (as underlay by Reineck and Singh, 1973).
Fig. 1—Geological relationships of formations of the Corbies Creek Group. Lithological key in Figure 4.

UMU SILTSTONE

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

ONE O’CLOCK FORMATION

The One O’Clock Formation consists largely of fine to medium grained calcareous sandstone. There are some units of interbedded muddy sandstone, siltstone and shale. Marine fossils are only found in the lower two-thirds of the formation. Unidenti...
wood fragments become much more common in the upper portion of the formation, and are overlain conformably by the terrestrial Long Gully Formation.

The formation was most likely deposited as an active delta-front sand sheet. The thickness of the formation (231 m) and its relative mineralogical immaturity (up to 10% feldspar) indicate rapid erosion and deposition with little reworking. In addition, the persistent normal and thrust faults within the larger isoclinal fold limbs appear to displace units of different thickness on either side of the fault trace (Fig. 2). Superficially these are similar to growth faults, which form concurrently with deposition in near-prograding delta wedges (Curtis, 1970). However, considering the structural complexity of Torlesse rocks here and elsewhere, such an interpretation must be viewed with caution.

Three alternative depositional models of less strongly regressive clastic shoreline do 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 brachiopods and ophiurid starfish have been found in both supposed lagoonal deposits. Furthermore, these sandy units are quite unlike barrier, beach or bar deposits, such as the Putai Sandstone.

Secondly, the One O’Clock Formation is unlikely to have been deposited in a ridge or chenier plain, like the modern Nayarit Coast (Curry et al., 1969). One objection is the high occurrence of stenohaline organisms and the nature of the sandstones do not fit this interpretation. Moreover, abundant roots and root casts, and swale peats were found evenly distributed through a chenier plain deposit, whereas in the One O’Clock Formation plant material is rare, fragmentary and increasingly abundant higher in the formation. A further objection to this model is that conglomerate and intraformational breccias are widespread in the One O’Clock Formation.

Thirdly, the One O’Clock Formation is unlikely to have been deposited in an estuarine 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 and the sandstones would be more mineralogically mature and thinly bedded, with horizontal bioturbation (Reineck and Singh, 1973). Estuarine sands commonly lie on an older surface and are capped by tidal flat deposits, not seen in the case of the One O’Clock Formation. Finally, fossils in the lower two-thirds of the One O’Clock Formation indicate fully marine salinities, unusual for estuaries.

Modern deltas may be classified according to the depositional processes dominating their formation (Elliott, 1978). Tide-dominated deltas have an arcuate coastal outline and distributary mouths which widen seawards. Tidal flat silt, stabilized by mangrove, generally overlies the thick delta-front sand. Examples are the Klang Langat (Cole et al., 1970), Ganges-Brahmaputra and Mekong Deltas (Morgan, 1970). Sea-dominated deltas have arcuate to lobate coastal outlines and distributary mouths are narrow and constricted by spits and shoals. They characteristically develop both beaches and beach ridge plains overlying the delta-front sand, as in the modern Ganges Delta (Elliott, 1978). River-dominated deltas have lobate to digitate coastal outlines and 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 modern Mississippi Delta (Shepard, 1956).

Of these three alternatives, the One O’Clock Formation was evidently deposited by a digitate, river-dominated delta. Strong wave and tidal influence can be rejected on the same grounds as a beach ridge or estuarine depositional model. Thus the One O’Clock Formation was probably deposited by a digitate delta during what Scrutton (1960) termed its constructional phase. It is likely that the Umu Siltstone and the Putukitaki Sandstone represent the destructional reorganization of an earlier delta lobe by waves and tides.

Each of the units (A to F of Fig. 1) within the One O’Clock Formation can be interpreted as a subenvironment of a digitate delta, as has been described for the more
Mississippi Delta by Coleman and Gagliano (1965). Units A to E are best exposed just downstream of the Long Gully Syncline south of the road from Backyards Homestead, and these units pass laterally into Unit F, which forms the whole thickness of One Cell Formation south of fossil locality S117/f633 (Figs. 2, 3).

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

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

Unit C is 102 m of fine to medium-grained, blue-grey, strongly (40%) calcareous sandstone, commonly trough cross-bedded and ripple marked. This unit also contains siltstone, coarse sandstone and intraformational shale breccia in normally graded beds from 15 cm to 1 m thick. A poor assemblage of brachiopods has been collected from the base of Unit C (S117/f631) and bivalves, with an ophiurid starfish and a scaphopod near the middle and top (S117/f696 and f617). Unit C contains increasingly consistent plant fragments up-section. It probably formed a distributary mouth bar. An accumulation of carbonate aggregates and nodules in the distributary mouth bar area has been reported from both the Fraser (Johnston, 1921) and Mississippi delta sands (S117/f697, 1956). This evidently results from the local mixing of water masses of different salinity and temperature.

Unit D is 29 m of interbedded muddy, micaceous siltstone and calcareous sandstone. The siltstone contains large ovoid calcareous concretions and nodules (in the style of Brewer, 1964). Towards the top of the unit there are several lenses of well-rounded conglomerate with conspicuous angular shell fragments. Plant fragments are also common. In some places (S117/f702) Unit D contains brachiopod coquinas, largeiomorphs (Alipunctifera), with some bivalves. In other places (S117/f697) only bivalves (Nuculana, Balantioselena, Praegonia, Donella and cardiids), scaphopods and
columns are found. Siltstone is commonly riddled with carbonaceous burrows. Lenses are curvilinear, arranged at random low angles to the bedding planes and between 15 and 5 mm wide. Unit D was probably a largely-subaqueous levee and interdistributary deposit. This is especially suggested by the laterally variable fossil assemblages and shoreline conglomerates and coquinas. Calcareous nodules are also common in 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 siltstone, intraformational breccia. Trough cross-bedding is widespread in the sandstone, and several epsilon cross-sets (in the sense of Allen, 1963) were observed in the siltstone/shale sequences. Plant fragments and vermicular carbonaceous burrows are common. Unit E was probably deposited by a distributary channel, flanked by subaerial levees.

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

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

**LONG GULLY FORMATION**

Only 76 m have been preserved of this terrestrial formation which conformably overlies the One O’Clock Formation and completes the regressive cycle of the Upper Corbies Creek Group. Abundant and well-preserved fossil plants, coal and roots indicate that it was deposited as a succession of freshwater coastal plains. A lenticular pebbly conglomerate bed in the formation is probably the channel lag deposit of a braided stream. Generally the formation crops out poorly from under modern colluvium and alluvium. The Long Gully, and the soft shales and coal are deeply weathered (Fig. 3). The measured section along the road (Fig. 4) revealed a small isoclinal anticline parallel to the regional isoclinal syncline mapped by Ryburn (1967). These folds probably formed by movement of incompetent shales and coals into the core of the Long Gully Syncline. This is indicated by the severe shearing and tectonic thickness variation observed in these beds (Fig. 4). Analysis of the coal (number CS9263 of the Chemistry and Geological Survey Divisions, DSIR, New Zealand) indicates that it is very weathered and medium volatile bituminous (R. P. Suggate, pers. comm., 1975). It is a lower rank coal than those of the Tank Gully Coal Measures (Retallack, 1979), but is also compatible with the metamorphic grade of the enclosing rocks low in the prehnite-pumpellyite zone and of the metagreywacke facies of Coombs (1960). These features, together with the increased abundance of plant fragments in the higher underlying marine formations and the structural concordance of these formations with the Long Gully Formation, makes it unlikely that the Long Gully Formation is an infaulted outlier of Jurassic coal measures 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 sandstone and siltstone and shale often fine upwards and are of a thickness and type comparable to modern crevasse splay (Coleman, 1969) and flood deposits (McKee et al., 1970). Palaeosols preserved in the Long Gully Formation appear to have been more widespread in the present outcrop than those in the Tank Gully Coal Measures, but are otherwise similar. These were poorly-differentiated alluvial soils or fluviums, and so indicative...
Fig. 4—Plan (upper right) and composite stratigraphic section (left) of part of the Lower Wairau Formation exposed in cuttings along the Backyards road (see Figure 1).
soil formation was constantly interrupted by episodic sedimentation at intervals of more than one hundred years. This implies a subsidence rate of at least one metre every hundred years.

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

![Plant megafossils and their localities in the Long Gully Formation](image)

- *Todites maoricus*
- *Cladophlebis* sp. cf. *C. takezakii*
- *Townrovia petasata*
- (?)*Peltaspernum* sp.
- *Pachydermophyllum dubium*
- *P. praecordillerae*
- *Telemachus lignosus*
- *Heidiphyllum elongatum*
- *Karkenia fecunda*
- *Sphenobaiera robusta*
- *Taeniopteris* sp.
- *Desmiophyllum* sp.
- *Ginkgophytopsis* lacerata
- *Linguifolium arctum*
- *L. lilleanum*
- *L. steinmannii*
- *L. tenison-woodsii*
- *Carpolithus mackayi*
- unidentified cone A
- unidentified cone B
- roots with helical rootlets
- roots with rootlet bundles
- logs of pycnosxylc wood

Fig. 5—Plant megafossils and their localities in the Long Gully Formation (from Retallack, 1977). Black boxes indicate more abundant species. Localities (specimen numbers) are S117/f751 (OU14205), S117/f751 (B1090.1-16), S117/f752 (B1089.1-4), S117/f753 (B1088.1-7), S117/f754 (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 Creek Coal Measures (Retallack, 1979). Here also, coal, compressed and ferruginized fern logs, some with growth rings preserved, and autumnal accumulations of fossil leaves are common. This association is relatively impoverished and poorly preserved in the lower portion of the measured section (S117/f753 and f752) but quite diverse with common preserved fructifications in the upper portion of the section (S117/f754 and f751). The differences could record the gradation from heath or scrub, growing on distributary levees, passing into the woodland climax further inland.
The two highest localities (S117/f755 and H39/f3) contain conspicuous and abundant *Pachydermophyllum* (Fig. 5). Associations characterized by these fossil leaves have been identified and understood near Benmore Dam, where they seem to have been a mangrove vegetation (Retallack, 1977). Because of the complex configuration of digitate deltas, nothing of this could be argued from the high position of this association in the regressive Long Gully Formation. 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 preceding papers for a time within the Ladinian when the upper One O'Clock Formation was deposited in a distributary bed of a digitate delta. The faunal assemblages are reconstructed from observations of our own collections, from illustrations of Trechmann (1918), Legg (1927), Marwick (1953), Fleming (1962, 1963, 1964), Ryburn (1967), and Simpson and Gair *et al.* (1962) and from comparable interpretations of Stanley (1970), Steven...
Freneix and Avias (1977) and Retallack (1979). The following account describes the likely panorama, processes and climate.

The source area has been omitted from the reconstruction because no definite idea of its morphology can be gained from rocks of the Corbies Creek Group. The lack of the coarse conglomerates could indicate a more subdued topography, compared to that which supplied the Mt Potts Group, but as Garner (1959) indicates, most of the Ancestral mountain chain only delivers fine detritus to the sea. The relative mineralogy and immaturity of the Corbies Creek Group could be due to cold climate with little chemical weathering, active subsidence or a source land of considerable relief. On petrographic grounds, the source terrain probably included a high proportion of granitoid rocks (Ryburn, 1961). Conglomerate clasts in the Corbies Creek Group include chert, quartz, felsitic rhyolites and dacites, fine-grained quartzose sandstones and quartzite, with lesser amounts of intermediate volcanics, granitoids, slates and greywackes. None of the features excludes a mountainous source, like that postulated for the Mt Potts Group (Retallack, 1979).

During Ladinian time, about 1200 m of marine sediment accumulated to build a deltaic coastal plain. The barrier bar (Putakitaki Sandstone) and landward tidal flat (Umu Siltstone) probably formed from the destruction of an older delta lobe by overwash and tides. Imperceptibly building out into the sea nearby is a digitate delta (One O’Clock Formation). Each distributary is flanked by narrow, mound fed levees which continue offshore into a series of arcuate mouth bar shoals. In times of flood these levees may be breached, and crevasse splays of sandier sediment spread over wider areas of the distributary flanks. As in the Fraser Delta (Johnston, 1921), these massive influxes of fresh water probably killed large numbers of marine organisms. Burrowing bivalves and faunas near the sandy distributaries were probably better adapted to shifting subperiodic shallowing and exposure, and lower salinities, than brachiopod-dominated faunas of offshore silts. In this area of salt and fresh water mixing calcium carbonate is commonly precipitated as concretions and nodules in levees and as widespread speleothem carbonate aggregates, later consolidated into the hard calcareous matrix of sandstones in the One O’Clock Formation. Interdistributary bays are floored by finer shales and sandstones, somewhat protected from river flow and ocean swell by elongate distributary fingers. Richer faunas including stenohaline forms, such as the spiriferinid brachiopod *Alpunctifera kaihikuanu* and the pteriid bivalve *Daunella*, flourished here. These bays were fringed by beaches of sand, granules and shell fragments in more seaward areas of the delta.

The immaturity of soils on the delta plain indicates aggradation at a rate of at least 1 metre every 500 years. The more exposed younger levees of the distributaries support a relatively impoverished *Linguifolium* scrub. Further inland more diverse *Linguifolia* woodlands cover the peaty delta plain. At the seaward margin of these woodlands, *Pachydermophyllum* mangroves fringe interdistributary bays and lagoons.

A cool temperate climate during deposition of the Corbies Creek Group is indicated by its mineralogical immaturity, by prominent growth rings in both fossil wood and many shellfish and by the low specific diversity and morphological conservatism of its fossil flora and fauna. Fossil logs in the Corbies Creek Group are no larger than those found in the coeval Mt Potts Group (up to 27 cm in original diameter (Retallack, 1979)) but 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 by 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 and terrestrial sedimentary rocks, crops out in a narrow fault-bounded strip, extending 1 km through Backyards homestead from the Otematata River to the flanks of Mount Homer 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 Corbies Creek Group are quartzofeldspathic, consisting largely of quartz, K-feldspar, plagioclase and rock fragments. Occasional thin veins and shatter-fillings containing prehnite-pumpellyite metagreywacke facies of regional metamorphism. The Corbies Creek Group is tightly folded about at least four roughly coaxial with its faulted margins: respectively from southwest to northeast: Matagour Creek Anticline, Long Gully Syncline, Backyards Anticline and Elder Creek Syncline. The group includes nine formations, discussed below in their order of superposition.

RABBITERS HUT SANDSTONE Ryburn, new name

* Mappable features: Bluff-forming, massive sandstones, characteristically indurated, 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 rabbiters hut from which the formation takes its name (grid reference 773246 on 1:63,240 topographic map sheet S117).

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

* Contacts: The base of the Rabbiter's Hut Sandstone is obscured by Quaternary alluvium and appears to have been disrupted by the boundary faults of the Corbies Creek Group. Its upper contact with the overlying Elderberry Formation is a gradational lithostratigraphic change, mapped as the top of the highest sandstone bed of appreciable thickness.

* Lithology: At the type locality, the lowest 61 m of the Rabbiter's Hut Sandstone consists of micaceous, moderately well-bedded sandstone, which is finer grained and more massive than that higher in the formation. From 61 to 122 m above the observed base of the formation, it consists of bluff-forming, medium to coarse grained, moderately well sorted micaceous sandstone. At this level mudstone partings are spaced at intervals of 1 to 2 m. Cross-bedding, oscillation ripples, pebble conglomerate horizons and shellbeds are common. One pebble conglomerate 88 m above the base of the formation consisted of well rounded...
siliceous pebbles averaging 6 mm in diameter. A shellbed exclusively of gastropod (Kamupena greggi) was found at 67 m above the exposed base of the formation, another of disarticulated trigonid (Agonisca corbiensis) valves, mostly convex up, and 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 resistant sandstones of comparable thickness.

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

**Palaentology:** 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 mollusc shellbed accumulations, particularly of the gastropod Kamupena greggi and the trilobate bivalve Agonisca corbiensis. More diverse marine assemblages were found in the middle and lower sandstones of the upper and lower portions of the formation. For example, the gastropod Donella and terebratulid brachiopods were found in the lower part of the formation in the type area, and these, as well as lingulid and rhynchoconulid brachiopods Balantioselena and other bivalves, Kamupena and scaphopods in the upper part of the formation in the same area.

**ELDERBERRY FORMATION Ryburn, new name**

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

**Type locality:** A type section was measured through a steeply dipping sequence of sands and shales at the foot of Middle Range (g.r. 806224), between two branches of Elderberry Creek, after which the formation is named. The stratigraphic succession is not apparently conformable, but may be dislocated by faults at a low angle to bedding, or are recognized a short distance along strike.

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

**Contacts:** As already noted, the contact of the Elderberry Formation with the under- lying Rabbiters Hut Sandstone is gradational. It is possibly also interfingering, as the upper 91 m of medium to coarse grained quartzofeldspathic sandstone, with the upper erosional base, some 70 m stratigraphically above the top of the Rabbiters Hut Sandstone near its type locality along Corbies Creek. Connection of this sandstone, probably channel fill, with the main body of the Rabbiters Hut Sandstone was not seen, and it is formally mapped as an anomalous lentil within the Elderberry Formation.

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

**Lithology:** Micaceous siltstone and muddy sandstone occur in roughly equal proportions within the Elderberry Formation, in beds ranging from a few centimetres to several metres thick. Contacts between beds are commonly gradational or obscure, or mottling from organic burrowing. These dark grey rocks weather brown and display a range of diagenetic alteration into small angular chips. Occasional less muddy sandstone beds characteristically show weather-resistant ledges. In the type section, medium to coarse grained sandstones up to 15 cm thick are prominent from 125 to 140 m above the base of the formation. There is a distinctive horizon of brachiopod-bearing concretions about 128 m above the base.

**Distribution:** The Elderberry Formation can be traced southeast from the type area through numerous minor faults into Putakitaki Creek as far as its junction with Rabbiters Gully. It also crops out in the core of the Backyards Anticline (g.r. 795228), where...
is a conspicuous horizon of calcareous sandstone with abundant brachiopods. North of Backyards Homestead to Corbies Creek two parallel exposures of Elderberry Formation overlie the fault-disrupted Rabbits Hut Sandstone. Along Corbies Creek the southwestern exposure belt (GR 770237), a brachiopod shellbed in a calcareous concretionary horizon is similar to that in the core of the Backyards Anticline. Two outcrop areas isolated by alluvium and solifluxion debris north (GR 787222), southeast (GR 791223) of Backyards homestead are correlated with the Elderberry Formation along strike to the northwest.

Palaeontology: Fossils are very common in the Elderberry Formation and form the diverse assemblages known from formations of the Corbies Creek Group. Bivalve brachiopods are found as scattered individuals and in modest shellbeds. Many bivalves are thin-shelled infaunal forms, found with valves still joined or close together, evidently little transported. Brachiopods of the Elderberry Formation include limpets, terebratulids, and rhynchonellids, as well as common spirifers *Alipunctifera kaihikura*, *Menzelioptis spinosa*. Bivalves include the pterid *Daoella*, the astarid *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, which overlies two branches of Elderberry Creek (GR 806224). The formation is 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 comparable thickness (61 m) in the southwest limb of the nearby Backyards Anticline. Geophysical thickness of the Taylor Siltstone in the nose of this fold is probably due to deformation. To the northwest along Corbies Creek the Taylor Siltstone is at least 122 m thick where it overlies the Elderberry Formation. Deformation here too, up against a fault, is indicated by an irregularly flexed and cross-faulted sandstone bed, 1 m thick, some 61 m above the Elderberry Formation. However, there is no clear evidence of structural repetition of the formation here, and it may have been organically thicker in this direction.

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

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

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

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

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

**CHARLIE FREE SANDSTONE** Ryburn, new name

*Mappable features:* Ridge-forming, medium to coarse grained, massive, moderately sorted sandstone, characteristically with shellbeds of brachiopods preserved as rain- and casts.
Type locality: This is in the southwest limb of the Backyards Anticline between Elderberry and Matagouri Creeks (g.r. 796226), near a field referred to as the “Charlie Free paddock”. Charlie Free is reputed to have been an early fence builder and the word “free” in the formation name has no textural connotations.

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

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

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

Palaeontology: Brachiopods are found scattered and in shellbeds in the Charlie Free Sandstone and include terebratulids, rhyynchonellids and the spirifers *Alipurna kaihikuana* and *Mentzeliopsis spinosa*. Fragments of the pterid bivalve *Daonella* are also common.

MATAGOURI SILTSTONE Ryburn, new name

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

Type locality: The type section is across the southwest limb of the Backyards Anticline (from g.r. 800233 to 779219), on the slope overlooking Elderberry Creek, between Elderberry and Matagouri Creeks. Exposures are poor, even here, and consist of two small spur into the headwaters of Matagouri Creek, after which the formation is named.

Thickness: 259 m in the type section.

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

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

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

Distribution: The Matagouri Siltstone extends throughout the headwaters of Elderberry and Matagouri Creeks, through a series of folds (the Elderberry Creek Syncline, Backyards Anticline, Long Gully Syncline and Matagouri Creek Syncline respectively) from northeast to southwest. Other fault-disrupted exposures of the Matagouri Siltstone extend southward along the ridge between Long Gully and Putakitaki Creek.
Palaeontology: The Matagouri Siltstone is relatively devoid of fossils, compared to the formations of the Corbies Creek Group. A few localities near the base of the formation have yielded a moderately diverse fossil fauna largely of brachiopods, as well as occasional burrowing and plant fragments. An exceptional locality in the centre of the formation along Matagouri Creek (S117/f620) is a 46 cm thick, coarse-grained sandstone containing numerous Alipuncifera kaihikuana.

PUTAKITAKI SANDSTONE Ryburn, new name

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

Type locality: This is 120 m east of the axis of the Long Gully Syncline (indicating a prominent change of direction of the strike ridge of Putakiti Sandstone), on the ridge separating Elderberry and Matagouri Creeks from Long Gully and Putakiti Creek (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 Putakiti Sandstone passes gradationally into the Matagouri Siltstone.

The contact of the Putakiti Sandstone and the overlying Umu Siltstone is in general sharp and conformable everywhere.

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

Distribution: Along the ridge separating Elderberry and Matagouri Creeks from Putakiti Creek and Long Gully, the well-exposed strike ridge of Putakiti Sandstone provides a clear trace of the Backyards Anticline, Long Gully Syncline and Matagouri Creek Anticline (from northeast to southwest). The Putakiti Sandstone also occurs further south along the ridge separating Long Gully from Putakiti Creek, where it is cut and terminated by faulting at a low angle to bedding.

Palaeontology: Only rare and indeterminable plant fragments have been found within the Putakiti Sandstone.

UMU SILTSTONE Ryburn, new name

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

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

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

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

Lithology: Most of the Umu Siltstone is laminated, dark micaceous siltstone, interbedded with muddy and with numerous light-coloured sandy laminae. Sandstone interbeds from 50 to 30 cm thick are common near the top of the formation. Ripple-drift cross-laminations and shallow scour-and-fill structures are also common.

Distribution: The recessive-weathering Umu Siltstone occurs everywhere west of the underlying Putakiti Sandstone, both units outlining the southeasternly-plunging Long Gully Syncline.
Palaeontology: No body fossils were found in the Umu Siltstone, although trace fossils are 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, 5-24 m thick, well bedded units, with intervening sequences of interbedded sandstone, siltstone and shale.

**Type locality:** The southwest limb of the Long Gully Syncline from near Umu Stream, (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 laterally extensive channel-like sandstone bodies, with erosive bases. The contact is generally more gradational and is mapped at the base of the first sandstone above the Umu Stream, with a thickness of more than 50 cm.

The upper contact of the One O’Clock Formation and the Long Gully Formation is gradational and difficult to place within 15 m of the contact. It is poorly exposed. It is mapped below the lowest occurrence of brownish or yellowish rootlet-bearing sandstones and carbonaceous siltstones characteristic of the Long Gully Formation.

**Lithology:** The base of the One O’Clock Formation in the type section is largely composed of partially-coalesced channel-like bodies of cross-bedded sandstone. This is overlain by 21 m of alternating dark micaceous siltstone and medium to coarse grained sandstone, the latter being 20-40 cm thick. The lithology which typifies the One O’Clock Formation in this section is developed from 27 to 129 m above the base of the type section. This is a very resistant, moderately well bedded, fine to medium grained sandstone, which is characteristically hard and bluish in colour, because of calcareous cement (as much as 40% of the rock in places), and it weathers spheroidally. Beds are defined by fine partings and occasional thin beds of muddy siltstone, the latter supplying clasts for parts of this section. Overlying this unit in the type section is 29 m of interbedded calcareous shale, muddy micaceous siltstone and calcareous sandstone. The uppermost 73 m of the uppermost One O’Clock Formation is poorly exposed, consisting mainly of light-coloured sandstone with some sandy siltstone and intraformational breccia.

**Distribution:** Continuing southeast from the type area to the Otematata River, sandstone and shale interbeds become rare in the One O’Clock Formation. Most of the foraminifera in this formation are of the feedbacks to calcareous nodules and concretions up to 50 cm long. The remaining 15 m of the uppermost One O’Clock Formation is poorly exposed, consisting mainly of light-coloured sandstone with some sandy siltstone and intraformational breccia.

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

**Palaeontology:** The One O’Clock Formation is moderately fossiliferous with a high diversity. Siltstones and shales may contain brachiopod shellbeds, lamellibranchs such as *Alipunctifera kaiikuana*, and (at other localities) bivalves such as *Nuculana*, *Balantidonta*, *Praegonia* and *Daonella* and cardiids, as well as scaphopods and crinoids. Some of the sandy facies of the southwestern limb of the Long Gully Syncline is fossiliferous in bedded sandstone and bivalves and in mixed and transported assemblages. Carbonaceous plant debris is common, especially in the upper part of the One O’Clock Formation.

**LONG GULLY FORMATION** Ryburn, new name

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

**Type locality:** Cuttings along the road from Backyards homestead to the Otematata River, in upper Long Gully (g.r. 804209).
**Thickness:** Considering the poor exposure and complex and uncertain structure of the 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 more.

**Contacts:** As already discussed, the basal contact of the Long Gully Formation with the 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 of the Long Gully Syncline. The uppermost portion of the formation is concealed by alluvium at the bottom of Long Gully.

**Lithology:** The Long Gully Formation is very heterogeneous lithologically, with the same lithology seldom forming units more than 1.3 m thick. Sandstones are commonly micaceous, medium grained, and may range from grey and indurated to yellow to mottled and friable. Some of this weathering is probably due to continuing water flow down the Long Gully Syncline and Long Gully watershed. Judging from several holes of fossil root traces in place, some of this weathering is probably also of Triassic age. Siltstones and shales are generally grey and more or less carbonaceous. Also present are 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 Long Gully Syncline, a position virtually eliminating the possibility that it is in fault contact mapped by Mutch (1963).

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